The heterogeneous effects of macroprudential policies in Central, Eastern, and Southeastern Europe

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Abstract

The effects of macroprudential policies are of paramount interest to policy-makers that seek to maintain financial stability. Structural characteristics of countries likely mediate these effects and potentially drive heterogeneities in them. We study the dynamic responses to macroprudential shocks for countries in Central, Eastern, and Southeastern Europe, which were exposed to pronounced macrofinancial boom-bust cycles and adopted such measures comparatively early. We find that a macroprudential tightening curbs credit growth and reduces capital inflows but responses differ considerably across countries, especially for cross-border capital flows. Structural characteristics such as the exchange rate regime, the level of financial development, or the external openness of countries play key roles in shaping the effects of macroprudential policies. These mediating factors should be considered by policy-makers aiming to preserve financial stability, together with the appropriate choice from the set of prudential regulations at their disposal.

Keywords: Macroeconomic policy, financial stability, structural characteristics, panel vector autoregression

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1 Introduction

Macroprudential policies (MPPs) have the objective of enhancing financial stability from a systemic perspective. They extend the microprudential perspective, which aims at enhancing the stability of individual banks or financial institutions, and incorporate the broader limiting macroeconomic costs from financial distress in their target-setting (Galati and Moessner, 2018; Forbes, 2021). MPPs may be suitable tools to prevent or mitigate imbalances resulting from large and volatile capital flows (Aikman et al., 2015; Forbes, 2021) as, even though they are not inherently designed to limit these flows, introducing them preemptively can contain the build-up of systemic vulnerabilities over time. Such precautionary actions could increase the resilience of the financial system to aggregate shocks, including those arising from exuberant capital inflows and their reversals (Aguirre et al., 2019; Takáts and Temesvary, 2019). The structural characteristics of countries are increasingly recognized to be potentially important factors shaping heterogeneous effects of MPPs (Claessens, 2015; IMF, 2017). Identifying those that matter and determining how they influence the effects of MPPs is highly relevant, especially in times of growing financial integration. Yet, the empirical investigation of such structural characteristics that shape the link between MPPs, credit growth and capital flows has received limited attention.

Countries in Central, Eastern, and Southeastern Europe (CESEE) experienced pronounced credit and housing price growth in the run-up to the global financial crisis (GFC), hand in hand with a surge of international capital inflows (Eller et al., 2010). While country authorities and international institutions initially considered these patterns to be part of the catch-up to more advanced economies, they grew concerned about the potential consequences in case of a slowdown or reversals, especially with respect to cross-border capital inflows (Bakker and Klingen, 2012). These concerns led to the implementation of macroprudential measures in a range of CESEE countries, even before the wake of the GFC, making them early adopters in this respect (Vandenbussche et al., 2018; Poghosyan, 2020). This mix of early MPP adoption and boom-bust cycles in macrofinancial quantities spurred efforts to evaluate the effectiveness of MPPs in this region, especially with respect

to their goals such as taming credit growth or house prices (see inter alia Vandenbussche et al., 2015; Kang et al., 2017; Dumičić, 2018). Recent studies also investigate the interplay between these measures and international capital flows in individual countries (Eller et al., 2021), finding considerable heterogeneity in dynamic responses across them. The role of structural characteristics shaping these heterogeneities however has been neglected so far.

In this paper, we investigate the dynamic effects of MPPs on credit growth and capital inflows in CESEE, with an emphasis on identifying structural characteristics that shape heterogeneities across countries. To account for issues riddling the prevalent literature on these effects, including endogeneity and impact heterogeneity (Forbes, 2021), we propose a novel dynamic framework in the form of a hierarchical Bayesian panel vector autoregressive model. We incorporate an intensity-adjusted index for MPPs (Eller et al., 2020b) as well as a host of country-specific and global factors to model a rich spectrum of interdependencies between MPPs and their potential target variables. Doing so, we provide empirical evidence on the effects of MPPs on typical targets such as credit growth and the less investigated link between MPPs and capital flows. We then focus on potential country characteristics that may drive impact heterogeneities, which are especially prevalent for capital flow responses (see also Eller et al., 2021). The proposed dynamic framework allows for treating country heterogeneity within country groups endogenously, enhancing the comparability of responses across them. Using this framework, we provide empirical evidence on the influence of structural characteristics on the effectiveness of MPPs, a link scarcely investigated for cross-border capital flows.

We find that MPPs are effective with regards to its goal of taming the domestic leverage cycle in the CESEE region. Credit growth is also curbed in most sub-panels and individual countries investigated. On the contrary, the impact of a tighter macroprudential environment on capital flows is more ambiguous. While there is some evidence that MPPs slightly reduce capital inflows in CESEE overall, there are substantial heterogeneities in responses across countries. Digging deeper, the empirical results suggest that differences in the exchange rate regime, the level of financial development, and the degree of exter-

nal openness are important drivers for heterogeneous responses to a MPP shock, among others. These insights are an important impetus for further analyses into the transmission channels of MPPs on capital flows and other targets, both of a theoretical and an empirical nature. Equipped with our results, as well as with findings of concurrent and future research, policy-makers can base their decisions on solid, evidence-based research to achieve the goal of enhanced financial stability.

We proceed as follows. The next section provides an overview of the related literature. Section 3 then introduces the empirical framework employed, gives an overview of MPP activity in CESE, describes the data used, and elaborates on the identification scheme used for identifying a tightening MPP shock. Section 4.1 presents credit and capital flow responses to a macroprudential tightening in CESEE, highlighting heterogeneities across countries. Reflecting on these discrepancies, Section 4.2 discusses potential structural characteristics driving them. Section 5 concludes.

2 Related Literature

Taming the domestic leverage cycle in order to enhance financial sector resilience is one major goal of MPPs (ESRB, 2014). Excessive credit growth is preceding major financial crises and contributes to the likelihood of (banking) crises to occur (Büyükkarabacak and Valev, 2010; Schularick and Taylor, 2012; Jordà et al., 2016; Greenwood et al., 2022). Large and volatile capital flows in turn are often associated with elevated foreign borrowing, credit booms (and sometimes their busts), and ultimately impact systemic financial sector risk as well (Reinhart and Rogoff, 2009; Fratzscher, 2012). The link between MPPs and their main objective of enhancing financial stability is an area of active research. The theoretical literature focuses on the effects of MPPs on credit extension and asset prices (e.g. Korinek, 2018; Jeanne and Korinek, 2019). MPPs can significantly reduce the probability of financial crises from excessive over-borrowing of the private sector (Bianchi, 2011; Bianchi and Mendoza, 2018) and the volatility of house prices and resulting household debt (Gelain et al., 2013), especially when different measures are used in combination (Goodhart et al., 2013). Similarly, empirical studies focus on the role of MPPs in taming

the domestic leverage cycle (Cerutti et al., 2017a; Dumičić, 2018), dampening excessive asset price growth (Vandenbussche et al., 2015; Kuttner and Shim, 2016), or both (Akinci and Olmstead-Rumsey, 2018; Alam et al., 2024). Generally, MPPs are found to be effective in reducing exuberant credit growth, as well as stabilizing housing prices (albeit to an attenuated extent) (Araujo et al., 2024). Most studies also find that the effectiveness of macroprudential measures in curbing credit growth or extension depends on country characteristics. Effects of MPPs vary with developmental status of economies (e.g. Cerutti et al., 2017a; Akinci and Olmstead-Rumsey, 2018), with the chosen exchange rate regimes (Kim et al., 2019; Ghosh and Kumar, 2022), financial development and openness (Cerutti et al., 2017a) or the indebtedness of the private sector (Kim and Mehrotra, 2022). Furthermore, for both credit and asset price growth results vary with the type of policies employed, the state of the business cycle and the direction of the macroprudential intervention (see e.g. Cerutti et al., 2017a; Araujo et al., 2024).

Regarding the interplay between MPPs and capital flows, the theoretical literature is comparatively scarce. Actively setting MPPs can mitigate the negative effects of foreign borrowing shocks fueled by large capital inflows, their sudden reversals, and rapid asset price appreciation (Ghilardi and Peiris, 2016). They reduce the amount and the riskiness of financial liabilities financed by domestic and foreign lenders, i.e., those financed by capital inflows, and can thus decrease the incidence and severity of crises by mitigating contractionary effects of exchange rate depreciations (Korinek and Sandri, 2016) or by stabilizing capital flows from banks in response to an increase in foreign interest rates (Kitano and Takaku, 2020). A priori however, there is no clear indication about the direction and magnitude of the direct effects of MPPs on capital flows. Foreign exchange (FX)-based MPPs mostly target loans denominated in foreign currencies, impacting cross-border (banking) flows directly (Eller et al., 2021). Borrower-based MPPs such as loan-to-value (LTV) ratios on the other hand often have the aim to mitigate excessive borrowing. Given the bidirectional links between capital flows and domestic credit growth (Lane and McQuade, 2014; Igan and Tan, 2017), MPPs can thus indirectly reduce recapitalization needs of bank subsidiaries. Conversely, increasing capital, liquidity

or reserve requirements for banks may force foreign-owned subsidiaries to retort to their parent banks for recapitalization. Both of the latter two channels are especially prevalent in countries with high shares of foreign-owned banks, as is is the case in CESEE (Eller et al., 2016), and work in opposite directions with regards to their potential impact on capital flows. Last, by strengthening the resilience of the domestic financial system, MPPs could also make it more attractive for international investors and thus increase capital inflows. The direct impacts of MPPs might be a promulgation of all of these channels and may differ across instrument types as well as structural characteristics of countries.

The role of such country characteristics driving country heterogeneities in responses of cross-border capital flows has important implications for the evaluation of the efficacy of MPPs. Both for the extensive and the intensive use of MPPs characteristics related to the economic structure, institutions and financial markets of a country (henceforth subsumed under its *structural characteristics*) may be important determinants (Claessens, 2015), as is also recognized in the policy debate (IMF, 2017). However, theoretical contributions on the role that these characteristics play in shaping responses to changes in the macroprudential environment are scant. Unsal (2013) shows in an open-economy DSGE model that under a fixed exchange rate regime higher levels of macroprudential regulation result in slightly muted capital flow and credit responses to a financial shock. Compared to a regime with flexible exchange rates however, capital flow responses are stronger for both broader and more targeted macroprudential measures, with the absence of exchange rate appreciation effects offered as an explanation for this differential effects. Farhi and Werning (2016) also consider the role of exchange rate regimes for the optimality of monetary and macroprudential policy, showing that the role and effects of macroprudential policies (or related macroprudential capital controls) differ across them. For fixed exchange rates, macroprudential policies such as restrictions or taxes on capital inflows and outflows can be a second-best way of regaining some degree of monetary policy autonomy and dampen the effects of capital flows in booms and recessions. Finally, Ahnert et al. (2021) offer some theoretical insights for FX-based MPPs, where borrowers substitute from FX lending from banks towards other financial sectors. This insight implies some role of the level

of financial development, with more developed markets or deeper financial institutions allowing easier switching towards other sources and thus potentially more muted effects of MPPs on both credit and capital flows. Further, it also implies that the degree of indebtedness of economies and the structure of this debt may play a role for the effects of MPPs. Yet, providing evidence on the existence of structural drivers for capital flow response heterogeneities is ultimately an empirical exercise.

The empirical literature on the relation between MPPs and capital flows in general, however, is also still in its infancy. Recent papers focusing on their effects on the leverage cycle and asset prices shed light on the possible dynamics of MPPs and capital flows (inter alia Forbes et al., 2015; Fendoğlu, 2017; Aizenman et al., 2020), with some evidence pointing towards a stabilizing effect of MPPs for cross-border banking flows and lending shocks (Takáts and Temesvary, 2019) . Only few papers study the direct response of capital flows to macroprudential policy measures, most of them focusing on the effects of FX-based measures, with mixed findings. Some studies find evidence for MPPs leading to reductions of capital inflows (Bruno and Shin, 2015; Aguirre et al., 2019; Frost et al., 2020), whereas others point in the other direction, namely that borrower countries with more frequent use of MPPs attract larger capital inflows (Cerutti and Zhou, 2018; Akdogan, 2018). FX-based MPPs have been shown to meaningfully reduce domestic credit growth and short-term cross-border banking flows (Aguirre et al., 2019; de Crescenzio et al., 2017), but can have the unintended consequence of banks increasing FX bond issuance as a response to lower FX borrowing, shifting the exposure to other sectors of the economy (Ahnert et al., 2021). Another recent study utilizes a novel quantile regression framework to study capital flows to emerging markets and the impact of several policies, including MPPs Gelos et al. (2022). Within this context, MPPs can mitigate the downside risks of adverse global shocks on portfolio flows. Importantly, institutional frameworks matter for the medium-term bounce-back of foreign flows to the receiving country.

This mixed evidence with regards to the effects of MPPs on capital flows is a strong indication for country heterogeneity, a finding supported by recent studies of the dynamic reactions to MPP shocks. Most notably for our context, Eller et al. (2021) find supporting

evidence for the overall effectiveness of MPPs to rein in excessive credit growth and to reduce capital inflows but their results reveal substantial heterogeneity, especially so for capital inflows. In a related study, Eller et al. (2020b) also find that the effects of MPPs on credit extension differ across types of MPPs, with borrower-based measures affecting credit growth most strongly, and the type of credit, with household credit growth being affected in a more pronounced fashion. Compared to these studies, we introduce a unified modelling framework in the next section that bridges the gap between country-specific VAR estimation, as is done in Eller et al. (2021), and fixed-effects regressions that capture heterogeneity across countries by merely including a country-specific intercept, as is done on Eller et al. (2020b). This allows us to draw inference for country groups that have different structural characteristics and compare them, while simultaneously acknowledging and endogenously modelling the heterogeneity across countries within a given group.

3 Econometric Framework & Data

The early empirical literature on the effects of MPPs mostly relied on simple fixed-effect panel regressions.[1] Such models can be problematic in at least two respects. First, they are generally not able to appropriately capture the endogenous interaction between macroeconomic, financial and policy variables over time (Galati and Moessner, 2018; Forbes, 2021). Second, they often lack appropriate recognition of cross-country heterogeneity, with differences only being captured by unit-specific intercepts. Country-specific conditions such as financial development, the exchange rate regime or macroeconomic stability are factors that should be considered for an appropriate identification of the effectiveness of MPPs (IMF, 2017). Heterogeneous patterns in the conduct of and responses to MPPs, potentially caused by these factors, highlight the need to go beyond simple fixed-effect panel regressions. Recently, there have been advances in these respects, most notably in the realm of dealing with endogeneity issues. These include Richter et al. (2019); Rojas et al. (2022); Fernandez-Gallardo (2023), who use local projections to investigate the impact of

[1] See, inter alia, Claessens et al. (2013); Vandenbussche et al. (2015); Kuttner and Shim (2016); Cerutti et al. (2017a); Dumičić (2018); Alam et al. (2024).

an MPP shock on macroeconomic quantities; Kim and Mehrotra (2017, 2018); Kim et al. (2019) that rely on panel vector autoregressions to study the impact of macroprudential and monetary policy as well as their interrelation; Gelos et al. (2022) that employ a novel quantile regression framework; and (Chari et al., 2022) that rely on an instrumental variable approach to extract exogenous MPP shocks. A host of studies tries to investigate heterogeneities across countries by grouping them according to structural characteristics (e.g. Cerutti et al., 2017a; Akinci and Olmstead-Rumsey, 2018; Alam et al., 2024) but stays within the simple fixed-effects regression framework.

In this paper, both of these problems are tackled in a unified manner by employing hierarchical Bayesian panel vector autoregressions. The proposed model setup allows for modelling a set of economies jointly, while capturing both local and global economic conditions adequately. The proposed model extends the one introduced by Jarociński (2010), allowing for (1) an efficient modeling of dynamic responses to an exogenous MPP shock and (2) identification of country heterogeneities in these responses. It has the advantage of acknowledging heterogeneities between countries within a given panel explicitly, making comparisons across panels in which countries share certain characteristics more meaningful.

Specifically, we assume for each country $i = 1, \ldots, N$ in a given panel that the M-dimensional vector of endogenous variables specific to country i, $\boldsymbol{y}_{i,t}$ $(t = 1, \ldots, T_i)$, follows a VAR(p) process:

$$\boldsymbol{y}_{i,t} = \sum_{j=1}^{p} \boldsymbol{A}_{i,j}\boldsymbol{y}_{i,t-j} + \boldsymbol{B}_i\boldsymbol{w}_t + \boldsymbol{a}_i + \boldsymbol{\varepsilon}_{i,t}, \quad \boldsymbol{\varepsilon}_{i,t} \sim \mathcal{N}(0, \boldsymbol{\Sigma}_i), \tag{1}$$

where $\boldsymbol{y}_{i,t-j}$ denotes the j-th lag of the endogenous variables and $\boldsymbol{w}_t$ is a $W \times 1$ vector of exogenous variables. For the main empirical analyses, we chose a lag order of $p = 4$ for the endogenous variables as well as including contemporaneous values of the exogenous ones. The matrices $\boldsymbol{A}_{i,j}$ contain autoregressive coefficients corresponding to the lagged endogenous variables. $\boldsymbol{B}_i$ holds coefficients related to the exogenous variables and $\boldsymbol{a}_i$ denotes the intercept vector. The vector $\boldsymbol{\varepsilon}_{i,t}$ holds Gaussian VAR innovations with zero mean and variance-covariance matrix $\boldsymbol{\Sigma}_i$. Collecting all coefficients related to lagged

endogenous variables, the exogenous variables as well as the country-specific intercepts in $\boldsymbol{A}_i = [\boldsymbol{A}_{i,1}, \ldots, \boldsymbol{A}_{i,p}, \boldsymbol{B}_i, \boldsymbol{a}_i]^\intercal$ (with resulting dimension $K \times M$, $K = Mp + W + 1$), accounting for parameter heterogeneity boils down to treatment of $\boldsymbol{A}_i$ and $\boldsymbol{\Sigma}_i$.

A common choice in the Panel VAR literature is to fully pool information across countries (see Canova and Ciccarelli, 2013, for an excellent survey), akin to country-fixed effects in a panel regression setup. This implies that the coefficients in $\boldsymbol{A}_i$ are assumed to be identical for all countries and heterogeneity across countries is captured only by the intercept terms $\boldsymbol{a}_i$. Such an approach is restrictive in that a high degree of homogeneity across countries and their parameters is presumed. Instead, we propose using a modeling approach that allows for coefficient heterogeneity, as is natural in hierarchical Bayesian modelling (see Jarociński, 2010).

Specifically, we assume that country coefficients contained in $\boldsymbol{A}_i$ arise from a Gaussian distribution with a common mean. Let $\boldsymbol{\alpha}_i = vec(\boldsymbol{A}_i)$ for all i. Then

$$\boldsymbol{\alpha}_i | \bar{\boldsymbol{\alpha}}, \boldsymbol{\Sigma}_\alpha \sim \mathcal{N}(\bar{\boldsymbol{\alpha}}, \boldsymbol{\Sigma}_\alpha)\,, \tag{2}$$

where $\bar{\boldsymbol{\alpha}}$ denotes the common mean vector with dimension $m = KM$. This prior setup carries the notion that country coefficients within a panel sharing certain characteristics tend to be similar, but not identical.

The prior variance-covariance matrix $\boldsymbol{\Sigma}_\alpha$ effectively controls the country-specific deviations from the common mean. It is decomposed as $\boldsymbol{\Sigma}_\alpha = \boldsymbol{\Omega}_\alpha(\lambda_1 \otimes \boldsymbol{I}_m)$, where $\boldsymbol{\Omega}_\alpha$ has a structure similar to the well-known Minnesota prior (Litterman, 1980). This structure imposes structure by shrinking coefficients associated with endogenous variables towards the common mean increasing in the lag order j, while leaving coefficients of exogenous variables and deterministics unrestricted (see Appendix A for a closer description). λ_1 is the overall tightness parameter and effectively pushes the country coefficients towards the common mean. To achieve a data-driven balance between the two extreme cases of full

pooling across countries and country-specific estimation of the model, Jarociński (2010) treats λ_1 as an additional parameter to be estimated.[2]

We further extend the model proposed by Jarociński (2010) by efficiently pooling information across countries for the estimation of the error variances in $\mathbf{\Sigma}_i$. In particular, a hierarchical Wishart prior (Frühwirth-Schnatter, 2006; Malsiner-Walli et al., 2016) is imposed that carries a similar notion of combining information about the error variances across countries, but allows for deviations where the data deems it necessary. The conditional conjugacy of the whole prior setup implies that the (conditional) posterior distributions are well-known. See Appendix A for a detailed description of the full prior setup as well as hyperparameter choices and Appendix B for derivations of the various resulting posterior distributions. In this way, the degree of information pooling across countries is thus endogenized for both the autoregressive and variance parameters, and varies between panels, allowing for meaningful comparisons between panel-wide responses.

The heterogeneity across countries in turn informs both the sampling of the heterogeneity parameters and the common posterior moments for the autoregressive and variance coefficients. As described in Appendix B in more detail, the posterior distribution of the common mean for the autoregressive coefficients depends on the averaged country-specific coefficients, weighted by the updated (inverse) prior variance-covariance matrix $\mathbf{\Sigma}_\alpha$, and its prior mean. Larger deviations of country-specific coefficients from zero, and across countries, thus also push the common mean further away from it prior mean, which is centered around zero. A similar logic applies to the variance parameters of countries and their common scaling matrix. The posterior draws of the common mean coefficients $\bar{\boldsymbol{\alpha}}$ and the scaling matrix $\boldsymbol{C}_0$ can then be used to draw inference for the shocks of interest on an aggregate (i.e. panel-wide) level. Thus, based on this model setup, one can draw inference jointly for sets of countries, enabling comparisons between those groups. By treating λ_1, the heterogeneity coefficient, as an additional unknown parameter to estimate and accounting for uncertainty about it within panels, more meaningful comparisons between them become possible. Clustering countries in sub-panels based on different characteristics

[2]Recent contributions go a step further by allowing for country- and even coefficient-specific heterogeneity parameters using Bayesian shrinkage priors (Boeck et al., 2024).

of them then allows for a closer investigation of different reactions to a macroprudential policy shock. This way, key structural characteristics driving these differences may be identified.

3.1 Macroprudential policies in CESEE

The vast majority of studies regarding the effectiveness of MPPs relies on simple metrics to quantify such measures and their intensity. Most commonly, macroprudential activity is tracked by translating any tightening (loosening) incident into an increase (decrease) of one point in the respective country index and cumulatively summing up over time (e.g. Shim et al., 2013; Ahnert et al., 2021; Alam et al., 2024). These approaches come with the detriment that only the extensive margin of MPPs is captured, neglecting the strength of these adjustments — their intensity. As an example, a decrease in the loan-to-value (LTV) ratio by ten percentage points is treated identically to a lowering by one percentage point. The index used in this paper, introduced in Eller et al. (2020b), represents another approach for integrating the intensity of measures into an encompassing macroprudential policy index (MPPI) for eleven EU member states in CESEE.[3] By applying a set of different weighting rules for the various incorporated measures, differences in the intensity of the adjustments are reflected in the index. This way changes in the macroprudential environment are captured more precisely, allowing for a more accurate investigation of the effects of MPPs. A detailed description of the construction of the index, the underlying datasets, as well as the included instruments and exact weighting rules can be found in Eller et al. (2020b).

Figure 1 gives an overview of the MPPI for the given time period. It reveals, as previously mentioned, that a number of countries already implemented and tightened MPPs well before the GFC. Overall a substantial tightening in the region can be discerned from the CESEE-11 aggregate (constructed as a simple average across countries) in the top left panel. However, it also reveals heterogeneous patterns across countries. Some countries have been more active prior to the GFC, while others tightened their macroprudential

[3]These countries are: Bulgaria (BG), the Czech Republic (CZ), Croatia (HR), Estonia (EE), Hungary (HU), Latvia (LV), Lithuania (LT), Poland (PL), Romania (RO), Slovenia (SI), and Slovakia (SK).

stance only its aftermath and to a lesser extent. Figure C.1 in Appendix C gives closer insights in the composition of the overall MPPI and provides a more detailed overview of the most important developments.

3.2 Macrofinancial data

Alongside the intensity-adjusted index for macroprudential policies, we include several macrofinancial and macroeconomic quantities. The variables of primary interest in terms of responses to a macroprudential policy shock are credit growth and capital inflows. While the former is modelled as the quarterly change in total claims on the domestic private sector, the latter is measured in four-quarter moving sums of either gross total capital or gross other investment inflows as percentage of GDP. Other investment flows consist to a major part of flows originating from direct foreign lending to domestic banks (Hahm et al., 2013), and thus act as a proxy for banking flows. As most MPPs are targeted at the banking sector, the reactions of such flows are of particular interest. Further macroeconomic variables included in the empirical specification are GDP growth, the inflation rate, as measured by quarterly changes the (harmonized) consumer price index, and the short-term interest rate in order to control for interdependencies with monetary policy. German GDP growth and the German money market rate enter the model as exogenous variables as a means to account for leading role of Germany for the CESEE region.

Furthermore, a factor that captures the financial cycle for CESEE countries is included as an additional exogenous control to alleviate concerns with regards to a potential omitted variable bias. It is constructed by extracting the first principal component from a set of financial variables (in the spirit of Eller et al., 2020a). Compared to other global financial cycle indicators often used in macroeconomic studies (e.g. Miranda-Agrippino et al., 2015), the factor used here is more tailored to the context of CESEE countries with respect to the sample of countries. We also opted for choosing a more narrow set of financial variables than Eller et al. (2020a) that is more specifically to the MPP context, namely growth of credit and deposit stocks of banks as well as equity prices. Results using

these other indicators for the global financial cycle are qualitatively similar and available upon request.

The period under investigation ranges from Q1 1997 until Q4 2018, thus covering the global financial crisis but excluding the COVID-19 pandemic. The end of the sample period is due to the availability of the intensity-adjusted MPPI and other indicators as well as to keep up comparability with Eller et al. (2021) that report more country-specific results. Table D.1 in Appendix D gives an overview of the variables included in the analysis for each country with a short description, their transformations pre-estimation and the main sources used to obtain them.

3.3 Identification of a MPP shock

To identify a tightening macroprudential shock, variables included in the model are ordered recursively and short-term zero restrictions are imposed. The identified shock is scaled to represent to an one-unit increase in the MPPI. This corresponds, for example, to a decrease of the LTV ratio by five percentage points or an increase of the capital adequacy ratio for banks by one percentage point. We assume that the policy instrument for MPPs is contemporaneously exogenous to the macroeconomic variables included in the model. This carries the notion that changes in the macroprudential policy stance are lagging behind changes in economic conditions for a quarter. Other studies employing vector autoregressive models impose similar identifying assumptions (Kim and Mehrotra, 2017; Kim et al., 2019), but presume that macroprudential policy is instantaneously reactive to changes in economic conditions. We consider these identifying assumptions as somewhat problematic as there is typically a legislative process involved in setting MPPs. While policy-makers do observe economic conditions, their ability to react within the same quarter by proposing and implementing new macroprudential measures based on them is thus often hindered by a need for coordination with lawmakers (see e.g. Meeks, 2017). The existence such decision lags can be exploited for the identification of fiscal policy shocks in a VAR framework (Blanchard and Perotti, 2002; Giordano et al., 2007; Ilzetzki and Jin, 2021), a setting very related to ours. Nonetheless, we also consider cases

where the macroeconomic variables are assumed to be contemporaneously exogenous to the macroprudential policy instrument as well as interchanging the reaction function of monetary and macroprudential policy. The main results obtained by such alternative identification schemes are qualitatively similar, as reported in Appendix E. The use of data on quarterly frequency also alleviates some of the concerns regarding endogeneity of policy responses. Recent advances for alternative identification schemes of MPP shocks have been proposed recently (see e.g. Rojas et al., 2022; Chari et al., 2022; Budnik and Rünstler, 2023). Lack of comparable data for most of the CESEE countries prevented us to follow similar strategies.

An additional concern when analyzing the effects of MMPs are potential anticipation effects. With a legislative process behind MPPs, there may be a considerable lag between the date of announcement and the date of actual implementation of these measures. The index used in this study accounts for such discrepancies by utilizing information on both the announcement and the implementation date of MPPs. In particular, for a tightening MPP the announcement date is taken into account, while for a loosening one the actual date of its implementation is used. This carries the notion that banks or other relevant actors react to a tightening in the macroprudential environment as soon as it is announced, e.g. by building up additional capital reserves. On the contrary, for loosening MPPs, banks have to adhere to the applicable regulations until the day of actual implementation. This way anticipatory effects are factored in and identification concerns stemming from them are mitigated.

4 Results & Discussion

4.1 Effects of macroprudential policy in CESEE

Before focusing on the effects of MPPs on typical targets like reining in excessive credit growth and or more unconventional ones such as dampening volatile capital inflows, a brief examination of reactions for all endogenous variables to a tightening in the macroprudential environment may prove insightful. Figure 2 shows the impulse responses of all

endogenous variables to a tightening macroprudential policy shock corresponding to an unexpected one-unit increase in the MPPI.

It shows that MPP has significant effects on real as well as macrofinancial variables. GDP growth and price inflation fall in response to an unexpected tightening in the macroprudential environment. The decrease in inflation is of a prolonged nature, indicating persisting effects of MPPs on inflation. There is also evidence for interdepencies between macroprudential and monetary policy. The short-term interest rate decreases on impact, while showing some erratic behaviour in the following quarters. Such an expansionary reaction of monetary policy is in accordance with theoretical contributions (Alpanda and Zubairy, 2017) and empirical analyses (Kim and Mehrotra, 2018).

Turning to macrofinancial variables, our results suggest that credit growth is significantly reduced for an extended period of time in response to a tightening MPP shock. Within the first quarters following such a shock the decrease is sizable and dissipates only slowly. This indicates that, in general, MPPs are effective with respect to their target of taming excessive credit growth in the CESEE region. For gross total capital and other investment inflows (CAP and OI inflows henceforth) the emerging picture is less clear. Both types of capital inflows slightly decrease on impact but the following short-term effect within the first year is rather ambiguous. About two years after the MPP shock, capital inflows are lowered significantly again. A potential explanation for this delayed decrease might be lower demand pressures for capital inflows resulting from substantially lower credit growth. Results for the variables discussed are qualitatively robust to the inclusion of additional economic variables, such as equity price growth, changes in the real effective exchange rate and capital outflows (see Figure E.1 in the Appendix). As discussed in Appendix F.1, effects of MPPs also depend on the main aspect they are targeting. Figure F.1 provides some insights into the effects of MPPs of different types, operationalized as subindices of the MPPI, on macrofinancial variables. It provides further evidence that different types of MPPs affect macrofinancial quantities differently, in line with the prevalent literature (Cerutti et al., 2017b; Richter et al., 2019). Further research in the effects of different MPPs is thus warranted.

Table 1 reports the values of a forecast error variance decomposition of the MPP shock for the three variables of main interest. This allows for inference regarding the relative importance of MPP shocks in explaining variation in these variables over time. It appears that the explanatory power of macroprudential policy for fluctuations in credit growth and capital inflows is rather limited. While close to four percent of the variance of credit growth is explained by a shock in the macroprudential environment, this value is even smaller for the capital inflows, with a maximum of 2.2% and 1.33% for CAP and OI inflows, respectively. This discrepancy is not surprising, considering that taming the leverage cycle is an explicit goal of MPPs while capital flows are no primary targets. Moreover, the latter are strongly driven by global financial factors, with regional and local conditions only of secondary importance (Eller et al., 2020a).

Up to now, the obtained results referenced to the overall effects of MPPs in the CESEE region. However, the nature of the proposed model allows for heterogeneities regarding country parameters. This in turn permits country-specific deviations of the responses from the regional results and a much more granular view with respect to the effects of MPPs in the individual countries. Figure 3 provides an overview of country-specific impulse responses for credit growth and capital inflows to a tightening MPP shock. It reveals that impulse responses to a macroprudential tightening vary substantially between countries. Credit growth is reduced significantly in a majority of countries, but differ in magnitude. The reactions of both CAP and OI inflows are much more diverse. While the peak responses in the individual countries are also often negative, some remain insignificant or even indicate an increase in inflow levels.

These findings of pronounced heterogeneity between countries regarding the impact of a tightening MPP shock, especially for capital inflows, are in line with previous research on the effectiveness of MPPs in the CESEE region (Eller et al., 2021). They also underline the potential importance of country-specific characteristics as determinants of capital flows and the effects of MPPs as already stressed by IMF (2017). The next section investigates a series of such structural characteristics that might be possible drivers of heterogeneities in the responses to a change in the macroprudential environment.

4.2 Structural differences driving heterogeneous MPP responses

As outlined in Section 3 the model approach taken in this paper allows for more meaningful comparisons between panels consisting of different countries. In such a way the responses of groups sharing some structural characteristics can be compared and possible drivers of the effectiveness of MPPs can be identified. In a first step, we analyze how institutional differences might affect the effectiveness of MPPs. The role of exchange rate regimes and the level of broad financial development is analyzed. Digging deeper with respect to the financial characteristics of countries, we then investigate the effect of financial openness of countries. Specifically, we investigate the role of external indebtedness and the share of loans in foreign currencies on total private sector loans. In what follows, we use the average of the splitting variable across countries as a splitting rule to distinguish between "high" and "low" categories of countries, where applicable. Applying this rule splits countries in similarly large country groups. While the exact thresholds that are used as splitting criteria are thus somewhat arbitrary, there is typically a clear divide around them, with countries being either clearly above or clearly below them.

The first and second columns of Figure 4 refer to results corresponding to sample splits based on the exchange rate regime. A majority of countries in the CESEE region have some sort of fixed exchange rate, most often pegged to the Euro, or adopted the Euro itself at some point in the observation period. The Czech Republic, Hungary, Poland and Romania on the other hand have (semi-)floating exchange rates. For both regimes a significant reduction in credit growth is observable, with the impact for countries with a fixed exchange rate regime being a bit more pronounced. Considering the reactions of capital inflows some striking differences are revealed. Countries with flexible exchange rates exhibit a tendency of reduced capital influxes, with OI inflows decreasing significantly in the first few quarters after such a shock. This is in contrast with the significant increase of such inflows for countries with fixed exchange rates together with a slight, but insignificant tendency for rising CAP inflows. These results could reflect that transmission channels of MPPs may be different for countries with differing exchange rate regimes

and indicates an important role of them regarding the effectiveness of MPPs, especially with regards to capital inflows.

Another possible determinant for the effectiveness of MPPs might be the level of overall financial development of countries. Based on average values of the index developed by Svirydzenka (2016) that captures several dimensions of financial development for the analyzed period, we differentiate countries by their relative financial development, with Czechia, Estonia, Hungary, Poland and Slovenia belonging to the financially more developed group, i.e. with "higher" financial development. The first and second columns in Figure 4 show impulse responses for these country groups. The insignificant impact of MPPs on credit growth in financially more developed countries, together with the significant decrease for financially less developed countries, is in line with previous results (Kim and Mehrotra, 2022). These differences likely stem from the complicated enforcement of MPPs in economies with more complex financial systems and a large shadow banking economy. However, other studies have found significant negative effects on credit growth in advanced economies (see Richter et al., 2019; Fernandez-Gallardo, 2023), implying that the degree of financial development might not correlate perfectly with economic development. Turning to the reactions of capital inflows there are also stark differences. For CAP inflows there is a slight reduction of inflow levels in financially more developed countries while there is no significant effect, but an upwards tendency, for economies with less developed financial systems. A similar but more pronounced pattern emerges for OI inflows. Here, influxes are significantly lower for countries with a higher level of financial development on impact and an extended period of time following a tightening MPP shock. On the other hand, these flows are elevated in countries with a less developed financial system. These results could reflect that for the latter type of countries, MPPs are perceived as being advantageous to the resilience of the financial system by foreign investors and thus lead to higher capital inflows. For countries that are already financially more developed this effect seems to be absent. We investigate alternative measures for the financial development of countries in Appendix F.2, including the debt-to-GDP ratio and the subindex for the depth of financial institutions from Svirydzenka (2016). Figure F.2

shows that results are qualitatively similar. Countries with lower private debt levels and less deep financial institutions show larger reduction in credit growth and capital inflows.

The degree of financial openness of an economy is another aspect that might be influencing the reaction of macrofinancial variables to a tightening MPP shock, especially so for cross-border capital flows. Two measures that can be considered for this aspect, among others, are the degree of external indebtedness and the share of loans extended to the private sector denominated in foreign currencies.

Impulse responses for countries with a high and low level of external debt are depicted in the first and second columns of Figure 5.[4] Comparing the impulse responses of these country groups with each other, differences in the capital flow responses again catch the eye. Countries with a high foreign debt exposure experience a minimal reduction in both CAP and OI inflows following a tightening MPP shock. However, there is a tendency of increased inflows in the first year after such a shock, with OI inflows even rising significantly. In contrast, for capital inflows in countries with a low external debt-to-GDP ratio a tightening in the macroprudential environment has no effect for an extended period of time followed by marginal decreases. The negative responses of credit growth are quite similar for these two country groups, however in countries with low external debt the reduction is a tad more prolonged. This indicates, together with the observed differences in capital inflow responses, that MPPs are affecting their target variables differently in these regimes and appear to be more effective in countries with a lower degree of external indebtedness.

A number of MPPs target, either directly or indirectly, the exposure of banks to foreign currencies. For example, this can take the form of higher risk weights for FX loans or stricter lending restrictions for loans in foreign currencies. Thus, the share of FX loans on total loans might provide some more insight in the efficacy of MPPs. The last two columns in Figure 5 show impulse responses of credit growth and capital inflows for countries

[4]Economies in the high external indebtedness sub-sample have had an average external debt-to-GDP ratio of more than roughly 80% in the observation period, the mean across countries in that period. Data on gross external debt in percent of GDP was obtained from the annual database of the Vienna Institute for International Economic Studies (wiiw). Bulgaria, Estonia, Croatia, Hungary, Latvia and Slovenia are considered to be countries with high external indebtedness.

grouped by their share of FX loans.[5] In terms of reducing these variables, MPPs are found to be more effective in those countries that feature a high share of loans in foreign currencies. Credit growth is decreasing sharply following a tightening MPP shock and is remaining at a lower level persistently. Capital inflows are falling on impact and are diminishing slightly again with a bit of a delay for these countries, with OI inflows being a bit more affected. On the other hand, for countries with a low share of FX loans, both CAP and OI inflows exhibit no significant reaction to an unexpected tightening shock in the macroprudential environment, neither on impact nor afterwards. Furthermore, the response of credit growth is also more muted for this country group, although a short-lived reduction is observable. These differences indicate that a tightening in the macroprudential stance, which often involves stricter regulations for foreign exposures, has a larger effect in countries that exhibit a high share of FX loans.

We also investigate differences with regards to the timing of macroprudential activity in Figure F.3, showing that macrofinancial quantities in countries that adopted MPPs earlier showed stronger credit growth responses in lines with the primary mandate to rein in excessive credit growth in this period. Capital inflows on the other hand appear to be impacted in both country groups, with OI inflows being more strongly impacted. Last, we also conduct a sample split by time period rather than by country characteristics, considering the periods before and after the GFC. Though the impulse responses are estimated somewhat imprecisely due to the low numbers of observations, Figure F.3 reveals stronger effects on credit growth in the pre-crisis period and mixed evidence for capital inflows. However, it again reveals substantial country heterogeneities as already reported in Figure 3.

5 Conclusion

The mediating impact of country characteristics on the effects on MPPs are important factors to consider for policy-makers in their decisions. This pertains to the effectiveness

[5]Data on FX loans to total loans obtained from the wiiw database. Countries with a share of less than roughly 35% form the group defined as having a low FX loans share based on the mean across countries. These were the Czech Republic, Poland, Slovenia and Slovakia.

of MPPs to achieve their direct targets, such as reining in exuberant credit growth, but also for their effects on cross-border capital flows, which are typically not considered to be directly targeted by MPPs. However, the interaction of capital flows with domestic financial variables makes the analysis of the effects of MPPs on capital flows, and the impact of structural characteristics, highly relevant. Yet, the heterogeneous effects of MPPs, especially with regards to capital flows, remains an understudied issue in the empirical literature; with few exceptions (Gelos et al., 2022).

In this paper, we investigate the effects of MPPs on private sector credit growth and capital inflows in CESEE. The region experienced a pronounced leverage cycle, boom-bust periods of cross-border capital flows, and adopted macroprudential regulations comparatively early on and frequently, making it an ideal subject for research of the effects of MPPs. We use a novel intensity-adjusted index that captures such policies in a more accurate way and employ a hierarchical Bayesian panel vector autoregressive model to efficiently pool information across countries while still allowing for parameter heterogeneity. This enables estimation and inference in a unified framework with explicit acknowledgment and utilization of country-specific heterogeneity, making comparisons across country panels more meaningful.

The empirical results suggest that macroprudential policy was effective in curbing credit growth and, to a lesser extent, capital inflows for the CESEE region. However, they also reveal substantial heterogeneities in response to a tightening in the macroprudential stance, especially so for capital inflows. Investigating these differences, we find that the effects of macroprudential regulation hinge on different country characteristics such as the exchange rate regime, the level of financial development or the (private) debt structure of an economy. These results are robust to a multitude of specification variations and highlight the importance of these determinants for the efficacy of macroprudential policies.

Taking the heterogeneities uncovered in the present study into account can be of importance for policy-makers in order to make well-informed decisions. Yet, further research is needed to trace the influence of such country characteristics, the differential effects of MPPs targeting different aspects of financial institutions, and the interaction thereof. The

extension of the intensity-adjusted MPPI used in this study to cover a broader sample of countries could be a valuable starting point for such analyses. These analyses include approaches for an endogenous clustering of countries, the subsequent use of cluster analyses to examine the importance of structural characteristic mode closely, and the exploration of interactions between macroprudential and monetary policy.

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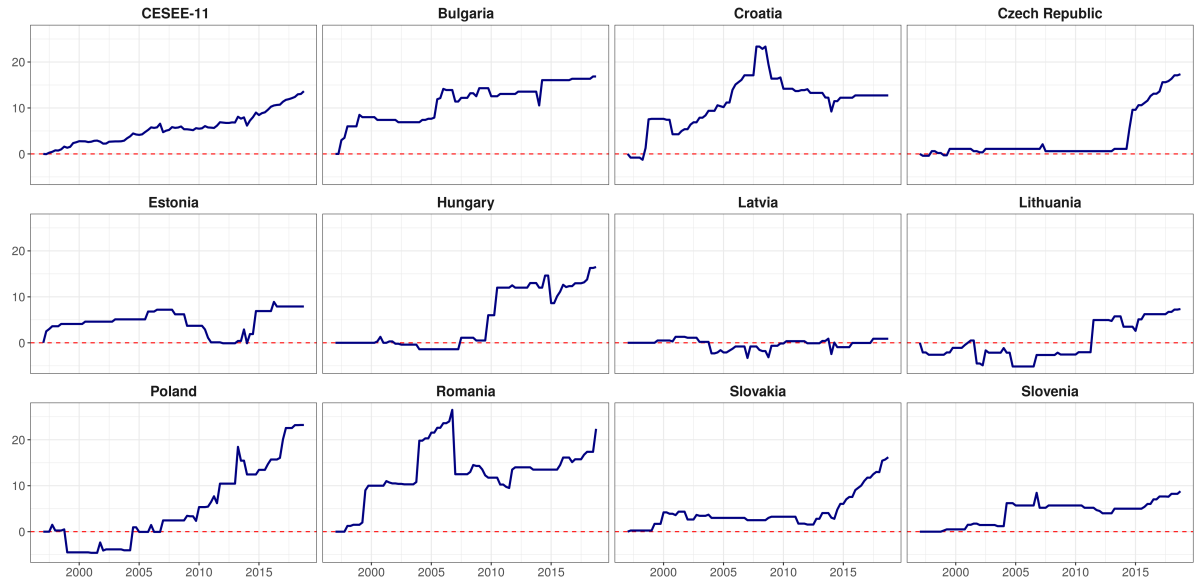
Figures & Tables

Figure 1: Intensity-adjusted macroprudential policy index (MPPI) for the time period Q1 1997 to Q4 2018 using announcement (implementation) dates of MPPs for tightening (loosening) measures.



Note: Authors' own calculations based on Eller et al. (2020b).

Figure 2: Impulse responses of macroeconomic quantities to a tightening MPP shock

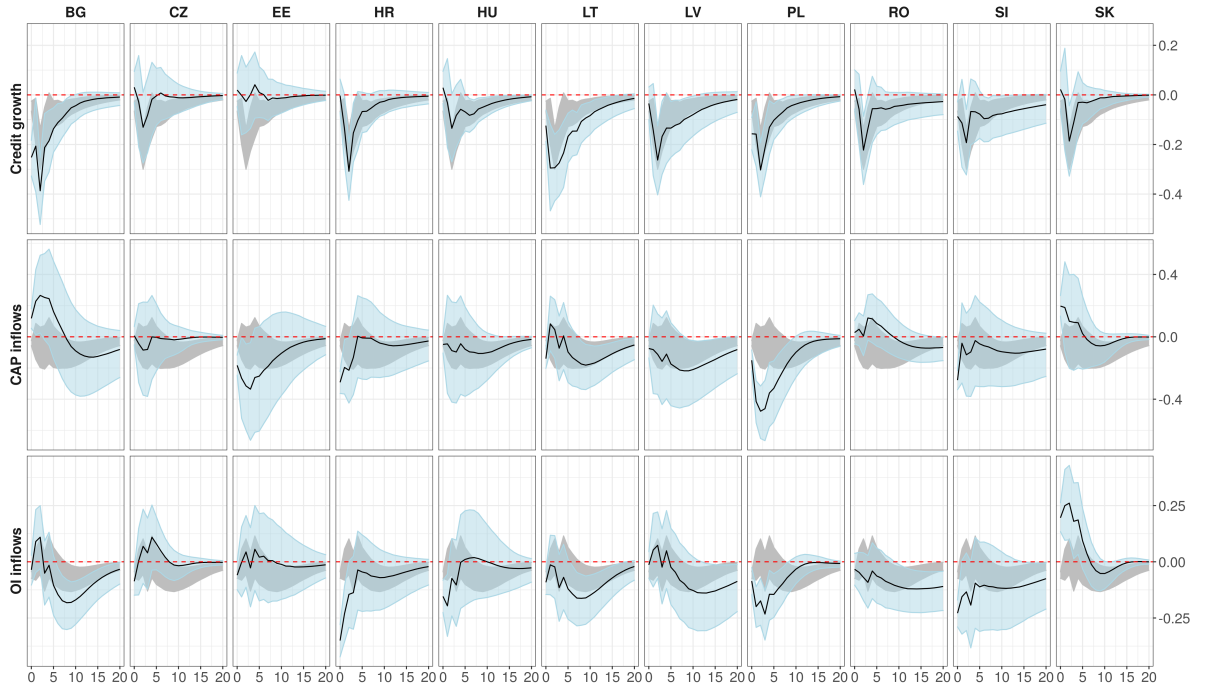
Note: Impulse responses for all included endogenous variables (except the MPPI) following a tightening macroprudential policy shock modeled as an unexpected one-unit increase in the MPPI for the CESEE region. Black lines denote the posterior median response, blue shaded areas refer to the 68% credible set.

Table 1: Forecast error variance decomposition for a tightening MPP shock

Horizon	1-year	2-year	3-year	4-year	5-year
Credit growth	3.71	3.90	3.96	3.97	3.98
	[1.73 – 6.67]	[1.77 – 7.13]	[1.77 – 7.22]	[1.78 – 7.25]	[1.78 – 7.26]
CAP inflows	1.08	1.53	1.97	2.15	2.20
	[0.34 – 3.19]	[0.53 – 4.19]	[0.76 – 4.72]	[0.84 – 5.00]	[0.86 – 5.08]
OI inflows	0.56	0.81	1.15	1.29	1.33
	[0.26 – 1.39]	[0.36 – 1.98]	[0.49 – 2.53]	[0.56 – 2.80]	[0.57 – 2.88]

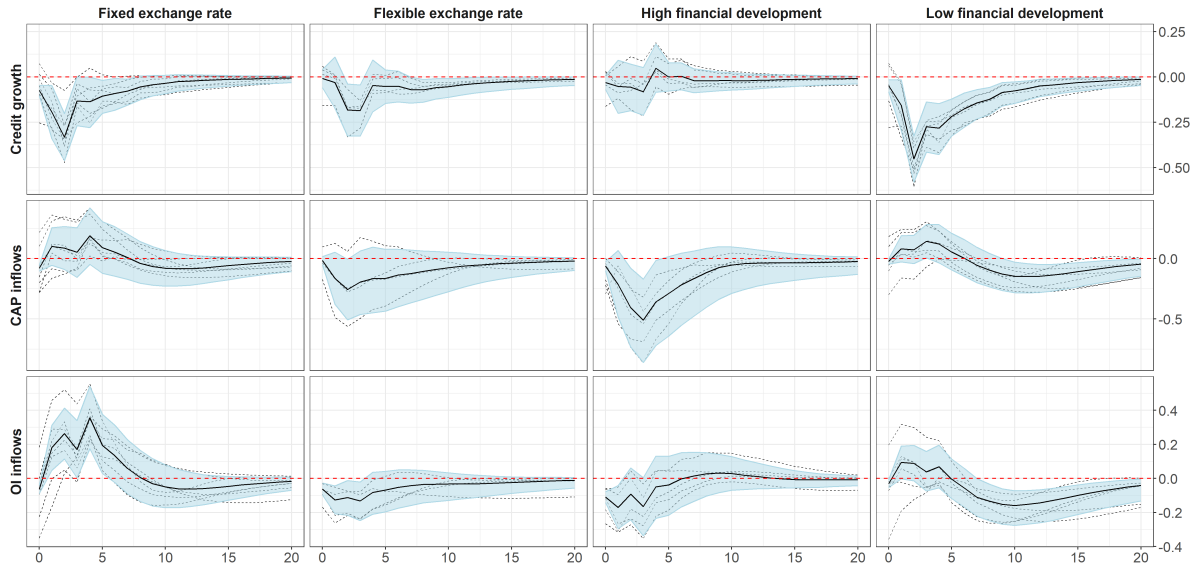
Note: Table shows forecast error variance decomposition of credit growth, gross total capital inflows and other investment inflows following a tightening macroprudential shock. The 68% credible intervals are in brackets. All values in percentage points.

Figure 3: Country-specific impulse responses of macrofinancial quantities to a tightening MPP shock



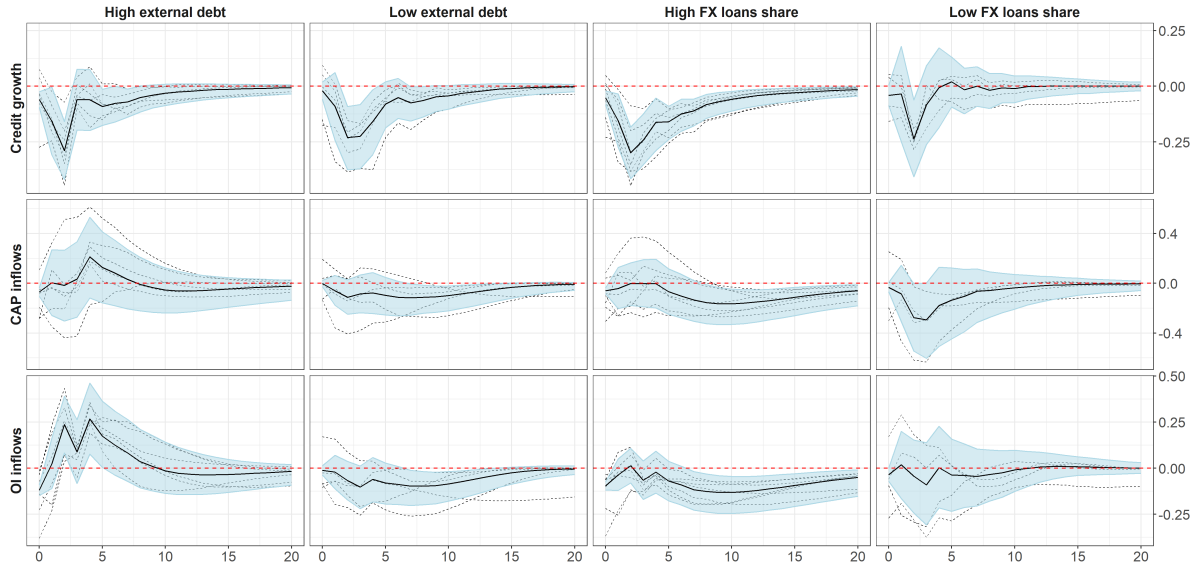
Note: Impulse responses for credit growth, gross total capital inflows and other investment inflows following a tightening MPP shock modeled as an unexpected one-unit increase in the MPPI. Black lines denote the posterior median response, blue shaded areas refer to the 68% credible set. Grey shaded area refers to the 68% credible interval of the impulse responses for the CESEE region.

Figure 4: Impulse responses of macrofinancial quantities for countries split by exchange rate regime and degree of financial development



Note: Impulse responses for credit growth, gross total capital inflows and other investment inflows following a tightening macroprudential policy shock modeled as an unexpected one-unit increase in the MPPI. The first and second columns refer to responses for countries with different exchange rate regimes. The third and fourth columns present responses for country groups differing in their degree of financial development. Black lines denote the aggregate posterior median response, blue shaded areas refer to the corresponding 68% credible set. Dashed, black lines denote posterior median responses of the individual countries within the panel.

Figure 5: Impulse responses of macrofinancial quantities for countries split by external indebtedness and FX loans share



Note: Impulse responses for credit growth, gross total capital inflows and other investment inflows following a tightening macroprudential policy shock modeled as an unexpected increase of one unit in the MPPI. The first and second columns refer to countries with high and low degrees of external indebtedness, respectively. The third and fourth columns present responses for countries with high and low ratios of FX loans to total loans, respectively. Black lines denote the aggregate posterior median response, blue shaded areas refer to the corresponding 68% credible set. Dashed, black lines denote posterior median responses of the individual countries within the panel.

Appendix A Full prior setup

Here, we specify the full prior setup for the hierarchical Bayesian VAR setup introduced in Section 3. First, on the common mean $\bar{\boldsymbol{\alpha}}$, we impose a Gaussian prior on the common mean, $\bar{\boldsymbol{\alpha}} \sim \mathcal{N}(\boldsymbol{b}_0, \boldsymbol{B}_0)$, with prior parameters set to relatively uninformative values, i.e. $\boldsymbol{b}_0 = \mathbf{0}$ and $\boldsymbol{B}_0 = 10^2 \boldsymbol{I}_m$.

Next, on $\boldsymbol{\Sigma}_\alpha$ we impose a structure that resembles the specification of the covariance matrix of the well-known Minnesota prior (Litterman, 1980). For that, we rely on a fixed diagonal covariance matrix $\boldsymbol{\Omega}_\alpha$, with $\boldsymbol{\Sigma}_\alpha = \boldsymbol{\Omega}_\alpha(\lambda_1 \otimes \boldsymbol{I}_m)$. The variance parameters of $\boldsymbol{\Omega}_\alpha$ corresponding to elements in α_i relating endogenous variables to the lags of themselves and other endogenous variables are given by:

$$\omega_{\alpha_{kl}} = \left(\frac{\sigma_k^2}{\sigma_l^2}\right)\left(\frac{\lambda_2}{j^{\lambda_3}}\right)^2,$$

where σ_k^2 and σ_l^2 are pooled OLS residual variances obtained from running M autoregressive models on the pooled data to control for relative coefficient sizes. λ_2 denotes a parameter relating to cross-variable lag coefficients specified as $\lambda_2 = 1$ for $k = l$ and 0.5 otherwise. λ_3 controls the degree of shrinkage for higher lags. Following large parts of the literature it is set equal to 1. For the coefficients regarding the exogenous variables and the intercept terms, the variance is given by:

$$\omega_{\alpha_{c_k}} = \sigma_k^2 \lambda_4^2,$$

where λ_4 is the variance parameter controlling prior tightness on these parameters. Setting λ_4 to a high value (e.g. 10^2) implies leaving these parameters almost unrestricted.

The full covariance matrix can then be constructed as $\boldsymbol{\Sigma}_\alpha = \boldsymbol{\Omega}_\alpha(\lambda_1 \otimes \boldsymbol{I}_m)$. λ_1 is the overall tightness parameter and effectively pushes the country coefficients towards the common mean. $\lambda_1 = 0$ implies that the country coefficients will all be equal to the common mean, i.e., full pooling of the data is achieved. For $\lambda_1 \to \infty$ the prior becomes uninformative, i.e. there is no information pooling across countries.

Jarociński (2010) achieves a balance between these two cases by treating λ_1 as an additional parameter to be estimated, in the spirit of hierarchical modeling. This way, the degree of information pooling across countries is endogenized and varies between panels. Deviating slightly from Jarociński (2010), who elicits a inverted Gamma prior on λ_1, we impose a Gamma prior on this parameter:

$$\lambda_1 \sim \mathcal{G}(v, s).$$

Combining this with the prior density of $\boldsymbol{\alpha}_i$ for all i (see Equation 2), it is easy to show that the conditional posterior distribution of λ_1 is of a generalized inverse Gaussian form. Specifying the prior in this way mitigates the problem of results being sensitive to prior parameter choices, as pointed out by Jarociński (2010) and Gelman (2006) for the inverted Gamma hierarchical prior setup. Given λ_1, it is then possible to construct $\boldsymbol{\Sigma}_\alpha$ and draw the country-specific coefficients in turn. We specify $v = s = 0.01$, implying a relatively uninformative prior for this parameter.

We extend the model proposed by Jarociński (2010) by efficiently pooling information across countries for the error variances $\boldsymbol{\Sigma}_i$ for each country i. A hierarchical Wishart prior (Frühwirth-Schnatter, 2006; Malsiner-Walli et al., 2016) of the following form is imposed on $\boldsymbol{\Sigma}_i^{-1}$:

$$\begin{aligned}\boldsymbol{\Sigma}_i^{-1} &\sim \mathcal{W}(\boldsymbol{C}_0, c_0)\,,\\ \boldsymbol{C}_0 &\sim \mathcal{W}(\boldsymbol{Q}_0, q_0)\,,\end{aligned}$$

The hyperparameters c_0, q_0 and $\boldsymbol{Q}_0$ are specified to achieve regularization of the variance-covariance matrices as:

$$\begin{aligned}c_0 &= 2.5 + \frac{M-1}{2}\,,\\ q_0 &= 0.5 + \frac{M-1}{2}\,,\\ \boldsymbol{Q}_0 &= \frac{100 q_0}{c_0}\boldsymbol{\Sigma}_0\,,\end{aligned}$$

where $\mathbf{\Sigma}_0 = diag(\sigma_1^2, \ldots, \sigma_M^2)$ is a scaling matrix containing the same pooled OLS residual variances as mentioned above.

This completes the introduction of the hierarchical prior setup used in this study. Appendix B provides details about the resulting (conditional) posterior distributions of the various quantities as well as the sampling scheme used to draw from them.

Appendix B Posterior simulation

The model proposed relies on a Markov chain Monte Carlo (MCMC) algorithm that consists of several blocks to simulate the posterior quantities of interest. In this section, we briefly summarize the conditional posterior distributions of the various quantities as well as an efficient sampling scheme to draw from them. The generic notation $|\bullet$ indicates conditioning on all remaining parameters as well as the data. As initial values, we use OLS estimates of $\hat{\alpha}_i$ and $\hat{\Sigma}_i$ for all i, set $\bar{\alpha} = N^{-1}\sum_{i=1}^{N}\hat{\alpha}_i$ and define $\lambda_1 = 0.1$. Conditional on these starting values, the algorithm cycles through the following steps:

1. Draw the country-specific coefficients from a multivariate Gaussian posterior distribution, i.e. $\boldsymbol{\alpha}_i|\bullet \sim \mathcal{N}(\bar{\boldsymbol{\alpha}}_i, \bar{\boldsymbol{V}}_i)$ with posterior mean and variance given by:

$$\begin{aligned}\bar{\boldsymbol{V}}_i &= \left(\boldsymbol{\Sigma}_i^{-1} \otimes \boldsymbol{X}_i^{\intercal}\boldsymbol{X}_i + \boldsymbol{\Sigma}_{\alpha}^{-1}\right)^{-1}, \\ \bar{\boldsymbol{\alpha}}_i &= \bar{\boldsymbol{V}}_i\left[(\boldsymbol{\Sigma}_i^{-1} \otimes \boldsymbol{X}_i^{\intercal})\boldsymbol{y}_i + \boldsymbol{\Sigma}_{\alpha}^{-1}\bar{\boldsymbol{\alpha}}\right],\end{aligned}$$

   where $\boldsymbol{y}_i = vec(\boldsymbol{Y}_i)$.

2. The posterior distribution of the common mean is also multivariate normal, $\bar{\boldsymbol{\alpha}}|\bullet \sim \mathcal{N}(\bar{\boldsymbol{b}}, \bar{\boldsymbol{B}})$ with:

$$\begin{aligned}\bar{\boldsymbol{B}} &= \left(N\boldsymbol{\Sigma}_{\alpha}^{-1} + \boldsymbol{B}_0^{-1}\right)^{-1}, \\ \bar{\boldsymbol{b}} &= \bar{\boldsymbol{B}}\left(\boldsymbol{\Sigma}_{\alpha}^{-1}\sum_{i=1}^{N}\boldsymbol{\alpha}_i + \boldsymbol{B}_0^{-1}\boldsymbol{b}_0\right).\end{aligned}$$

3. Derive the updated prior variance-covariance matrix for the country-specific coefficients, $\boldsymbol{\Sigma}_{\alpha}$, by first drawing the heterogeneity coefficient λ_1 from a generalized inverse Gaussian distribution:

$$\lambda_1|\bullet \sim \mathcal{GIG}\left(-\frac{NMK}{2} + v, \sum_{i=1}^{N}(\boldsymbol{\alpha}_i - \bar{\boldsymbol{\alpha}})^{\intercal}\boldsymbol{\Omega}_{\alpha}(\boldsymbol{\alpha}_i - \bar{\boldsymbol{\alpha}}), 2s\right).$$

   Then obtain $\boldsymbol{\Sigma}_{\alpha}$ from $\boldsymbol{\Sigma}_{\alpha} = \boldsymbol{\Omega}_{\alpha}(\lambda_1 \otimes \boldsymbol{I}_m)$.

4. Simulating the posterior draws of the country-specific variance-covariance matrix $\boldsymbol{\Sigma}_i$ within the hierarchical Wishart setup proceeds in two steps:

   (a) The common scaling matrix $\boldsymbol{C}_0$ has a Wishart posterior distribution, $\boldsymbol{C}_0|\bullet \sim \mathcal{W}(\bar{\boldsymbol{Q}}, \bar{q})$ with:

$$\bar{\boldsymbol{Q}} = \boldsymbol{Q}_0 + \sum_{i=1}^{N} \boldsymbol{\Sigma}_i^{-1}$$

$$\bar{q} = q_0 + N c_0$$

   (b) Draw $\boldsymbol{\Sigma}_i^{-1}$ (for $i = 1, \ldots, N$) from its Wishart conditional posterior distribution:

$$\boldsymbol{\Sigma}_i^{-1}|\bullet \sim \mathcal{W}(\bar{\boldsymbol{C}}_i, \bar{c}_i)$$

$$\bar{\boldsymbol{C}}_i = \boldsymbol{C}_0 + \frac{1}{2}\sum_{t=1}^{T_i}(\boldsymbol{y}_{i,t} - \boldsymbol{A}_i \boldsymbol{x}_{i,t}^{\intercal})(\boldsymbol{y}_{i,t} - \boldsymbol{A}_i \boldsymbol{x}_{i,t}^{\intercal})^{\intercal}$$

$$\bar{c}_i = c_0 + T_i/2$$

This algorithm is repeated 20,000 times with the first 5,000 draws being discarded as burn-in. From the remaining draws every third is stored and used for inference purposes. The convergence of the sampled parameters was assessed visually as well as with the aid of convergence diagnostics. Results confirm successful convergence toward their stationary distribution and are available on request.

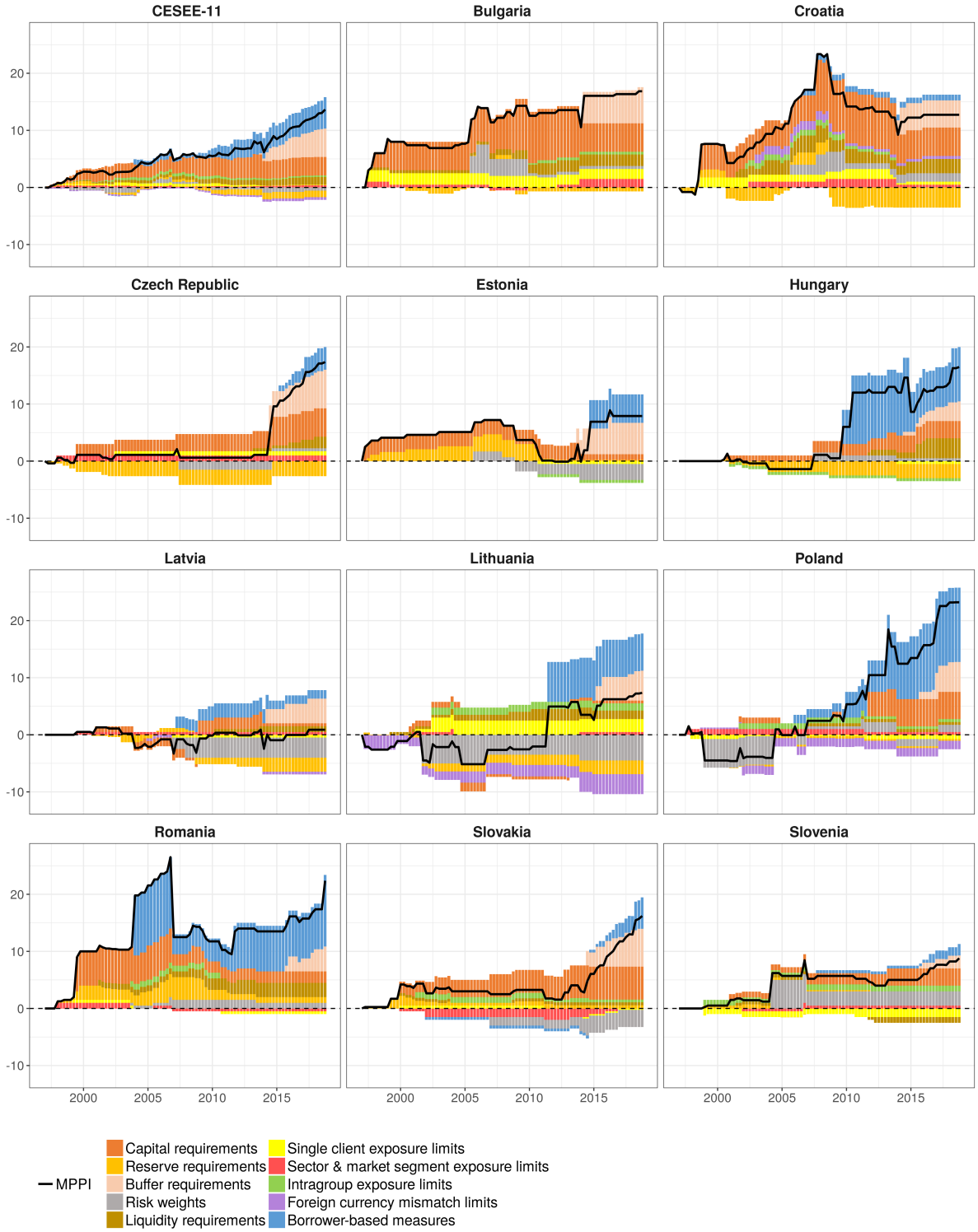
Appendix C Detailed MPP activity in CESEE

This Section gives a more detailed overview about the MPP activity of the eleven EU member countries in CESEE. These countries are: Bulgaria (BG), the Czech Republic (CZ), Croatia (HR), Estonia (EE), Hungary (HU), Latvia (LV), Lithuania (LT), Poland (PL), Romania (RO), Slovenia (SI), and Slovakia (SK).

While Figure 1 in the main part of this paper gives an overview of total macroprudential activity in CESEE, Figure C.1 allows for a more granular consideration. It depicts the individual subindices and their respective contributions to the overall MPPI. With regards to the employment of macroprudential policies there are striking patterns. First, there are some countries, like Bulgaria, Croatia, Estonia, Romania and Slovenia, that tightened their macroprudential stance substantially already before the GFC. Other countries such as the two remaining Baltic states and Poland also showed considerable usage of MPPs prior to the GFC, however the actions taken did not lead to a pronounced tightening until after the GFC. On the contrary, Hungary and the Czech Republic implemented rather few changes to the macroprudential environment prior to the GFC, but tightened substantially in its aftermath.

Second, in terms of composition, the types of instruments used is varying over time. In the pre-crisis period capital-based measures like minimum capital or reserve requirements in combination with risk weights were used most actively. This contrasts with the increased implementation of borrower-based measures like LTV or DSTI limits which is a post-crisis phenomenon. Romania constitutes the only case that shows considerable changes prior to the GFC for these measures. Poghosyan (2020) also notes that regarding the implementation of lending restrictions the CESEE region again has a pioneering role. In the more recent past, buffer requirements are the group of measures that have been implemented most actively.

Figure C.1: Detailed composition of the MPPI



Note: Different subindices (bars) of the intensity-adjusted MPP index using announcement (implementation) date for tightening (loosening) measures and their respective contribution to the overall index (black line) for the time period 1997Q1-2018Q4. Authors' own calculations based on (Eller et al., 2020b). Time series have been rescaled to start at 0.

Appendix D Data

Table D.1: Variable description

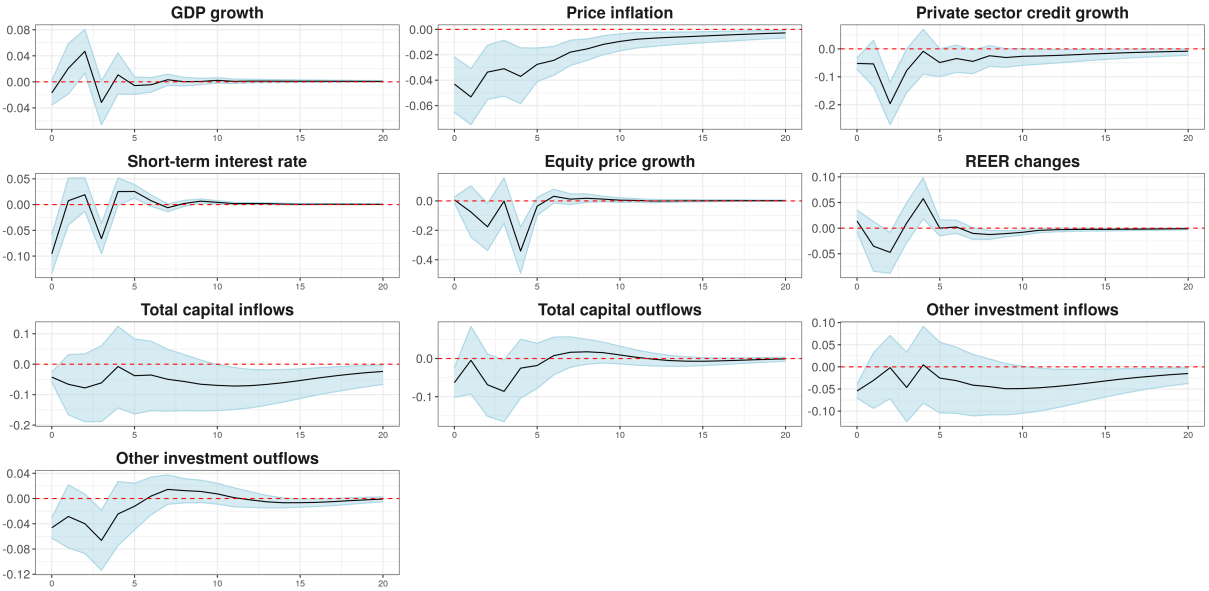
Variable	Description	Main source(s)
	Main variables	
MPPI	Intensity-adjusted macroprudential policy indicator, first differences	Eller et al. (2020b); own calculations
GDP growth	GDP volume, 2005=100, seasonally adjusted, in logarithms, quarter-on-quarter changes	IMF-IFS
Inflation rate	(Harmonized) consumer price index, 2005=100, seasonally adjusted, quarter-on-quarter changes	IMF-IFS; Eurostat
Credit growth	Claims on domestic private sector, (H)CPI deflated, seasonally adjusted, in logarithms, quarter-on-quarter changes	IMF-IFS; BIS
Short-term interest rate	Typically, three-month money market rate (per annum), first differences	IMF-IFS; ECB; Eurostat
Capital inflows	Cumulative four-quarter moving sums of gross total capital or gross other investment (BPM6 definition) inflows as percentage of GDP	IMF-IFS
	Exogenous variables	
German GDP growth	GDP volume, 2010=100, seasonally adjusted, in logarithms, quarter-on-quarter changes	IMF-IFS
German short-term interest rate	Three-month money market rate (per annum), first differences	OECD
Global financial factor	First principal component extracted from a set of equity price, credit and deposit growth rates for a global sample of 45 countries, no further transformations	Eller et al. (2020a); Eller et al. (2021); own calculations
	Additional variables	
Equity price growth	Equity price index, 2005=100, seasonally adjusted, in logarithms, quarter-on-quarter changes	IMF-IFS; OECD
REER	Real effective exchange rate, CPI-based index, seasonally adjusted, in logarithms, quarter-on-quarter changes	IMF-IFS
Capital outflows	Cumulative four-quarter moving sums of gross total or gross other investment (BPM6 definition) outflows as percentage of GDP	IMF-IFS

Notes: Table shows included variables for each country under investigation, a short description with their corresponding transformations for estimation as well as sources from where they are gathered. Seasonal adjustment was conducted using the Census X12 method. For Poland capital flow series were not satisfactorily available at quarterly frequency at the beginning of the sample; corresponding annual figures and the quarterly dynamics of the available sample were used for data interpolation. Missing equity price data was interpolated using either dynamics of similar OECD series (where available) or of GDP growth. Moreover, if the short-term interest rate was not available, dynamics of the deposit rate for data interpolation were used. In the case of few remaining missing observations at the beginning or the end of the sample, averages of the subsequent or previous four quarters to fill these gaps were used. All variables were transformed to be (approximately) stationary.

Appendix E Robustness checks

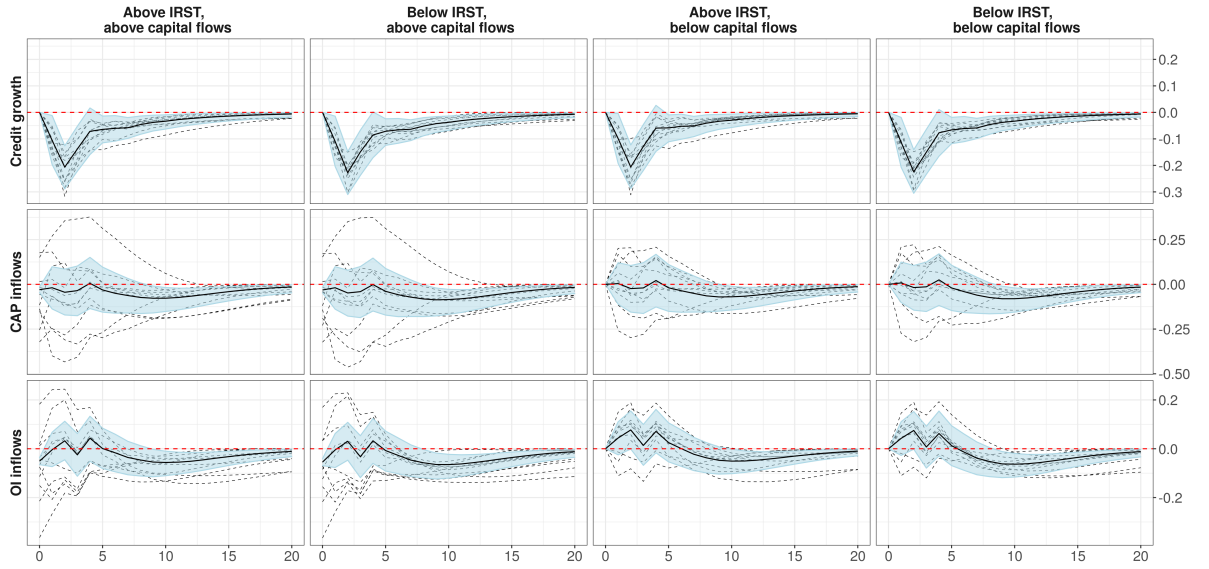
The baseline results discussed in Section 4.1 are fairly robust to a number of changes in the model specification. As a first robustness check the baseline model is extended with information about equity price growth, quarterly changes in the real effective exchange rate (REER) and capital outflows. The estimated impulse responses (see Figure E.1) are qualitatively similar and indicate strong reductions in credit growth together with more moderate decreases in capital inflows, although the effects are a bit more muted than in the baseline specification. Furthermore, as already argued in Section 3.3, the proposed identification scheme for a macroprudential policy shock might be controversial. Figure E.2 shows impulse responses for the macrofinancial variables of main interest under alternative identifying assumptions. It can be observed that, at least qualitatively, the main results are invariant to different orderings of variables corresponding to these alternatives. This is true for the cases where MPPs are assumed to be contemporaneously exogenous to capital flows, but not to real variables, and also holds for the cases where all variables are assumed to be contemporaneously exogenous to MPPs. As an additional robustness check we also change the ordering between the macroprudential and the monetary policy instrument. The obtained results are again qualitatively similar to the baseline results. Finally, changes in the lag order of variables, both regarding endogenous and exogenous ones, as well as using different sets of exogenous variables yield similar results and are available on request.

Figure E.1: Impulse responses for model with increased set of endogenous quantities



Note: Impulse responses following a tightening macroprudential policy shock modeled as an unexpected one-unit increase in the MPPI for model with an increased set of endogenous variables. Model includes equity price growth, changes in the real effective exchange rate and capital outflows (both for gross total capital and other investment) as additional variables. Black lines denote the aggregate posterior median response, blue shaded areas refer to the 68% credible set.

Figure E.2: Impulse responses of macrofinancial quantities under varying identifying assumptions



Note: Impulse responses for credit growth, gross total capital inflows and other investment inflows following a tightening macroprudential policy shock modeled as an unexpected one-unit increase in the MPPI for different identifying assumptions. The first column reports results for the specification where macroprudential policy is assumed to be reactive to real variables and credit growth but to be exogenous to the short-term interest rate and capital flows. The third column depicts results for the specification where all variables are assumed to be contemporaneously exogenous to both policy instruments. The second and fourth columns refer to specifications where the interest rate is assumed to be contemporaneously exogenous to macroprudential policy i.e. the order of the policy instruments is switched. Black lines denote the aggregate posterior median response, blue shaded areas refer to the corresponding 68% credible set. Dashed, black lines denote posterior median responses of the individual countries within the panel.

Appendix F Additional results

F.1 Effects of different MPPs

As depicted in Figure C.1 and described in more detail in Section C, the intensity-adjusted MPPI captures a multitude of macroprudential measures that aim at different aspects regarding the financial soundness of banks and other financial institutions. While the overall MPPI thus is an accurate representation of changes in the broader (macro)prudential environment, it is also conceivable that the effects of MPPs differ with respect to the main aspects they target. Figure F.1 presents responses of the main macrofinancial variables of interest following a tightening shock for different subindices of the MPPI. It can be discerned that there are indeed differences across MPP types. For capitalization- and liquidity-based MPPs (CAP-MPPI and LQ-MPPI; upper and middle panel in Figure F.1), effects on credit growth and capital flows are more muted but these quantities show an overall tendency to increase after a tightening of these measures. The increases in capital flows could be indicative for increased refinancing needs of subsidiary banks in CESEE countries that are met with transfers from abroad. On the contrary, for the borrower-based subindex (BB-MPPI; lower panel of Figure F.1) that captures measures such as loan-to-value or debt-service-to-income ratios, pronounced and long-standing decreases in the investigated macrofinancial quantities can be observed. This underscores the effectiveness of these measures for macroprudential goals that has also been identified in the recent empirical literature (Cerutti et al., 2017b; Richter et al., 2019). While the results presented here provide suggestive evidence of effect heterogeneity of MPPs with respect to their primary targets, more research in this direction is warranted.

Figure F.1: Impulse responses of macrofinancial quantities for CESEE countries for different subindexes of MPPI

Note: Impulse responses for credit growth, gross total capital inflows and other investment inflows following a tightening macroprudential policy shock modeled as an unexpected increase of one unit in different subindexes of the MPPI. The upper panel reports results for the subindex comprising capitalization-based measures such as capital buffers or reserve requirements. The middle panel reports results for the subindex comprising MPPs targeting the liquidity of financial institutions such as liquidity requirements or single client exposure limits. The lower panel reports results for the subindex comprising borrower-based measures such as loan-to-value (LTV) or debt-service-to-income (DSTI) ratios. Black lines denote the aggregate posterior median response, blue shaded areas refer to the corresponding 68% credible set.

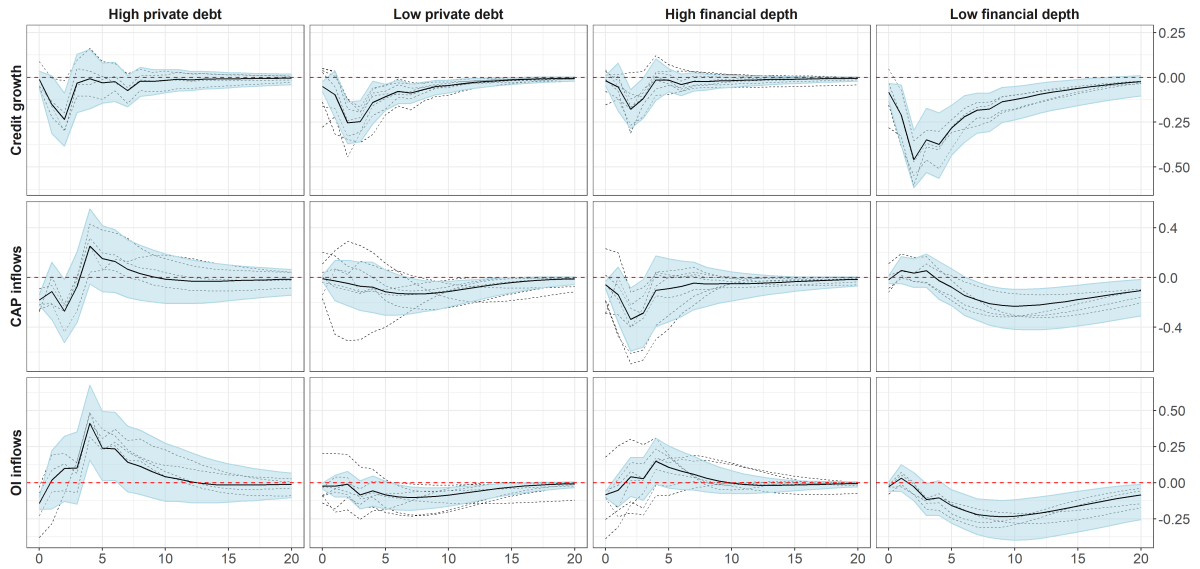
F.2 Additional structural characteristics

Going into more detail regarding the financial characteristics of countries, the sample is split according to the level of private debt as measured by the average ratio of loans extended to the non-financial private sector relative to GDP. The first and second columns of Figure F.2 report impulse responses for countries with high and low degrees of private sector debt, respectively. Credit growth is reduced stronger for an extended period of time in economies that exhibit a lower level of debt, in line with findings by Kim and Mehrotra (2022). A mixed picture emerges for capital inflows in countries with high debt levels. While CAP inflows are reduced significantly on impact and this effect is rather short-lived, OI inflows are rising about one year after being slightly reduced on impact. This pattern could reflect the need for banks to recapitalize when MPPs involving for instance stricter rules regarding their capitalization are implemented. This would be a

less pressing issue in countries with a lower level of private indebtedness. Indeed, both OI as well as CAP inflows are generally less affected from a tightening in the macroprudential environment and exhibit a small, but significant decrease as can be seen in the second column of Figure F.2.

As another measure of financial development, we split countries by the depth of their financial institutions as measured by the respective subindex of Svirydzenka (2016). The results, shown in the third and fourth columns of Figure F.2, are qualitatively similar to the ones derived for the overall index reported in Figure 4. Countries with lower financial depth show more pronounced and longer persisting responses to a macroprudential tightening for credit growth as well as capital inflows. More integrated financial institutions seem to increase the effects of leakage, with OI inflows not decreasing significantly but rather showing an upwards tendency within the first year after the macroprudential tightening. For countries with financially shallower institutions on the other hand, both overall capital inflows as well as OI inflows are reduced with a certain lag compared to credit growth, potentially caused by reduced financing needs of subsidiary banks.

Figure F.2: Impulse responses of macrofinancial quantities for countries split by total private indebtedness and depth of financial institutions

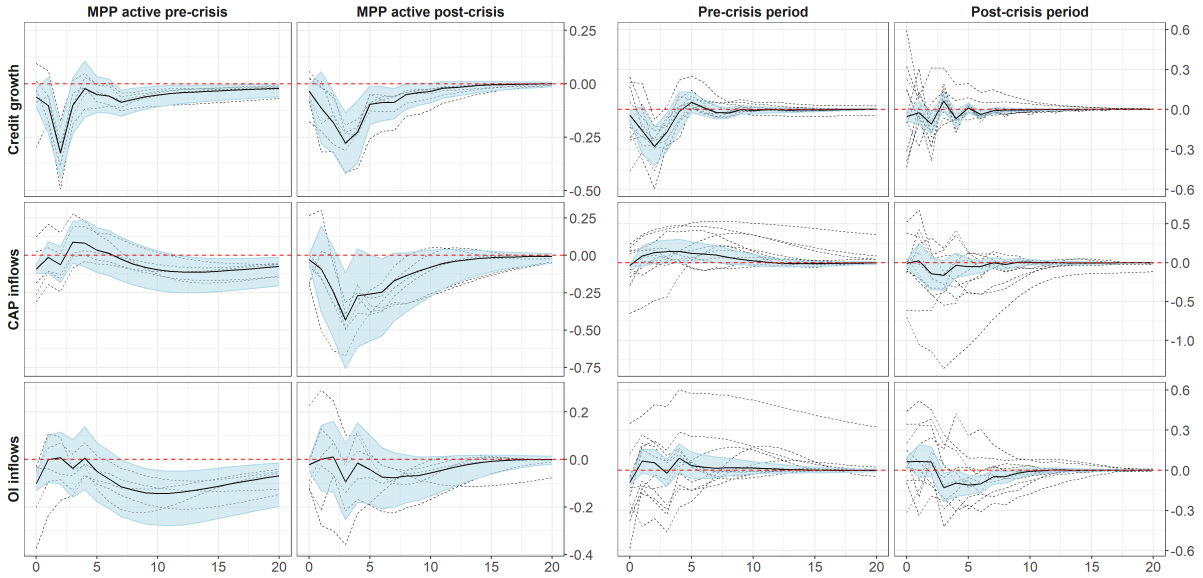


Note: Impulse responses for credit growth, gross total capital inflows and other investment inflows following a tightening macroprudential policy shock modeled as an unexpected increase of one unit in the MPPI. The first and second columns report results for countries with high an low levels of private debt (measured by the ratio of total loans to GDP), respectively. The third and fourth columns report results for countries with a high and low degree of financial depth (as measured by Svirydzenka (2016)), respectively. Black lines denote the aggregate posterior median response, blue shaded areas refer to the corresponding 68% credible set. Dashed lines are posterior median responses of the individual countries.

As mentioned in Section 3.2, and elaborated in Appendix C, there are heterogeneous patterns in the conduct of macroprudential measures across countries. Some countries started adopting MPPs earlier and have been more active in this respect than others. This implies that the respective authorities in these countries already incorporated the goal of financial stability in their policy function to a greater extent and makes a comparison between these two groups of countries interesting. The first column of Figure F.3 thus shows the impulse responses for countries that have already been active prior to the GFC, while the second column presents them for countries that tightened their stance rather in its aftermath. Considering credit growth, both groups exhibit significant reductions of this variable following a tightening in the macroprudential environment. The short-term effect for countries that were already active in the pre-crisis period is stronger but also dissipates faster. Regarding capital inflows there are again marked discrepancies. While for OI inflows MPPs tend to have a stronger decreasing effect for countries active in the pre-crisis period the opposite is observable for CAP inflows. This could reflect the prevailing focus on taming the leverage cycle – that was often fueled by cross-border banking inflows – of authorities in these countries at the time. Countries more active in the aftermath of the GFC often put more focus on increasing the resilience of the financial system more generally.

To investigate the effects of the global financial crisis (GFC), we consider a split of the observation period instead of forming subpanels of countries. The third and fourth columns of Figure F.3 show results for the period before and after the GFC, respectively. Credit growth is reduced in both periods but more strongly in the pre-crisis one, in line with the focus of authorities on taming the leverage cycle in this time as mentioned before. Responses of capital inflows differ between periods, with a tendency of increasing in the pre-crisis period, whereas decreasing after the crisis. However, it should be noted that in both periods substantial country heterogeneities are present as indicated by the dotted lines in Figure F.3. Moreover, the precision of the estimated impulse responses suffers from the rather short observation periods available. For a more detailed investigation

Figure F.3: Impulse responses of macrofinancial quantities for countries split by MPP activity and observation period split by onset of the GFC



Note: Impulse responses for credit growth, gross total capital inflows and other investment inflows following a tightening MPP shock modeled as an unexpected increase of one unit in the MPPI. The first and second columns presents results for countries that were already active in conducting MPPs prior to the GFC or became active only in its aftermath, respectively. The third and fourth columns present results for splits in the observation period, respectively for the period prior to the GFC (i.e. before 2009Q1) and thereafter. Black lines denote the aggregate posterior median response, blue shaded areas refer to the corresponding 68% credible set. Dashed lines are posterior median responses of the individual countries.

of the effects of MPPs in different interest rate environments, roughly corresponding to periods preceding and subsequent to the GFC, see Eller et al. (2021).