

# The Transmission of Macroprudential Policy in the Tails: Evidence from a Narrative Approach\*

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## Abstract

We estimate the causal effects of macroprudential policies on the entire distribution of GDP growth for advanced European economies using a narrative-identification strategy in a quantile-regression framework. While macroprudential policy has near-zero effects on the centre of the GDP-growth distribution, tighter policy brings benefits by reducing the variance of future growth, significantly boosting the left tail while simultaneously reducing the right. Assessing a range of channels through which these effects materialise, we find that macroprudential policy particularly operates through ‘credit-at-risk’: it reduces the right tail of future credit growth, dampening booms, in turn reducing the likelihood of extreme GDP-growth outturns.

**Key Words:** Growth-at-Risk; Macroprudential Policy; Narrative Identification; Quantile Local Projections.

**JEL Codes:** E32, E58, G28.

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# 1 Introduction

Macroprudential policies are now an increasingly important part of policymakers’ toolkits. Targeted at maintaining financial stability, a key aim of macroprudential policy is to reduce ‘tail risks’—i.e., minimise the potential economic costs of negative shocks by bolstering the resilience of the financial sector (Carney, 2020). However, building this resilience may not always be costless. So, while macroprudential policies can contain risks and contribute to macroeconomic stability, they may also have macroeconomic costs by constraining economic growth.

In order to gauge these potential costs and benefits, it is important to attain accurate estimates of the causal effects of macroprudential policies on the *entire distribution* of potential macroeconomic outcomes. While the development of quantile-regression techniques to estimate growth-at-risk—i.e., the size of potential ‘1-in- $x$  bad outcomes’—offer policymakers a greater understanding of the drivers of tail risks when monitoring financial stability (see, e.g., Adrian, Boyarchenko, and Giannone, 2019; Aikman, Bridges, Hacıoglu Hoke, O’Neill, and Raja, 2019; Adrian, Grinberg, Liang, Malik, and Yu, 2022; Lloyd, Manuel, and Panchev, 2023), identifying the causal effects of macroprudential policies on growth-at-risk presents a number of important empirical challenges. Crucially, as with other macroeconomic policies, macroprudential policy is not ‘randomly assigned’ and may be anticipated by economic agents. So a simple comparison of future economic outcomes under different policies is unlikely to uncover reliable estimates of causal effects.

In this paper, our key contribution is to estimate the causal effects of macroprudential policies on the entire GDP-growth distribution by incorporating a novel narrative-identification strategy within a quantile-regression framework. Narrative identification methods have been used to uncover the effects of monetary policy (Romer and Romer, 1989) and fiscal policy (Romer and Romer, 2010; Cloyne, Martinez, Mumtaz, and Surico, 2022), and have recently been employed in the macroprudential-policy literature (Richter, Schularick, and Shim, 2019; Rojas, Vegh, and Vuletin, 2022; Fernández-Gallardo, 2023). We build on this work by looking beyond the effects of specific prudential instruments and beyond just mean outcomes for GDP, considering the tails of the GDP-growth distribution. To do so, we exploit the Macroprudential Policy Evaluation Database (MaPPED), which covers a range of macroprudential policy actions across advanced European economies (Budnik and Kleibl, 2018). This dataset includes a wealth of information on each policy action. Most importantly for our narrative identification, it records whether

a policy action has countercyclical motivation or design—i.e., whether it is set *in response to* (expected) macroeconomic outcomes.

Other features of the dataset and our empirical strategy additionally contribute to the novelty of our approach. The detailed information on announcement and enforcement dates of policy actions recorded within MaPPED helps to account for policy-implementation lags, and strip away policy-anticipation effects.<sup>1</sup> Alongside this, we build on recent advances to the identification of dynamic causal effects within quantile-regression settings (Lloyd and Manuel, 2023) by controlling for factors that potentially feature in macroprudential policymakers’ reaction function through a ‘one-step’ estimation approach. We show that this approach identifies causal effects under a standard ‘selection-on-observable’ assumption, in comparison to a ‘two-step’ approach in which the policy reaction function is first estimated and then its residuals are used in a second-stage quantile regression. By combining this approach with our narrative identification, we effectively pin down unanticipated and exogenous macroprudential policy ‘shocks’ to identify causal effects.

Applying these shocks, we document how macroprudential policy affects different parts of the conditional distribution of future GDP growth. We find that tighter macroprudential policy significantly and robustly boosts the left tail of GDP growth (i.e., reduces downside tail risk or ‘GDP-at-Risk’), while reducing the right tail (i.e., reducing upside tail risk), with broadly zero effect on the centre of the distribution. The left-hand side of Figure 1 presents this visually, demonstrating how the predictive distribution of GDP growth shifts in response to a tightening in macroprudential policy (of +2 tightening activations),<sup>2</sup> when all other control variables are set to their cross-country and cross-time average for the 12 economies in our 1990Q1-2017Q4 sample. We specifically plot the 4-year-ahead predictive distribution—the horizon at which we find the largest peak causal effects in our analysis. As we show later, however, the predictive distributions at other horizons would provide a similar qualitative picture. The figure illustrates our main empirical result: that macroprudential policy reduces the risk of large economic downturns in ‘bad’ states of the world, although restricts economic growth in ‘good’ states—in turn, reducing the variance of future GDP growth.

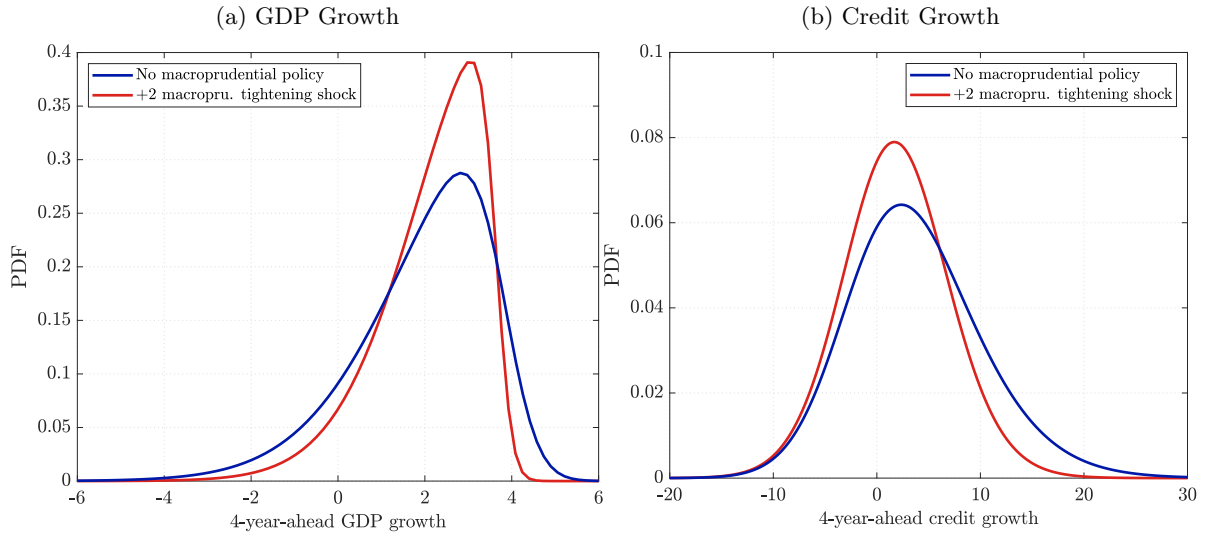
Armed with this result, we then consider the channels through which macroprudential policies affect the GDP-growth distribution. Amongst the channels we consider, it is the link from

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<sup>1</sup>Similar information has previously been employed in the fiscal-policy literature to account for potential confounding factors to narratively-identified shocks (Mertens and Ravn, 2012).

<sup>2</sup>The values of our macroprudential shock series range from  $-2$  to  $6$ . So a  $+2$  tightening lies well within that range.

Figure 1: Illustration of main results: The effect of a macroprudential policy tightening shock on the distributions of 4-year-ahead GDP and credit growth



*Notes:* Blue lines show distributions of 4-year-ahead GDP (Panel (a)) and credit (Panel (b)) growth when all control variables are set to their cross-country and cross-time average values, and the macroprudential policy index is 0. Red lines show the same distribution when the macroprudential policy index is +2 (that index ranges from  $-2$  to  $6$  in our sample), which corresponds to a macroprudential policy tightening shock, with all other variables kept at their average values. Distributions approximated by fitting skew- $t$  distribution to quantile-regression estimates at  $\tau = [0.1, 0.25, 0.5, 0.75, 0.9]$ .

macroprudential policy to GDP-at-Risk via *credit quantities* that is most significant—in line with the extensive literature linking periods of excessive credit growth with financial-stability risks (e.g., [Schularick and Taylor, 2012](#); [Müller and Verner, 2023](#)). Using our quantile-regression framework, we demonstrate that tighter macroprudential policy reduces credit growth, with this effect being particularly large at the right tail of the credit-growth distribution. This highlights that macroprudential policy can be particularly effective at mitigating excessive credit ‘booms’, operating through a ‘credit-at-risk’ channel.<sup>3</sup> The right-hand side of Figure 1 presents this logic, illustrating how a tightening in macroprudential policy especially impacts the right tail of the credit-growth distribution over the same 4-year horizon shown for GDP.

Interacting an indicator variable for periods of high credit growth with credit growth itself in our GDP-at-Risk regression, we then show that it is precisely this right tail of credit growth that is a significant driver of GDP-at-Risk. So, while an implication of previous growth-at-risk studies is that lower credit growth can be effective at reducing risks to financial stability (e.g., [Aikman et al., 2019](#); [Adrian et al., 2022](#); [Lloyd et al., 2023](#)), our findings go one step further.

<sup>3</sup>Throughout this paper, we use the term ‘credit-at-risk’ to refer specifically to the right tail of the credit growth distribution.

Tighter macroprudential policy can be effective at reducing the likelihood of extreme GDP-growth outturns *because* it reduces the right tail of credit growth. By dampening the impact of credit booms on GDP tail risks, macroprudential policy influences growth-at-risk through ‘credit-at-risk’.

To further understand the links between macroprudential policy, and tail risks to credit and GDP, we also consider the effects of policy on the composition of credit. Preexisting work has shown that household credit booms, not business credit booms, are strongly associated with financial-stability risks, subsequent decline in GDP growth and deeper financial recessions (Mian, Sufi, and Verner, 2017; Jordà, Kornejew, Schularick, and Taylor, 2020). Within our quantile-regression framework, we find that tighter macroprudential policy appears to be equally effective at preventing household *and* business credit booms. Given the differential financial-stability risks associated with household and corporate credit, a key policy implication from this result is that macroprudential policy may have a heterogeneous impact on the tails of the GDP-growth distribution, and financial stability overall, through its effect on credit allocation. Finally, amongst the other channels we consider, we find limited evidence of significant transmission through house prices.

Overall, our results provide novel evidence about the causal effects of macroprudential policy on the distribution of future macroeconomic outcomes. In particular, our results suggest that, by defusing upside credit-at-risk (i.e., credit booms), tighter macroprudential policy can be effective in mitigating extreme—downside and upside—macroeconomic risks.

**Related Literature.** Our paper contributes to three main strands of literature. First, our work builds on studies applying quantile-regression techniques to assess the drivers of macroeconomic tail risks (e.g., Adrian et al., 2019, 2022; Lloyd et al., 2023). While some papers have sought to assess the association between macroprudential policy and tail risks to GDP growth (Aikman et al., 2019; Galán, 2020; Franta and Gambacorta, 2020), we build on recent developments in macroprudential policy measurement and quantile identification to plausibly identify causal impacts.<sup>4</sup> The dataset we use is crucial in this regard, allowing us to overcome concerns

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<sup>4</sup>Using a heterogeneous panel of advanced and emerging economies, Franta and Gambacorta (2020) investigate the impact of two macroprudential measures: loan-to-value (LTV) and loan-loss provisioning, on the tails of the GDP-growth distribution. To estimate the impact of loan-loss provisioning, they do not identify plausible exogenous variation in the policy, which means their estimates cannot be interpreted causally under general assumptions. However, when assessing the impact of changes in LTV, they utilise the dataset of Richter et al. (2019), which contains LTV changes that can be considered orthogonal to the real business cycle (e.g., real GDP), but not to the financial cycle (e.g., total credit). As a result, their findings for LTV changes could be interpreted causally under some assumptions: for example, no policy anticipation, and no systematic correlation between real

regarding both endogeneity and anticipation effects. We complement this narrative approach with additional robustness exercises to demonstrate that our results are broadly unchanged when additionally controlling for macroeconomic forecasts made at the time of macroprudential policy decisions (similar in spirit to the identification strategy of [Romer and Romer \(2004\)](#) to estimate monetary-policy effects). To do this, we build on recent work on the identification of dynamic causal effects with confounding factors in a quantile-regression setting in [Lloyd and Manuel \(2023\)](#). This work demonstrates that previous attempts to identify the effects of macroprudential policies within a quantile regression by first estimating a series of ‘policy shocks’ from a first-stage regression ([Brandão-Marques, Gelos, Narita, and Nier, 2021](#); [Gelos, Gornicka, Koepke, Sahay, and Sgherri, 2022](#)) suffer from a form of omitted-variable bias, which we avoid by employing an alternate ‘one-step’ quantile regression estimator with variables that potentially feature in the policy reaction function as controls.

Second, we contribute to a more general literature on macroprudential policy identification. We employ a narrative strategy to identify the effects of macroprudential policy, in line with a range of recent papers ([Richter et al., 2019](#); [Rojas et al., 2022](#); [Fernández-Gallardo, 2023](#)). We build on this by looking beyond the effects of specific instruments (e.g., LTV requirements) and beyond just mean outcomes. While previous literature has employed narrative methods to separately estimate potential costs (e.g., reductions in economic growth) and benefits (e.g., reduced probability of financial crises) of macroprudential policies, by using quantile-regression techniques we are able to simultaneously assess costs and benefits by examining the effects of macroprudential policy across the entire distribution of GDP-outcomes. In the context of cost-benefit analyses frameworks for macroprudential policy (e.g., [Suarez, 2022](#)), our results—based on historical data—suggest that tighter macroprudential policy can, on net, be beneficial by mitigating downside risks to GDP growth without reducing expected (i.e., mean) growth.

Third, we contribute to a range of work assessing the transmission channels of macroprudential policy to the macroeconomy through the financial system. A key finding in the previous literature is that tighter macroprudential policy can be effective at reducing rapid credit growth ([Claessens, Ghosh, and Mihet, 2013](#); [Cerutti, Claessens, and Laeven, 2017](#); [Forbes, 2021](#); [Acharya, Bergant, Crosignani, Eisert, and Mccann, 2022](#)), and in turn that reduced credit growth is associated with lower financial-crises probabilities ([Belkhir, Naceur, Candelon, and Wijnandts, 2022](#); [Fernández-Gallardo, 2023](#)). We show that tighter macroprudential policy can

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and financial cycles.

be effective at reducing tail risks to GDP growth precisely because it reduces the probability of credit booms (i.e. reduces the right tail of the credit-growth distribution).

**Outline.** The remainder of this paper is structured as follows. Section 2 describes our empirical specification, data and narrative-identification strategy. Section 3 presents our baseline results for the effects of macroprudential policy on the distribution of future GDP growth. Section 4 investigates the role of different transmission channels. Section 5 concludes.

## 2 Empirical Specification, Data and Identification

In this section, we present our overarching empirical framework. We describe our narrative measure of macroprudential policy and explain how we tackle the challenge of identifying macroprudential policy shocks—which form a key part of our contribution to the growth-at-risk literature.

### 2.1 Empirical Specification

As in previous growth-at-risk studies, we employ a quantile-regression framework (Koenker and Bassett, 1978) to assess how changes in a set of conditioning variables—in our case, macroprudential policy in particular—are associated with the distribution of future GDP growth, and (later on) credit growth and asset prices. We present our approach within a panel setting,<sup>5</sup> where time is denoted by  $t = 1, \dots, T$  and the countries for whom we estimate the conditional distribution of GDP are labelled with  $i = 1, \dots, N$ .

We specify the following local-projection model (Jordà, 2005) for the conditional quantile function  $Q$  of  $h$ -period-ahead annual average GDP growth, which we denote by:  $\Delta^h y_{i,t+h} \equiv (y_{i,t+h} - y_{i,t}) / (h/4)$  for  $h = 1, \dots, H$ :

$$Q_{\Delta^h y_{i,t+h}}(\tau | \Delta MaPP_{i,t}, \mathbf{x}_{i,t}) = \alpha_i^h(\tau) + \Delta MaPP_{i,t} \beta^h(\tau) + \mathbf{x}_{i,t}' \boldsymbol{\theta}^h(\tau), \quad \tau \in (0, 1) \quad (1)$$

where  $Q$  computes quantiles  $\tau$  of the distribution of  $\Delta^h y_{i,t+h}$  given covariates.  $\Delta MaPP_{i,t}$  denotes the scalar narrative-based macroprudential policy shock for country  $i$  at time  $t$ , with

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<sup>5</sup>We focus on a panel specification in order to use as much data as possible—across time and countries. Doing so is particularly helpful for the precision of estimated causal effects across the GDP-growth distribution. An implication of this choice is that we implicitly assume causal effects are, on average, the same across time and countries. To mitigate concerns about this assumption, we focus on a cross-section of similar European economies, for whom it is reasonable to assume relatively homogeneous causal effects—especially since aspects of macroprudential regulation are harmonised across countries through, for example, supra-national bodies and regulation.

associated parameter  $\beta^h(\tau)$ . The  $K \times 1$  vector of control covariates  $\mathbf{x}_{i,t}$  has associated parameter vector  $\boldsymbol{\theta}^h(\tau)$ .

In equation (1),  $\alpha_i^h(\tau)$  represents country- and quantile-specific fixed effects, which control for time-invariant unobserved heterogeneity. For our baseline panel specification, we estimate these fixed effects following the approach of [Kato, Galvao Jr, and Montes-Rojas \(2012\)](#), who show that for panel quantile regressions like ours, with many time periods compared to the number of cross-sectional units (i.e.,  $T \gg N$ ), this fixed-effects estimator is consistent and asymptotically normal.<sup>6</sup>

In our baseline specification, we include the following controls in  $\mathbf{x}_{i,t}$  to account for time- and country-varying observed macro-financial conditions: the annual growth of real credit; the annual growth of real house prices; the annual growth of general CPI prices; contemporaneous and lagged values of the dependent variable; and the US VIX. These span both domestic and foreign drivers of the GDP-growth distribution, over and above macroprudential policy. The US VIX, in particular, helps to account for global factors affecting the distribution of GDP growth ([Lloyd et al., 2023](#)). We include both the contemporaneous and first lags of each of our controls in our baseline specification. In robustness analyses, we carry out extensive tests on the sensitivity of our results to alternative controls.

Our baseline sample runs from 1990Q1 to 2017Q4, at quarterly frequency for 12 advanced European economies. The selection of this sample is determined by the availability of narrative-based macroprudential policy series  $\Delta MaPP_{i,t}$  that we explain subsequently in Section 2.2.

With this specification, and armed with the discussion of identification in Section 2.3, our coefficient of interest  $\beta^h(\tau)$  can be interpreted as the *causal* response of the  $\tau$ -th conditional quantile of GDP growth at horizon  $h$  to a tightening in macroprudential policy that is activated at time  $t$ . Throughout, we focus the majority of our presentation on the 10th, 50th and 90th percentiles of GDP growth.<sup>7</sup> We choose those quantiles to estimate the impact of a macroprudential policy shock not only on the median, but also on the tails of the GDP-growth distribution, which constitute measures of the macroeconomic downside and upside risk, respectively. Therefore, those percentiles can be interpreted as representing how ‘bad’ (‘good’) growth may be under adverse (favourable) circumstances.

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<sup>6</sup>In robustness analysis, we also present results using country- and quantile-specific fixed effects estimated following the approach of [Machado and Santos Silva \(2019\)](#).

<sup>7</sup>We additionally use estimates for the 25th and 75th percentiles to fit the skew- $t$  distributions to quantile-regression outputs in Figure 1.



## 2.2 Macroprudential Policy Index

We construct our macroprudential policy index  $\Delta MaPP_{i,t}$  by using the Macroprudential Policies Evaluation Database (MaPPED). This database contains around 480 policy actions taken between 1990Q1 and 2017Q4 for the following 12 advanced economies: Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Netherlands, Finland, Sweden, Portugal and the UK.<sup>8</sup> The dataset covers 11 categories of policy instruments, spanning: capital requirements, capital buffers, risk weights, leverage ratios, provisioning systems, lending standards restrictions, limits on credit growth, taxes on financial activities, limits on large exposures, liquidity requirements and limits on currency and maturity mismatch, and other measures. Our sample end date of 2017Q4 marks the last publicly-available update of the dataset.

Relative to other macroprudential policy databases such as the IMF’s Integrated Macroprudential Policy (iMaPP) Database (Alam, Alter, Eiseman, Gelos, Kang, Narita, Nier, and Wang, 2019) and the International Banking Research Network’s Prudential Policy Database (Cerutti, Correa, Fiorentino, and Segalla, 2017), MaPPED has several advantages for our purposes. Importantly, the survey designed for MaPPED ensures that policy tools and actions are reported in the same manner across countries. Therefore, MaPPED allows for comparability of policy actions across countries, avoiding potential biases from unstandardised open-text questionnaires and lending itself most naturally to our panel specification. Furthermore, MaPPED includes a wealth of information on each policy action. It tracks the life cycle of each policy instrument, including when it was activated, recalibrated and (if relevant) deactivated. So it allows us to account for the potentially differential effects of different types of policy changes. It also distinguishes between announcement and enforcement dates of policies, allowing us to control for policy anticipation effects. Most importantly though, in tracking the nature (loosening, tightening, or ambiguous) of each policy action, it also records narrative information about whether a policy action has countercyclical motivation and/or design. This feature is key to our identification strategy, as we explain in detail in Section 2.3.<sup>9</sup>

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<sup>8</sup>For the post-1995 period, MaPPED includes all policy actions—both those in force prior to 1995 and new policy activations post-1995. However, pre-1995, the dataset only includes policies that still remained in force in 1995. Therefore, the dataset does not include policies activated prior to 1995 that were deactivated between 1990 and 1994. Nevertheless, the dataset is still likely to include the vast majority, if not all, of the policies implemented between 1990 and 1994 for two reasons. First, macroprudential policy deactivations represent a very small percentage of total policy actions (only 2%). Second, within MaPPED, policies that are eventually deactivated have an average duration of around 14 years. Therefore, it is unlikely that during the first years of the sample, 1990-1994, policies were enforced and deactivated prior to 1995.

<sup>9</sup>We refer the reader to Budnik and Kleibl (2018) for detailed information on the advantages of MaPPED over other existing macroprudential policy databases.

In our baseline specification, we construct an overall macroprudential policy shock index  $\Delta MaPP_{i,t}$  for each country in the sample by combining all non-systematic policy actions—an approach also followed by [Fernández-Gallardo and Payá \(2023\)](#).<sup>10</sup> To do so, we use the announcement date of the policy to assign a value to each policy action, giving a positive value to tightening actions, a negative value to loosening actions, and a value of zero to policy actions with ambiguous impacts or no announced policy action in a given period. We focus on announcement dates, since it is common for there to be lags in the implementation of macroprudential policy following announcements that financial entities might respond to at the time of initial communication. These lags can arise because of legal requirements around policies (e.g., increases in bank capital buffers should be announced one year prior coming into force), but also because, in practice, policymakers may prefer to announce and communicate policy changes in advance to allow financial entities time to prepare. As an example, MaPPED records the fact that the January 2014 changes to the risk weights assigned to loans backed by residential and commercial property in the UK were first announced and communicated by the Bank of England’s Financial Policy Committee (FPC) over six months before, in June 2013.

When constructing the macroprudential policy index, we also account for the fact that different types of policy actions—e.g., activations/deactivations, changes in scope of existing policies, renewals of existing policies—may have differing importance. In our baseline, we assign different weights to different policy actions based on importance, following the weighting scheme proposed by [Meuleman and Vander Venet \(2020\)](#). Under this scheme, activations and deactivations are given the highest weights. Second-tier actions, including changes in the existing level or scope of the policy are given a lower weight. Finally, an announcement that reaffirms or maintains existing policy levels is given the lowest weight. [Appendix A](#) details the weights assigned to the different policy actions. However, this weighting does not materially influence our main qualitative results; these are robust to alternative weighting schemes.

## 2.3 Identification of Macroprudential Policy Shocks

In order to apply the macroprudential index to study the impact of policy changes on the GDP-growth distribution, we ensure that our measure  $\Delta MaPP_{i,t}$  pins down only the ‘non-systematic’ component of macroprudential policy—a step that is crucial for identifying causal effects. We refer to the non-systematic component of the policy actions—actions that do not systematically

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<sup>10</sup>In robustness analysis, we analyse potential heterogeneity across different ‘types’ of macroprudential policies (e.g., borrower- vs. lender-based measures).

respond to short- to medium-term economic fluctuations—as macroprudential policy ‘shocks’.

Overall, we face two empirical challenges to identify unanticipated macroprudential policy shocks. First, some macroprudential policies are endogenous, as they are activated or adjusted in response to current or future economic conditions. Those policies are likely contaminated by reverse causality and therefore are invalid to recover causal effects. Second, lags between the announcement and activation of macroprudential policies—either due to legally-binding implementation lags or a preference amongst policymakers to announce a policy in advance to allow firms time to prepare—can pose an empirical challenge for disentangling the relationship between macroprudential policy and the GDP-growth distribution. In either case, policy actions subject to a delay between announcements and the implementation of the legislation may be partially anticipated, implying that economic agents can endogenously react to such prudential policy news. Policies with and without implementation lags can therefore have very different effects on macroeconomic variables, as shown by [Mertens and Ravn \(2012\)](#) in the fiscal policy context.

**Building the Narrative Series.** In our baseline specification, we address the first threat to identification, endogeneity, using the narrative information provided in MaPPED. Our approach builds on that proposed by [Fernández-Gallardo \(2023\)](#), and we apply it within our quantile-regression framework. To identify macroprudential policy actions that are plausibly exogenous, we exclude policy actions with a specific countercyclical design, as those interventions are primarily aimed at short- to medium-term stabilisation rather than implemented to address structural vulnerabilities in the financial system. In the MaPPED questionnaire, an instrument is defined as having a countercyclical design if its calibration is regularly revised along with judgements about the intensity of cyclical systemic risk ([Budnik and Kleibl, 2018](#)). For the 12 advanced economies selected in this paper, countercyclical policies in MaPPED represent approximately 10% of the total set of policies covered by the database. They include, amongst other policies, changes in countercyclical capital buffer (CCyB) rates, which are altered in response to cyclical systemic risk.<sup>11</sup>

We therefore construct our  $\Delta MaPP_{i,t}$  indicator for each country in the sample following the steps explained in Section 2.2 by excluding policy actions with countercyclical design and

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<sup>11</sup>In particular, among the eleven categories in which MaPPED classifies macroprudential policy instruments, five of them include *at least one* (but not necessarily all) policy action(s) that has countercyclical motivation and/or design. These five policy categories are capital buffers, lending standards restrictions, provisioning systems, risk weights, and a final category labeled ‘other measures’.

motivation. By doing this, our index therefore focuses on policy actions that are legitimate observations for identifying causal effects because such policies are less likely to be systematically correlated with other underlying factors affecting the GDP-growth distribution. Indeed, [Fernández-Gallardo \(2023\)](#) shows that, after excluding countercyclically-motivated policies, the remaining macroprudential policy index is unpredictable based on a range of real, financial and monetary variables, and that it does not respond systematically to financial-crises episodes, supporting our claim that this captures genuinely exogenous moves in policy.

**Analysing the Narrative Series.** The resulting index can be interpreted as a composite measure of overall macroprudential policy ‘shocks’ in each of the advanced economies. Despite excluding countercyclical policies, it still retains information on a range of other macroprudential tools (e.g., systemic risk buffers, risk weights) aimed at addressing systemic risks of a long-term, non-cyclical nature. Figure 2 plots the changes in our narrative macroprudential policy index over time for each country in the sample. The index displays significant heterogeneity across countries, reflecting the fact that different macroprudential policy authorities in different countries have chosen to tighten or loosen policies to different extents over time.

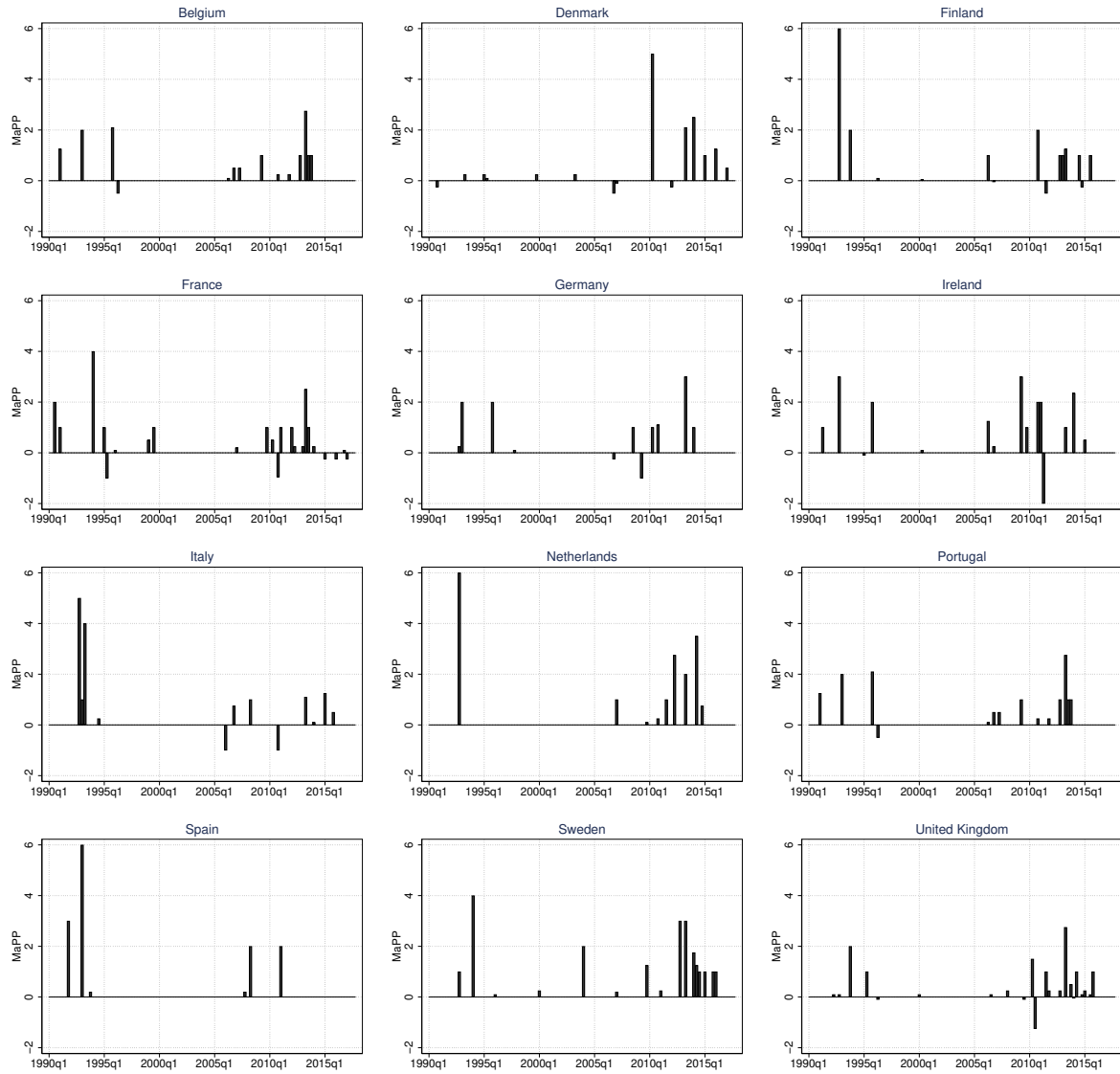
Importantly, however, the resulting series pick up a range of relevant events, plausibly unrelated to cyclical macro-financial factors. Focusing on the UK as an example (bottom-right panel), we see moves associated with a range of policy actions.<sup>12</sup> The first major UK policy tightening occurs in 1993Q4, where the index takes the value +2, when two new and related policies were activated. In October 1993, policymakers announced a new limit on banks’ aggregate large exposures to clients (or groups of connected clients), which could not exceed 800% of eligible capital, alongside limits on interbank exposures of up to 20% of eligible capital. Both came into force in February 1994, but are recorded in 1993Q4 on account of their announcement. As both represented new policy activations, they are assigned equal weight in that period.

Similarly, in 1995Q2, the UK index takes the value +1 when the UK implementation of the Basel I accord was announced, introducing an 8% capital adequacy ratio (CAR), with effect from January 1996. Subsequent changes to the CAR are also recorded, albeit with a lower value, given the higher weight assigned to new policy activations in our baseline measure. For instance, in March 2000, the scope of the CAR was extended to cover market risk, with effect from November 2000. So, in 2000Q1, the UK index takes a positive value (+0.1) to reflect this

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<sup>12</sup>Further narrative information on other countries in our sample can be found [here](#).

Figure 2: Changes in the Narrative-Based Macroprudential Policy Index over Time



Notes: Plot of narrative-based  $\Delta MaPP_{i,t}$  over time for each advanced-economy in our sample. Period is 1990Q1-2017Q4.

announced tightening in policy.

The UK, as well as other countries' narrative series also include policy loosening. For instance, in 2010Q3 the UK index takes the value  $-1.25$ , reflecting two announcements. First, the deactivation of the October 1993 800%-of-eligible-capital limit on banks' aggregate large exposures to clients from December 2010 was announced in September 2010. Since this represents a deactivation of an existing policy, our weighting scheme implies that this explains 80% of the index in 2010Q3. Second, and at the same time, looser interbank exposure limits were announced.

Thereafter, the UK index takes numerous positive values, reflecting the range of macroprudential tools implemented following the 2007-9 Global Financial Crisis (GFC). These capture a combination of policy tightenings and loosening, including the June 2013 announcement of new CET1 and Tier-1 capital ratios that came into force in January 2014, the loosening of risk weights on loans backed by commercial property in 2013Q2, as well as the December 2015 announcement of a capital buffer for Global Systemically Important Institutions that came into force in January 2017. Importantly, however, the index excludes changes in the UK CCyB rate owing to this policy's explicit countercyclical design. So, for example, the values in Figure 2 do not reflect either the announced increase in the CCyB rate from 0 to 0.5% March 2016 following a cyclical build-up of domestic credit, or the announced reduction in that same rate, back to 0%, in July of the same year in response to the potential macroeconomic consequences of the UK's vote to leave the European Union.

**Addressing Additional Threats to Identification.** An alternate approach, frequently employed in the literature, is to identify 'as good as random' moves in macroprudential policies by controlling for variables that plausibly feature in a macroprudential 'reaction function'. The underlying identifying assumption in this approach is 'selection on observables': conditioning on a set of observable factors, changes in macroprudential policy are exogenous with respect to all other drivers of future outturns in the outcome variable of interest. Although not typically explained in this way in the macroprudential-policy literature, this is the assumption underpinning identification via propensity scores (Forbes, Fratzscher, and Straub, 2015; Richter, Schularick, and Shim, 2019), as well as via the estimation of policy shocks as the residuals from a reaction function (Ahnert, Forbes, Friedrich, and Reinhardt, 2021; Chari, Dilts-Stedman, and Forbes, 2022; Gelos, Gornicka, Koepke, Sahay, and Sgherri, 2022).

There are well-known challenges with this approach, most notably that it may be infeasible in practice to correctly identify and then control for all the variables that potentially feature in the policy reaction function, especially in the face of limited dimensionality in finite samples. For example, controlling for the wide range of economic and financial indicators that feed into judgements on the overall level of systemic risk and subsequent CCyB policy decisions poses significant challenges.<sup>13</sup>

An advantage of our approach is that we directly utilise detailed information on policies from narrative records to effectively exclude those with a specific countercyclical design and/or motivation. However, our approach does not preclude identification by additionally controlling for potential confounding factors. To ensure our approach is ‘doubly robust’ we can further control for variables which plausibly simultaneously drive macroprudential policy decisions and macroeconomic outcomes. In our baseline specification we include a range of control variables intended to capture the level of cyclical systemic risk—including measures of credit growth, house-price growth and financial conditions. Moreover, in the spirit of [Romer and Romer \(2004\)](#), we explore the sensitivity of our baseline results to the inclusion of forecasted GDP growth as an additional control. This allows us to account for the information set that policymakers have available on the future state of the economy when the policy is announced.<sup>14</sup>

To operationalise this robustness exercise, we build on recent work on estimating dynamic causal effects in a quantile-regression setting in [Lloyd and Manuel \(2023\)](#). A common approach in the literature is to first estimate policy shocks as a residual from a regression of the policy reaction function, and then to employ these shocks within a second-stage regression (typically a local projection). Recent approaches to estimate the effects of macroprudential policies within a quantile-regression framework have followed this approach ([Gelos et al., 2022](#); [Brandão-Marques et al., 2021](#)). In OLS settings, this ‘two-step’ approach is equivalent to directly regressing the outcome variable on the policy variable with reaction function variables as controls, a result that follows directly from the Frisch-Waugh-Lovell theorem. But in quantile regression, [Lloyd and Manuel \(2023\)](#) show that coefficient estimates from this two-step approach suffer from a form

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<sup>13</sup>Taking the UK again as an example, the Bank of England’s FPC publish a set of around 20 core indicators that they use when assessing systemic risk, but their [CCyB Policy Statement](#) explicitly states that (*emphasis added*): “These indicators are only a *subset* of the *wide range* of economic and financial indicators, and the *wealth* of supervisory and market intelligence that support the FPC’s assessment of the risk environment and its judgements on the CCyB.” Controlling for this entire information set beyond just these core indicators is likely to be infeasible.

<sup>14</sup>A key insight of [Romer and Romer \(2004\)](#) is that forecasts of the outcome variable at the time of policy decisions alone can act as a sufficient statistic to control for all potential confounding factors that simultaneously drive policy and outcomes (see comment by [Cochrane, 2004](#)).

of quantile-regression omitted-variable bias and so generally fail to identify causal effects under a selection-on-observables assumption.<sup>15</sup> Based on the results in [Lloyd and Manuel \(2023\)](#), we therefore employ an alternate ‘one-step’ quantile-regression estimator of the outcome variable on the macroprudential policy variable, which includes potential-reaction-function variables as controls. We formalise this argument and provide an exact formula for the bias in the frequently-used two-step approach in [Appendix B](#).

In robustness, we also deal with another threat to identification: anticipation due to policy news. Here we use the information provided by MaPPED on the announcement and enforcement date of each policy action in the sample. This is a key advantage of MaPPED relative to other databases, allowing us to identify policies that are subject to implementation lag and therefore may be anticipated by economic agents. This approach mirrors that previously employed in the fiscal policy literature ([Mertens and Ravn, 2012](#)).<sup>16</sup>

We argue that our approach—employing narrative methods within a one-step quantile regression that potentially controls for any residual endogeneity—is crucial to plausibly identify the causal effects of macroprudential policy on conditional quantiles of GDP growth.

### 3 Empirical Results: Macroprudential Policy and GDP

In this section, armed with our narratively-identified macroprudential policy shocks and the empirical framework presented in [Section 2](#), we present results summarising the causal links between macroprudential policy and the entire distribution of future GDP growth.

#### 3.1 Baseline Specification

[Figure 3](#) presents the impulse responses of quantiles of the conditional GDP-growth distribution (for  $\tau = 0.1, 0.5, 0.9$ ) to changes in our narrative macroprudential policy index across different horizons  $h$  from our baseline specification (1). Panel A of [Table 1](#) presents the corresponding coefficient point estimates and standard errors at selected horizons, alongside complementary

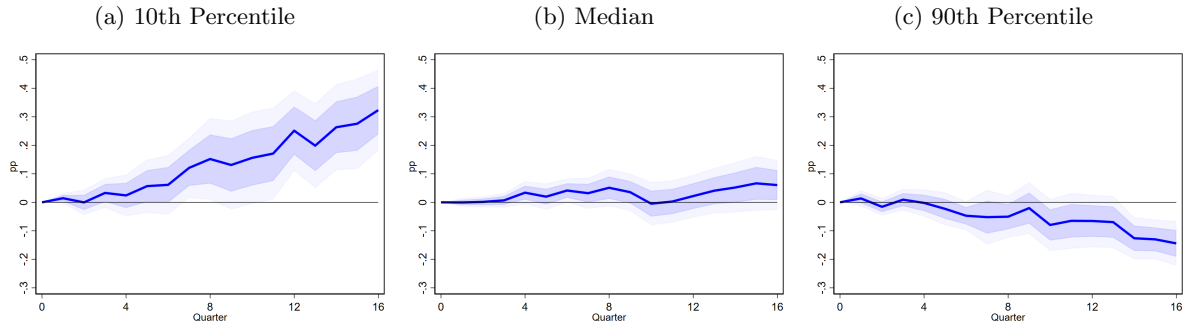
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<sup>15</sup>This result draws on the econometric insight from [Angrist, Chernozhukov, and Fernández-Val \(2006\)](#) that quantile regression can be interpreted as a weighted-least squares estimator, with weights that are a function of quantiles.

<sup>16</sup>An additional empirical challenge to policy-shock identification could come from the possibility that some macroprudential policy implementations could be partially anticipated, even in the absence of implementation lags. News to future policy shocks can pose serious challenges to identification as it has the potential to hinder invertibility, a crucial requirement for VARs ([Leeper, Walker, and Yang, 2013](#)) and proxy-VARs ([Stock and Watson, 2018](#); [Plagborg-Møller and Wolf, 2021](#)). Nevertheless, policy-shock anticipation seems less problematic for local projections, the method we use in our empirical analysis, as the aforementioned condition—invertibility—is not required (see, e.g., [Jordà, 2023](#)).



Figure 3: Dynamic Response of GDP-Growth Quantiles to Macroprudential Policy Tightenings



*Notes:* Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$  following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4, for 12 advanced economies. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence intervals based on bootstrap with 500 replications.

OLS-regression estimates in Panel B for comparison. The results highlight notable asymmetries in the effects of macroprudential policies on quantiles of the GDP-growth distribution, which can differ markedly from OLS estimates.

Comparing the estimates for the 10th and 90th percentiles with those for the median, we find that macroprudential policies affect the tails of the GDP-growth distribution disproportionately more than at the median. In fact, Panel (b) of Figure 3 indicates that the impact of tighter macroprudential policy on median GDP growth is small and statistically insignificant across horizons—and likewise for the mean implied by the OLS estimates in Panel B of Table 1.

Nevertheless, macroprudential policy does have significant impacts on the tails of GDP growth. Comparing Panels (a) and (c) of Figure 3 indicates that tighter macroprudential policies have opposing effects to the downside (i.e., the  $\tau = 0.1$  left tail) and upside (i.e., the  $\tau = 0.9$  right tail). In particular, while a tightening macroprudential policy shock has an insignificant effect at the median across different horizons, it has a positive (negative) effect on the left (right) tail of the GDP-growth distribution that persists over the long term. Effects in both tails are statistically significant after 2-3 years. However, our estimates reveal that the quantitative impact on the left tail is larger in magnitude than the impact on the right tail, suggesting that tighter macroprudential policy alters the skew of the GDP-growth distribution—an implication that we presented visually in the left-hand plot of Figure 1 after fitting skew- $t$  distributions to the fitted values implied by these quantile-regression estimates.

These results suggest that the benefits of tighter macroprudential policy on GDP growth are most clear at the left tail of the GDP-growth distribution—consistent with previous studies

Table 1: Coefficient estimates  $\beta^h(\tau)$  from baseline specification: regression of GDP growth on narrative measure macroprudential policy and controls

	$h = 4$	$h = 8$	$h = 12$	$h = 16$
PANEL A: Quantile-Regression Estimates				
$\tau = 0.1$	0.02 (0.04)	0.15** (0.08)	0.25*** (0.09)	0.32*** (0.08)
$\tau = 0.5$	0.03 <sup>^</sup> (0.03)	0.05 <sup>^</sup> (0.04)	0.02 (0.05)	0.06 <sup>^</sup> (0.06)
$\tau = 0.9$	-0.00 (0.03)	-0.05 <sup>^</sup> (0.04)	-0.07 <sup>^</sup> (0.05)	-0.14*** (0.05)
PANEL B: OLS-Regression Estimates				
OLS	0.02 (0.03)	0.02 (0.04)	0.03 (0.05)	0.06 <sup>^</sup> (0.05)

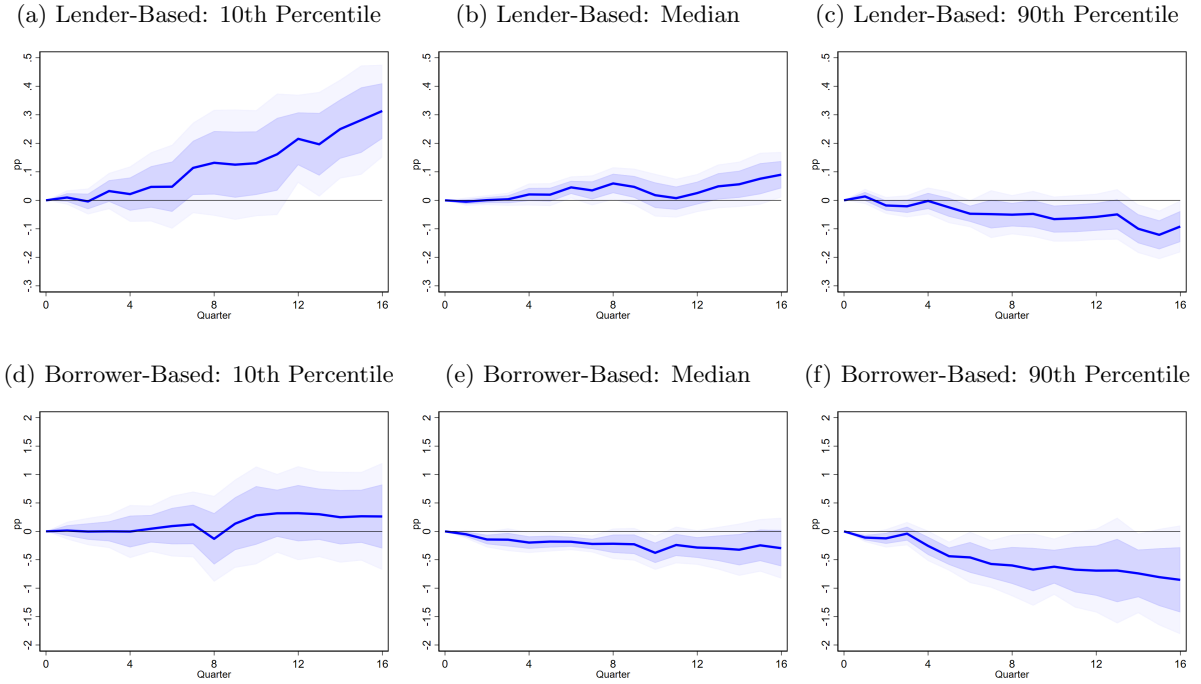
*Notes:* Panel A presents coefficient estimates for the causal effects of a 1-unit tightening in macroprudential policy on the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 4, 8, 12, 16$ . Panel B presents corresponding estimates from OLS regressions. Coefficient estimates for the fixed effects and controls are not reported. Sample period is 1990Q1-2017Q4, for 12 advanced European economies. Standard errors are based on bootstrap with 500 replications and are shown in parenthesis with: <sup>^</sup>  $p < 0.32$ , \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

of growth-at-risk and macroprudential policy (Galán, 2020; Franta and Gambacorta, 2020). As Panel (a) of Figure 1 shows, tighter macroprudential policy shifts the left-tail of the GDP-growth distribution to the right, reducing the probability of a severe contraction in GDP growth. Otherwise put, our results show that tighter macroprudential policy can improve ‘growth-at-risk’—a now standard measure of how bad growth can be under adverse circumstances typically associated with systemic distress (Adrian et al., 2019). Our results additionally imply that macroprudential policy can be effective at dampening tail risks to economic growth, and reducing the variance of future growth, without significant impacts at the centre of the distribution—again visible in Panel (a) of Figure 1. As a result, tighter macroprudential policy can make the growth outlook more resilient to negative future economic shocks.

**Heterogeneity Across Macroprudential Measures.** Our baseline results come from a single policy index that aggregates all macroprudential-policy actions. However, that index covers a range of different types of policies which could, in principle, have differential effects. To uncover heterogeneity across policy instruments, we distinguish between borrower- and lender-based measures, two widely used categorisations of macroprudential policy. Lender-based measures—which comprise the majority of measures in MaPPED—predominantly consist of capital measures, while borrower-based measures primarily include LTV and debt-service-to-income ratios.

We construct separate macroprudential-policy shock series for the non-systematic lender-

Figure 4: Dynamic Response of GDP-Growth Quantiles to Lender- and Borrower-Based Macroprudential Policy Tightenings



*Notes:* Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Lender-based measures only in panels (a)-(c); borrower-based measures only in panels (d)-(f). Sample period is 1990Q1-2017Q4, for 12 advanced economies. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence intervals based on bootstrap with 500 replications.

and borrower-based measures in the dataset. We then use these shock series in our baseline regression (1). The results are depicted in Figure 4, with impulse responses at the 10th, 50th and 90th percentiles for lender-based measures in Panels (a)-(c), and the corresponding impulse responses for borrower-based measures in Panels (d)-(f).

Reflecting the fact that lender-based measures explain the majority of variation in our aggregate macroprudential measures, the results for lender-based measures are broadly consistent with those in Figure 3 for our aggregate macroprudential policy shock. Tighter lender-based measures significantly increase the left tail of the future GDP-growth distribution, while simultaneously reducing the right tail. The former effect quantitatively dominates the latter such that the reduced variance of future GDP growth is also associated with a change in the skew—akin to that plotted in Panel (a) of Figure 1. Moreover, while our estimates for the impulse response to lender-based measures at the median are quantitatively small, they are marginally significant. Thus our results suggest that, if anything, tighter lender-based policies boost the centre of the GDP-growth distribution slightly.

Since borrower-based measures are less prevalent in our aggregate index, the estimated impulse responses in Panels (d)-(f) of Figure 4 have wider standard-error bands. In contrast to lender-based measures, however, the results suggest that borrower-based measures have larger effects on the right tail of the future GDP-growth distribution. While point estimates at the 10th percentile are broadly positive, they are statistically insignificant, and smaller in magnitude to the negative and significant coefficients for the 90th percentile. Therefore, our results indicate that tighter borrower-based macroprudential policy contributes to reduced macroeconomic tail risks by weighing particularly on right-tail outturns. Along with this, our estimates for the median are negative and statistically significant, albeit small in magnitude. Combined with the marginally positive and significant median effects of lender-based measures, these marginally negative and significant median effects for borrower-based measures help to explain why our median effects of the aggregate macroprudential index in Panel (b) of Figure 3 are insignificant. Moreover, the result for borrower-based measures is consistent with Richter et al. (2019), who find that borrower-based measures have a negative impact on average output growth over a four-year horizon.

Overall, therefore, our results imply that tighter macroprudential policy serves to reduce the variance of future GDP growth, boosting the left tail especially, as well as by reducing the right. Lender-based measures explain the majority of our aggregate results, though borrower-based measures also contribute to macroprudential policy’s role in making the growth outlook more resilient to future economic shocks.

### 3.2 Robustness Analyses

In this sub-section, we demonstrate how the results presented in Figure 3 and Table 1 are robust to a number of checks. We summarise each below. Full results are presented in Appendix C.

**Accounting for Macroeconomic Expectations.** Our benchmark results can be interpreted as capturing the causal effects of macroprudential policy on the GDP-growth distribution *provided that* the policies included in the narrative measure  $MaPP_{i,t}$  are not systematically correlated with macroeconomic expectations. To test this, we expand our baseline specification to include changes in expected GDP growth—formally, forecasted GDP growth over the following two quarters—as an additional control to proxy the information set available to policymakers

when policy is announced—similar in spirit to [Romer and Romer \(2004\)](#).<sup>17</sup> If our narrative macroprudential policy shock was *not* exogenous with respect to expectations in the baseline, then the addition of expected output growth as additional control should imply a significant change in the estimated impulse responses. However, we find that the results with and without the expected economic outlook in the set of controls are similar.

**Lags in Policy Implementation.** A key advantage of MaPPED is that it contains information on both the announcement and the enforcement date of each policy action in the sample. As discussed, we use the announcement date for all non-systematic policies in our baseline specification. However, some policies may have implementation lags that could influence estimated impulse responses. To account for this, we reconstruct the narrative shock index using policies with no implementation lag only.<sup>18</sup> Re-estimating our regression with these alternative shocks, our benchmark results and their economic implications are qualitatively unchanged. Estimation uncertainty is, however, larger than in the baseline with *all* non-systematic policies are included.<sup>19</sup>

**Alternative Controls.** We also assess the robustness of our findings to a range of alternative control specifications. First, we augment our specification with a financial conditions index (FCI) in our set of controls—that used by [Adrian et al. \(2022\)](#) and [Lloyd et al. \(2023\)](#). Our results are qualitatively similar when controlling for these FCIs. Second, we augment our specification to include controls for monetary policy—following recent research by [Loria et al. \(2022\)](#) who show that monetary policy has heterogeneous effects on the GDP-growth distribution.<sup>20</sup> This specification also helps to control for potential interlinkages between both monetary and macroprudential policies (e.g., [Kim and Mehrotra, 2018](#); [Altavilla, Laeven, and Peydró, 2020](#); [Coman and Lloyd, 2022](#)). Augmenting our baseline specification with short-term interest rates as an additional control, we find similar results to our baseline.

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<sup>17</sup>Our goal here is not to include all forward-looking variables that potentially feature in a macroprudential ‘reaction function’. Rather, we wish to control for any potential endogeneity between macroprudential policies and our outcome variable of interest, future GDP growth. In this case, controlling for GDP forecasts—and not forecasts of other variables—should be sufficient to remove this particular threat to identification (see comment by [Cochrane, 2004](#)).

<sup>18</sup>To operationalise this, we formally define policies with an implementation lag as those for which there is a delay between the announcement and the enforcement date of at least 90 days. Around 20% of the policy actions included in MaPPED suffer from implementation lag according to this definition. [Mertens and Ravn \(2012\)](#) use a similar 90-day threshold to account for fiscal policy implementation lags.

<sup>19</sup>The larger uncertainty in this specification can be explained by the lower variation in  $MaPPi_{i,t}$  when we only use policies without implementation lags to construct the index.

<sup>20</sup>In particular, they find that the 10th percentile of the predictive growth distributions responds about three times more than the median to a monetary policy shock.

**Alternative Macroprudential Policy Index.** As discussed, our baseline macroprudential policy measure weights different policy actions depending on their type: e.g., activation, recalibration, deactivation. However, this information is not included in other datasets, which instead assign integer values to quantify policy tightenings and loosening. To connect our results to alternative macroprudential policy datasets, we transform our *MaPP* index into a five-value discrete variable, and re-estimate our main regression.<sup>21</sup> The results with the discrete macroprudential policy index are qualitatively similar to the baseline results.

**Sample Stability: Excluding the GFC.** We re-estimate our baseline regressions for GDP growth using data up to 2007. We find that excluding the post-2007 period does not result in significant changes, and our baseline results remain qualitatively the same. This exercise confirms that the baseline estimates were not entirely driven by the economic events during the GFC, or the macroprudential policy reforms initiated following it.

**Alternative Country Fixed Effects.** We also explore robustness around the use of [Kato et al. \(2012\)](#) country-fixed effects, by re-estimating equation (1) using the [Machado and Santos Silva \(2019\)](#) quantiles-via-moments estimator. Our baseline results and their economic implications are not sensitive to the particular manner in which country-fixed effects are estimated.

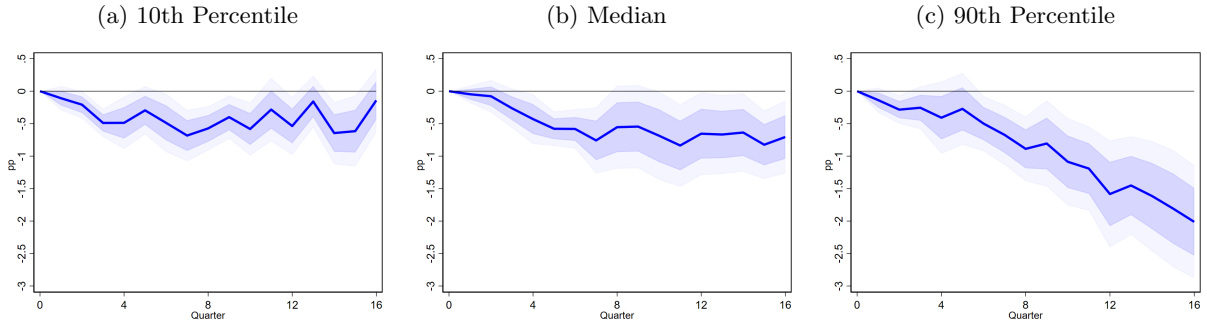
## 4 Exploring the Transmission Channels

So far, we have shown that tighter macroprudential policy has causal positive (negative) effects on the left (right) tail of the GDP-growth distribution, reducing its variance. In this section, we turn to analysing how macroprudential policy transmits in this way to the GDP-growth distribution, exploring the mechanisms behind these results. Why does macroprudential policy have positive effects on the lower end of the GDP growth distribution? Why do these policies have the opposite effect on the upper end of the GDP-growth distribution? To do so, we first investigate the impact of macroprudential policy on intermediate variables, like credit growth, and then link the effects of these intermediate variables to the GDP-growth distribution.

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<sup>21</sup>Formally, we allow  $\Delta MaPP_{i,t}^{new}$  to take values  $\{-2, -1, 0, 1, 2\}$ , where  $\Delta MaPP_{i,t}^{new} = -2$  if  $\Delta MaPP_{i,t} < -1$ ,  $-1$  if  $0 > \Delta MaPP_{i,t} \geq -1$ ,  $= 0$  if  $\Delta MaPP_{i,t} = 0$ ,  $= 1$  if  $0 < \Delta MaPP_{i,t} \leq 1$ , and  $= 2$  if  $\Delta MaPP_{i,t} > 1$ . This alternative weighting scheme is consistent with previous work on macroprudential policy (e.g. [Alam et al., 2019](#); [Gelos et al., 2022](#)) and reflects, as a general rule and in net terms, whether there was more than one loosening measure, one loosening measure, no change, one tightening measure, or more than two tightening measures in a given quarter, respectively. In practice, given the history of quarterly macroprudential policy implementations in our database, this alternative weighting scheme is very similar but not exactly equal to assigning equal weight to all policy actions.

Figure 5: Impulse Response of Quantiles of the Credit-Growth Distribution to Macroprudential Policy Tightenings



*Notes:* Estimated change in the  $\tau$ -th percentile of annual average real credit growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence intervals based on bootstrap with 500 replications.

#### 4.1 Quantity of Credit: A ‘Credit-at-Risk’ Channel

Preexisting empirical work has consistently found that financial booms, particularly credit booms, often precede financial crises (Schularick and Taylor, 2012; Jordà, Schularick, and Taylor, 2015; Richter, Schularick, and Wachtel, 2021). Therefore, the prevention and mitigation of credit booms is a natural candidate channel through which macroprudential policy can reduce the probability of tail outturns. Quantile regressions offer an ideal framework to explore this mechanism in detail.

Our approach consists of two steps. First, we show that macroprudential policy is particularly effective at mitigating excessive credit growth—i.e., we find that tightening macroprudential policy particularly pushes down the 90th percentile of the credit distribution. Second, we show that the upper tail of the credit distribution—i.e., the 90th percentile of credit growth, is strongly and systematically negatively (positively) related to the left-tail (right-tail) of the GDP growth distribution. This second step allows us to show that how macroprudential policy works through a ‘credit-at-risk’ channel: systematically reducing the likelihood of extreme GDP-growth outturns by influencing the tails of the credit-growth distribution.

**Causal Effects of Macroprudential Policy on Credit-at-Risk.** We start by estimating the responses of future credit quantiles to a tightening macroprudential shock by re-estimating our local-projection specification (1) for credit growth. Hence,  $\Delta y_{i,t+h}$  refers to the annual average real private credit growth over  $h$  quarters. This allows us to formally explore whether macroprudential policies have an asymmetric impact on the credit-growth distribution.

Table 2: Coefficient estimates for  $\beta^h(\tau)$  from regression of credit growth on narrative measure of macroprudential policy and controls

	$h = 4$	$h = 8$	$h = 12$	$h = 16$
PANEL A: Quantile-Regression Estimates				
$\tau = 0.1$	-0.49** (0.23)	-0.57*** (0.19)	-0.54** (0.29)	-0.14 (0.32)
$\tau = 0.5$	-0.43** (0.24)	-0.55^ (0.36)	-0.65^ (0.40)	-0.71** (0.31)
$\tau = 0.9$	-0.41^ (0.32)	-0.89*** (0.27)	-1.58*** (0.49)	-2.01*** (0.49)
PANEL B: OLS-Regression Estimates				
OLS	-0.39*** (0.08)	-0.59*** (0.15)	-0.67*** (0.21)	-0.87*** (0.24)

Notes: Panel A presents coefficient estimates for the causal effects of a 1-unit tightening in macroprudential policy on the  $\tau$ -th percentile of annual average real credit growth at horizon  $h = 4, 8, 12, 16$ . Panel B presents the corresponding estimates from OLS regressions. Coefficient estimates for the fixed effects and controls are not reported. Sample period is 1990Q1-2017Q4, for 12 advanced European economies. Standard errors are based on bootstrap with 500 replications and are shown in parenthesis with: ^  $p < 0.32$ , \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

We plot the impulse responses of the credit quantiles after a contractionary policy shock in Figure 5, with corresponding point estimates and standard errors shown in Table 2. We focus again on the 10th, 50th and 90th percentiles. The main takeaway from Figure 5 is that there is a clear asymmetry in the response of credit after a macroprudential policy shock. In particular, the 90th percentile responds more than the median, which in turn moves more than the 10th percentile. We find that a tightening prudential shock pushes down the right tail more strongly than other parts of the distribution.<sup>22</sup>

Together, these results imply that tighter macroprudential policy reduces the variance of future credit growth. But, as Panel (b) of Figure 1 demonstrates, the effect is most pronounced in the right tail of the distribution. If anything tighter macroprudential policy shifts the centre of the credit-growth distribution slightly to the left. However, how this maps to GDP-growth is a separate question, which we turn to now.

**Effects of Credit-at-Risk on GDP-at-Risk.** In our second step, we formally explore the role that credit-at-risk plays in shaping both downside and upside risks to the GDP growth by

<sup>22</sup>Following a macroprudential policy tightening, we see similar changes in the quantiles of country-specific FCIs. As we show in Appendix D.1, tighter macroprudential policy is associated with a reduction in financial ‘stress’ in the medium term, and disproportionately so in the right tail.



estimating the following quantile local projections:

$$Q_{\Delta y_{i,t+h}}(\tau | \Delta Credit_{i,t}, \mathbb{1}_{i,t}^{Boom}, X_{i,t}) = \alpha_i^h(\tau) + \Delta Credit_{i,t} \beta^h(\tau) + \mathbb{1}_{i,t}^{Boom} \theta^h(\tau) + \Delta Credit_{i,t} \times \mathbb{1}_{i,t}^{Boom} \gamma^h(\tau) + \mathbf{x}_{i,t}' \boldsymbol{\vartheta}^h(\tau), \quad \tau \in (0, 1) \quad (2)$$

where the dependent variable  $\Delta y_{i,t+h}$  now refers to  $h$ -period-ahead annual average real GDP growth. As before,  $\alpha_i^h$  refers to country- and quantile-specific fixed effects and  $h = 1, 2, \dots, H$ , with  $H = 16$ . We continue to focus on the 10th, 50th and 90th percentiles to capture the potentially non-linear impact of credit growth on the GDP-growth distribution. The set of controls  $\mathbf{x}_{i,t}$  also includes changes in our macroprudential policy index.

The key novelty of equation (2) comes from the fact that we create an indicator variable for credit booms  $\mathbb{1}_{i,t}^{Boom}$  based on the distribution of 2-year credit growth. In particular, we define the credit-boom indicator as:

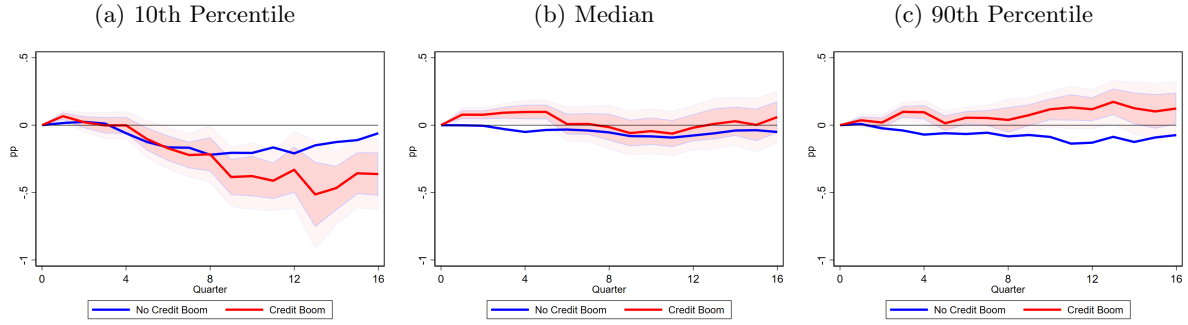
$$\mathbb{1}_{i,t}^{Boom} = \begin{cases} 1 & \text{if } \Delta_8 Credit_{i,t} > \Delta_8 Credit_{i,90th \text{ percentile}} \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

Our credit boom definition based on the distribution of past credit growth is consistent with the existing literature on credit boom measurement (see, e.g., [Greenwood, Hanson, Shleifer, and Sørensen, 2022](#)). In particular, we use the 2-year change in credit to capture persistent changes in this indicator, which have been shown to be a leading predictor of financial crises (e.g., [Schularick and Taylor, 2012](#)). The 90th percentile and therefore the assignment thresholds are country-specific, as they are based on the distribution of within-country credit growth.

Given these definitions,  $\beta^h(\tau)$  in regression (2) captures the association between real credit growth and the GDP-growth distribution in non-boom periods.  $\gamma^h(\tau)$ , in turn, tracks how the response of the  $\tau$ -th percentile of real annual GDP growth following a +1 standard deviation in credit growth differs in boom versus non-boom periods. Therefore,  $\beta^h(\tau) + \gamma^h(\tau)$  allows us to compute the average impact of real credit growth on the future GDP-growth distribution when the economy is already in a credit boom.

Figure 6 presents the main results from this exercise. Overall credit growth is associated with a significant reduction in the left tail of annual average domestic GDP growth, as Panel (a) demonstrates. This result holds in both boom and non-boom periods. However, this negative effect is particularly strong when the economy is already experiencing a credit boom, suggesting

Figure 6: Impulse Response of Quantiles of the GDP-Growth Distribution to +1 Standard Deviation Increase Credit Growth with and without a Credit Boom



*Notes:* Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$ , following a +1 standard deviation increase in credit growth. Non-linearity: credit booms versus non-credit booms periods. Sample period is 1990Q1-2017Q4. Shaded areas denote the 68% (dark red) and 90% (light red) confidence interval based on bootstrap with 500 replications.

that credit growth is especially associated with a deterioration in growth-at-risk over the medium term in financial boom episodes.

In contrast, as Panel (c) shows, credit growth has an association with the right tail of the GDP-growth distribution that varies in sign, depending on whether there is a credit boom in the economy. While credit growth does not have a significant impact on the right tail of the distribution in non-boom periods, it does increase the right tail of the distribution of GDP growth in boom periods.

Taken together, our results have an important policy implication. Excessive credit growth affects both downside and upside macroeconomic tail risks. In credit booms, increases in credit growth are associated with higher overall variance in the future GDP-growth distribution, shifting the left tail further left and shifting the right tail to the right. This is the case, even though the estimates in Panel (b) suggest that credit growth does not have significant impacts on median GDP growth over the medium term, independently of whether there is a credit boom or not. Taken together, our empirical findings, therefore, suggest that by defusing upside credit-at-risk (i.e., excessive credit growth) macroprudential policy can be effective in reducing GDP-growth volatility and mitigating macroeconomic tail risks.

## 4.2 Composition of Credit

In this section, we investigate the transmission of macroprudential policy through its effect on the composition of credit. In particular, we explore the extent to which macroprudential policy

is equally effective at preventing both household and business credit booms.

Preexisting empirical work has shown that household credit booms, not business credit booms, are more strongly associated with financial-stability risks, subsequent decline in GDP growth and deeper financial recession (Mian et al., 2017; Jordà et al., 2020).<sup>23</sup> Mian et al. (2017) show that the change in the household debt-to-GDP ratio consistently outperforms the change in the business debt-to-GDP ratio in predicting a subsequent decline in GDP growth. In related research, Jordà et al. (2020) focused on the recessionary trajectories of GDP following a cyclical peak. Their results demonstrate that a household credit boom significantly predicts a much deeper recession, while a business credit boom does not exhibit a noticeable drag on the economy. This empirical evidence is consistent with theoretical evidence that has revealed an important distinction between credit booms that tend to increase the productive capacity of the economy and those that tend to boost demand for final consumption goods (e.g., Kalantzis, 2015; Schmitt-Grohé and Uribe, 2016; Ozhan, 2020; Mian, Sufi, and Verner, 2020).

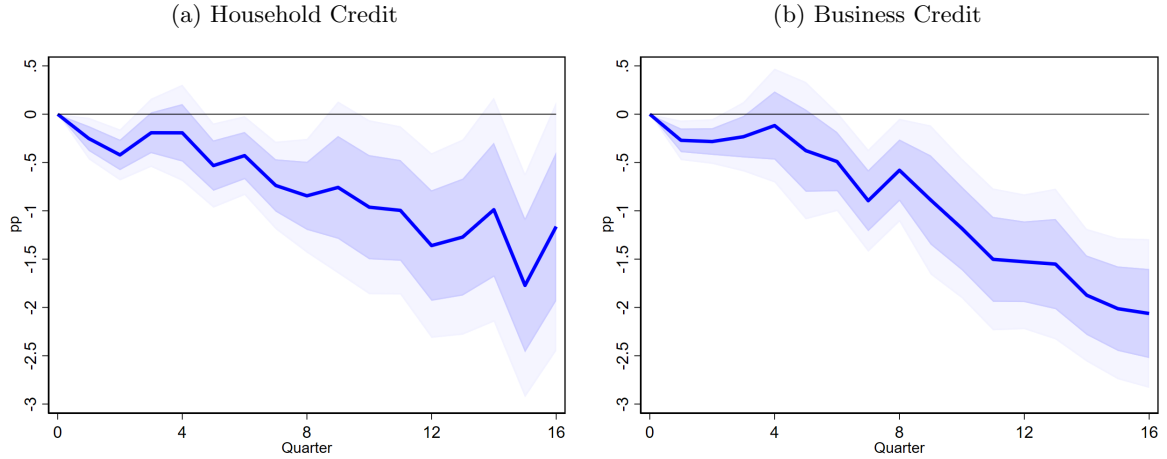
A key implication from the aforementioned empirical and theoretical evidence is that macroprudential policy can have different effects on financial stability through its effects on credit allocation. To gain deeper insights into this mechanism, we use quantile local projections and estimate the responses of real household and business credit following a tightening macroprudential policy shock. Given the findings in the previous sub-section, we focus on the 90th percentile of the credit distribution to explore the effectiveness of macroprudential policy to prevent household and business credit booms. The set of controls is the same as in our previous specification which had total credit as the dependent variable.

We present the response of the upper end of household versus business credit distribution following a macroprudential policy shock in Figure 7, and the coefficient estimates in Table 3. The main conclusion from Figure 7 is that macroprudential policy has a similar impact on the right tails of household and business credit growth. That is, macroprudential policy defuses both upside household and corporate credit tail risks. This empirical finding may imply that while macroprudential policy can bring benefits by preventing (household) credit booms that often end up in systemic financial crises, it may also have unintended negative consequences for

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<sup>23</sup>Moreover, Müller and Verner (2023) have recently shown that not all firm credit is alike. Using a novel database on sectoral credit distribution for 116 countries between 1940-2017, they show that lending to the non-tradable sector, rather than to the tradable sector, contributes to macroeconomic boom-bust cycles. In particular, they show that non-tradable credit is heavily associated with unsustainable demand booms, high financial fragility and resource misallocation across sectors. On top of that, they ultimately find that such lending booms also predict elevated financial crisis risk and productivity slowdowns. In contrast, tradable-sector credit expansions are followed by stable output and productivity growth without a higher risk of a financial crisis.

Figure 7: Impulse Response of 90th percentile of the Credit-Growth Distribution to Macroprudential Policy Tightenings



*Notes:* Estimated change in the 90th percentile of annual average real household and business credit at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence interval based on bootstrap with 500 replications.

growth prospects by preventing (business) credit booms that are systematically associated with future productivity gains, thereby limiting the right-tail of GDP growth.

Table 3: Coefficient estimates for  $\beta^h(\tau)$  from regression of household and business credit growth on narrative measure of macroprudential policy and baseline controls at 90th percentile

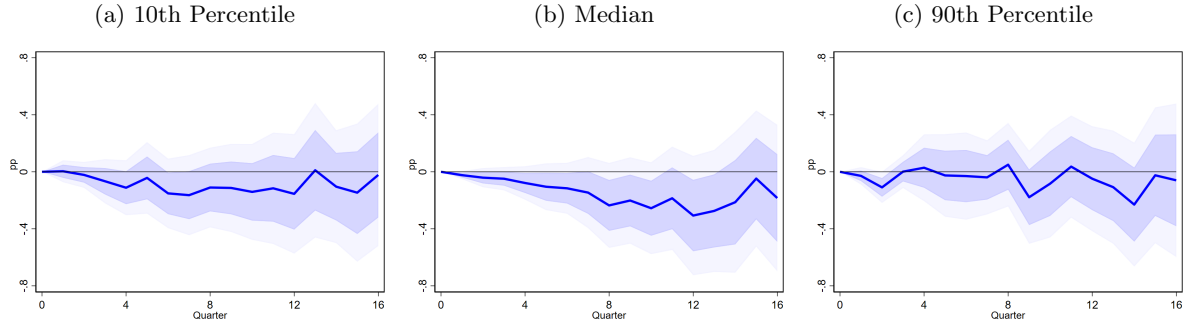
	$h = 4$	$h = 8$	$h = 12$	$h = 16$
PANEL A: Quantile-Regression Estimates for Household Credit				
$\tau = 0.9$	-0.19 (0.30)	-0.84** (0.35)	-1.36** (0.57)	-1.16^ (0.77)
PANEL B: Quantile-Regression Estimates for Business Credit				
$\tau = 0.9$	-0.12 (0.36)	-0.58** (0.30)	-1.53*** (0.42)	-2.06*** (0.40)

*Notes:* This table presents coefficient estimates reflecting the association between the 90th percentile of annual average real household and business credit growth at horizon  $h = 1, 2, \dots, 16$  and a tightening macroprudential policy activation. Coefficient estimates of fixed effects and controls not reported. Sample period is 1990Q1-2017Q4, for 12 advanced economies. Standard errors are based on bootstrap with 500 replications and are shown in parenthesis with: ^  $p < 0.32$ , \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

### 4.3 House Prices

In addition to the ‘credit-at-risk channel’, another candidate and interrelated channel through which macroprudential policy could affect the GDP-growth distribution is through changes in the house-price distribution. Asset-price dynamics, and in particular house-price bubbles, have been shown to be systematically associated with future severe financial crises, especially when

Figure 8: Impulse Response of Quantiles of the House-Price Distribution to Macroprudential Policy Tightenings



*Notes:* Estimated change in the  $\tau$ -th percentile of annual average real house prices growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence intervals based on bootstrap with 500 replications.

fuelled by credit expansions (Jordà et al., 2015; Richter et al., 2021). Therefore, to the extent to which macroprudential policy may defuse upside house-price growth risks, it may prevent extreme GDP-growth outturns.

In this sub-section, we formally explore the extent to which shifts in the house-price distribution following a tightening macroprudential policy activation are consistent with the observed post-policy tail-growth dynamic responses. To do so, we estimate quantile local-projection regression (1) for house prices.  $\Delta y_{i,t+h}$  now denotes the annual average real house-price growth over  $h$  quarters. This specification allows us to formally explore whether macroprudential policies have a heterogeneous impact on the house-price distribution, and if so, to what extent the house-price channel can explain the opposite effects we found on the left and right tail of the GDP-growth distribution after a tightening prudential shock.

Figure 8 presents the impulse response of quantiles of the conditional house-price growth distribution (for  $\tau = 0.1, 0.5, 0.9$ ) to changes in our narrative macroprudential policy index across different horizons  $h$ .<sup>24</sup> Our results point to a small negative impact of macroprudential policy on quantiles of the house-price growth distribution. However, the estimation uncertainty is very large, and the effect is not statistically significant across any horizons or quantiles. The main implication of our findings is that the responses across the whole GDP-growth distribution following a tightening macroprudential policy activation are unlikely to be driven by the house-price dynamics after a tightening prudential policy activation.

Overall, we find limited evidence of other significant channels through which macroprudential

<sup>24</sup>Corresponding point estimates and standard errors are tabulated in Appendix D.3, Table B.4.

policy affects the conditional distribution of GDP-growth and conclude that the ‘credit-at-risk’ channel plays a major role in explaining the heterogeneous impact of macroprudential policy on the tails of GDP growth.

## 5 Conclusion

What are the causal effects of macroprudential policy across the GDP-growth distribution? And what are the channels? In this paper, we answer both questions by exploiting a dataset covering a range of macroprudential policy actions across advanced European economies. We identify unanticipated and exogenous narrative macroprudential policy ‘shocks’ and employ them within a quantile-regression setup to identify causal effects across the distribution of future macroeconomic outcomes. Our main finding is that while macroprudential policy has muted effects on the centre of the GDP-growth distribution, tighter policy reduces the variance of future economic growth. A key implication from our analysis is that macroprudential policy can effectively enhance financial stability by significantly reducing the likelihood of extreme GDP-growth outturns. We further show that the ‘credit-at-risk’ channel is crucial to account for the dynamic effects of macroprudential policy in the tails of future GDP growth. In particular, our results suggest that by defusing upside credit-growth risk tighter macroprudential policy can be effective in mitigating downside and upside macroeconomic tail risks. Overall, our paper provides novel evidence on the causal effects of macroprudential policies on the entire distribution of potential macroeconomic outcomes.

## References

- Acharya, V. V., K. Bergant, M. Crosignani, T. Eisert, and F. Mccann (2022, October). The Anatomy of the Transmission of Macroprudential Policies. *Journal of Finance* 77(5), 2533–2575.
- Adrian, T., N. Boyarchenko, and D. Giannone (2019). Vulnerable growth. *American Economic Review* 109(4), 1263–89.
- Adrian, T., F. Grinberg, N. Liang, S. Malik, and J. Yu (2022). The term structure of growth-at-risk. *American Economic Journal: Macroeconomics* 14(3), 283–323.
- Ahnert, T., K. J. Forbes, C. Friedrich, and D. Reinhardt (2021). Macroprudential FX regulations: Shifting the snowbanks of FX vulnerability? *Journal of Financial Economics* 140(1), 145–174.
- Aikman, D., J. Bridges, S. Hacıoglu Hoke, C. O’Neill, and A. Raja (2019). How do financial vulnerabilities and bank resilience affect medium-term macroeconomic tail risk. *Bank of England Staff Working Paper* (824).
- Alam, Z., A. Alter, J. Eiseman, R. G. Gelos, H. Kang, M. Narita, E. Nier, and N. Wang (2019, March). Digging Deeper: Evidence on the Effects of Macroprudential Policies from a New Database. IMF Working Papers 2019/066, International Monetary Fund.
- Altavilla, C., L. Laeven, and J.-L. Peydró (2020). Monetary and Macroprudential Policy Complementarities: Evidence from European credit registers. *ECB Working Paper No. 20202504*.
- Angrist, J., V. Chernozhukov, and I. Fernández-Val (2006). Quantile regression under misspecification, with an application to the u.s. wage structure. *Econometrica* 74(2), 539–563.
- Belkhir, M., S. B. Naceur, B. Candelon, and J.-C. Wijnandts (2022). Macroprudential policies, economic growth and banking crises. *Emerging Markets Review* 53(C).
- Brandão-Marques, L., R. G. Gelos, M. Narita, and E. Nier (2021). Leaning against the wind: An empirical cost-benefit analysis. CEPR Discussion Papers 15693, C.E.P.R. Discussion Papers.
- Budnik, K. and J. Kleibl (2018). Macroprudential regulation in the European Union in 1995-2014: introducing a new data set on policy actions of a macroprudential nature. Working Paper Series 2123, European Central Bank.
- Carney, M. (2020, 3). The grand unifying theory (and practice) of macroprudential policy. Speech given at Logan Hall, University College London.
- Cerutti, E., S. Claessens, and L. Laeven (2017). The use and effectiveness of macroprudential policies: New evidence. *Journal of Financial Stability* 28(C), 203–224.
- Cerutti, E., R. Correa, E. Fiorentino, and E. Segalla (2017). Changes in prudential policy instruments - a new cross-country database. *International Journal of Central Banking* 13(2), 477–503.

- Chari, A., K. Dilts-Stedman, and K. J. Forbes (2022). Spillovers at the extremes: The macro-prudential stance and vulnerability to the global financial cycle. *Journal of International Economics* 136, 103582.
- Claessens, S., S. R. Ghosh, and R. Mihet (2013). Macro-prudential policies to mitigate financial system vulnerabilities. *Journal of International Money and Finance* 39(C), 153–185.
- Cloyne, J., J. Martinez, H. Mumtaz, and P. Surico (2022). Short-term tax cuts, long-term stimulus. Technical report, National Bureau of Economic Research.
- Cochrane, J. H. (2004). Comments on “A New Measure of Monetary Shocks: Derivation and implications”. Comments at NBER EFG Meeting, July 2004.
- Coman, A. and S. P. Lloyd (2022). In the face of spillovers: Prudential policies in emerging economies. *Journal of International Money and Finance* 122(C).
- Fernández-Gallardo, Á. (2023). Preventing financial disasters: Macroprudential policy and financial crises. *European Economic Review* 151, 104350.
- Fernández-Gallardo, Á. and I. Payá (2023). Macroprudential policy in the euro area. *Journal of Money, Credit and Banking* (forthcoming).
- Forbes, K. J. (2021, August). The International Aspects of Macroprudential Policy. *Annual Review of Economics* 13(1), 203–228.
- Forbes, K. J., M. Fratzscher, and R. Straub (2015). Capital-flow management measures: What are they good for? *Journal of International Economics* 96(S1), 76–97.
- Franta, M. and L. Gambacorta (2020). On the effects of macroprudential policies on growth-at-risk. *Economics Letters* 196, 109501.
- Galán, J. E. (2020). The benefits are at the tail: uncovering the impact of macroprudential policy on growth-at-risk. *Journal of Financial Stability*, 100831.
- Gelos, G., L. Gornicka, R. Koepke, R. Sahay, and S. Sgherri (2022). Capital flows at risk: Taming the ebbs and flows. *Journal of International Economics* 134, 103555.
- Greenwood, R., S. G. Hanson, A. Shleifer, and J. A. Sørensen (2022). Predictable financial crises. *The Journal of Finance* 77(2), 863–921.
- Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American economic review* 95(1), 161–182.
- Jordà, Ò. (2023). Local projections for applied economics. *Federal Reserve Bank of San Francisco Working Paper* 2023-16.
- Jordà, Ò., M. Kornejew, M. Schularick, and A. M. Taylor (2020). Zombies at large. *Corporate Debt Overhang and the Macroeconomy*. Federal Reserve Bank of New York.
- Jordà, Ò., M. Schularick, and A. M. Taylor (2013). When credit bites back. *Journal of money, credit and banking* 45(s2), 3–28.



- Jordà, Ò., M. Schularick, and A. M. Taylor (2015). Leveraged bubbles. *Journal of Monetary Economics* 76, S1–S20.
- Kalantzis, Y. (2015). Financial fragility in small open economies: firm balance sheets and the sectoral structure. *The Review of Economic Studies* 82(3), 1194–1222.
- Kato, K., A. F. Galvao Jr, and G. V. Montes-Rojas (2012). Asymptotics for panel quantile regression models with individual effects. *Journal of Econometrics* 170(1), 76–91.
- Kim, S. and A. Mehrotra (2018). Effects of monetary and macroprudential policies—evidence from four inflation targeting economies. *Journal of Money, Credit and Banking* 50(5), 967–992.
- Koenker, R. W. and G. Bassett (1978, January). Regression Quantiles. *Econometrica* 46(1), 33–50.
- Leeper, E. M., T. B. Walker, and S.-C. S. Yang (2013). Fiscal foresight and information flows. *Econometrica* 81(3), 1115–1145.
- Lloyd, S. and E. Manuel (2023). Controls, Not Shocks: Estimating Dynamic Causal Effects in the Face of Confounding Factors. Working paper.
- Lloyd, S., E. Manuel, and K. Panchev (2023). Foreign vulnerabilities, domestic risks: The global drivers of gdp-at-risk. *IMF Economic Review*.
- Loria, F., C. Matthes, and D. Zhang (2022). Assessing macroeconomic tail risk. *Available at SSRN 4002665*.
- Machado, J. A. and J. Santos Silva (2019). Quantiles via moments. *Journal of Econometrics* 213(1), 145–173.
- Mertens, K. and M. O. Ravn (2012). Empirical evidence on the aggregate effects of anticipated and unanticipated us tax policy shocks. *American Economic Journal: Economic Policy* 4(2), 145–81.
- Meuleman, E. and R. Vander Vennet (2020). Macroprudential policy and bank systemic risk. *Journal of Financial Stability* 47, 100724.
- Mian, A., A. Sufi, and E. Verner (2017). Household debt and business cycles worldwide. *The Quarterly Journal of Economics* 132(4), 1755–1817.
- Mian, A., A. Sufi, and E. Verner (2020). How does credit supply expansion affect the real economy? the productive capacity and household demand channels. *The Journal of Finance* 75(2), 949–994.
- Müller, K. and E. Verner (2023). Credit allocation and macroeconomic fluctuations. *Review of Economic Studies* (forthcoming).
- Ozhan, G. K. (2020). Financial intermediation, resource allocation, and macroeconomic interdependence. *Journal of Monetary Economics* 115, 265–278.

- Plagborg-Møller, M. and C. K. Wolf (2021). Local projections and vars estimate the same impulse responses. *Econometrica* 89(2), 955–980.
- Richter, B., M. Schularick, and I. Shim (2019). The costs of macroprudential policy. *Journal of International Economics* 118, 263–282.
- Richter, B., M. Schularick, and P. Wachtel (2021). When to lean against the wind. *Journal of Money, Credit and Banking* 53(1), 5–39.
- Rojas, D., C. Vegh, and G. Vuletin (2022). The macroeconomic effects of macroprudential policy: Evidence from a narrative approach. *Journal of International Economics* 139, 103644.
- Romer, C. D. and D. H. Romer (1989). Does monetary policy matter? a new test in the spirit of friedman and schwartz. In *NBER Macroeconomics Annual 1989, Volume 4*, pp. 121–184. National Bureau of Economic Research, Inc.
- Romer, C. D. and D. H. Romer (2004). A new measure of monetary shocks: Derivation and implications. *American Economic Review* 94(4), 1055–1084.
- Romer, C. D. and D. H. Romer (2010, June). The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks. *American Economic Review* 100(3), 763–801.
- Schmitt-Grohé, S. and M. Uribe (2016). Downward nominal wage rigidity, currency pegs, and involuntary unemployment. *Journal of Political Economy* 124(5), 1466–1514.
- Schularick, M. and A. M. Taylor (2012). Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008. *American Economic Review* 102(2), 1029–61.
- Stock, J. H. and M. W. Watson (2018). Identification and estimation of dynamic causal effects in macroeconomics using external instruments. *The Economic Journal* 128(610), 917–948.
- Suarez, J. (2022). Growth-at-risk and macroprudential policy design. *Journal of Financial Stability* 60, 101008.

## Appendix: For Online Publication

### A Weighting Scheme, Data Sources and Summary Statistics

Table A1: Weighting Scheme for Different Macroprudential Policy Actions in Narrative Measure

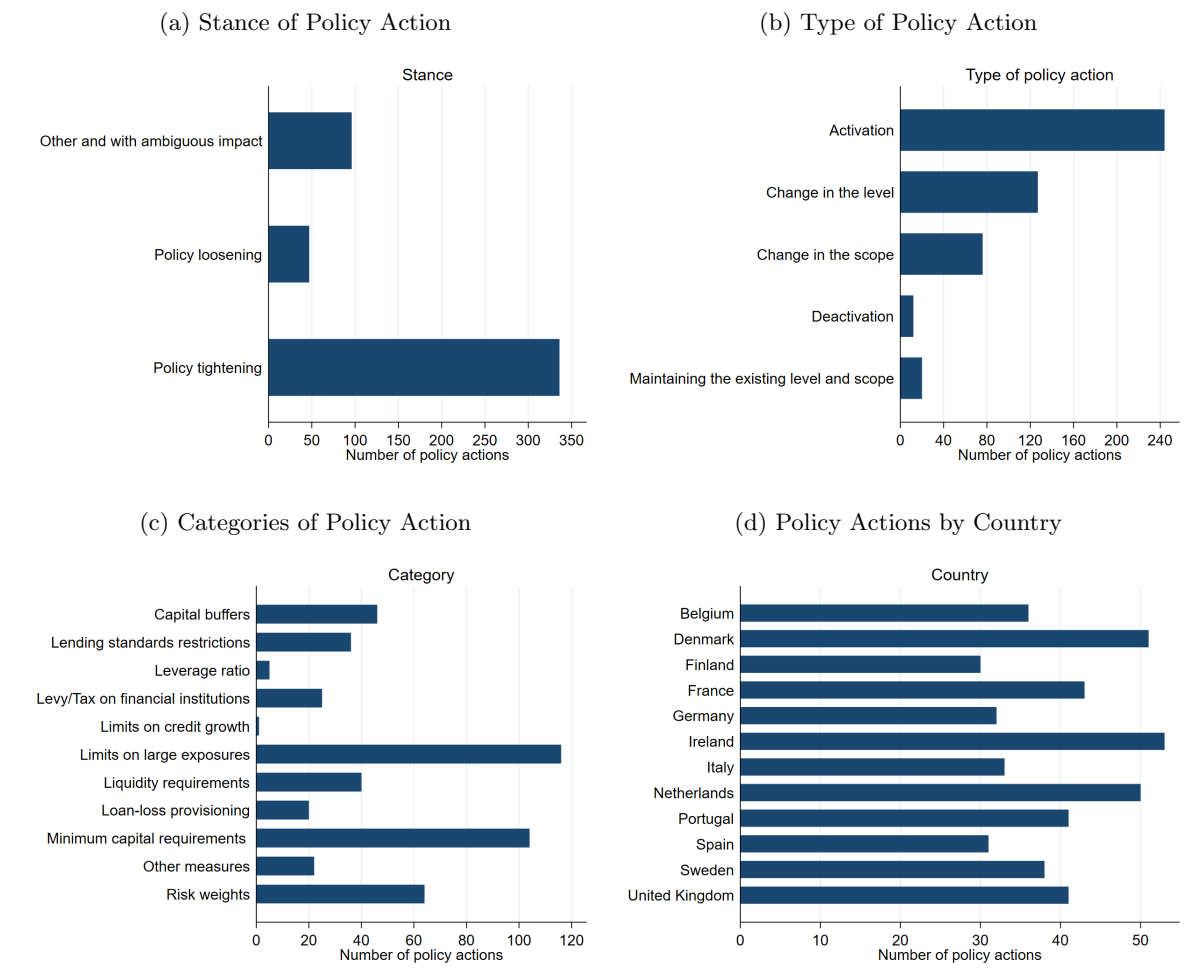
Type of Policy Action	Weight	Strengthening / Loosening	Sign	Final Weight
Activation	1	Tightening	+	1
		Other/ambiguous impact		0
		Loosening	-	-1
Change in the Level	0.25	Tightening	+	0.25
		Other/ambiguous impact		0
		Loosening	-	-0.25
Change in the Scope	0.10	Tightening	+	0.10
		Other/ambiguous impact		0
		Loosening	-	-0.10
Maintaining the Existing Level and Scope	0.05	Tightening	+	0.05
		Other/ambiguous impact		0
		Loosening	-	-0.05
Deactivation	Dependent on the life-cycle of the tool (cumulative index drops to zero)			

Notes: Description of the weights used to construct the cumulative index for each policy instrument based on [Meuleman and Vander Venet \(2020\)](#).

Table A2: List of Data Sources

Variables	Source
Gross Domestic Product (GDP)	OECD database
Consumer Price Index (CPI)	Federal Bank Reserve of St.Louis (FRED)
Total Credit to the Private Non-Financial Sector	Bank for International Settlements (BIS)
Total Credit to Households	Bank for International Settlements (BIS)
Total Credit to non-financial corporations	Bank for International Settlements (BIS)
House Prices	Bank for International Settlements (BIS)
VIX	Datastream
GDP forecast	OECD database
3-Month or 90-day Rates and Yields: Interbank Rates	IFS + FRED
Macroprudential Policy Index ( <i>MaPP</i> )	Authors' estimation using MaPPED database

Figure A1: Number of policy actions by stance, category, type and country



## B Identification in Quantile Regression with Confounders

In this Appendix, we formalise some of the discussion around identification in Section 2.3. Our exposition follows closely that in Angrist et al. (2006) and Jordà et al. (2013), and builds on work on identification in quantile regression in Lloyd and Manuel (2023).

We are interested in formalising the assumptions under which our estimated coefficients can be interpreted as capturing the causal effect of macroprudential policies. We define  $y_{t+h}$  and  $MaPP_t$  as in Section 2.1, as  $h$ -period ahead annual average real GDP growth and our narrative-based macroprudential policy indicator, where we drop the cross-sectional country index in the panel for ease of exposition. We also define  $\mathbf{x}_t$  as a set of conditioning variables capturing the state of the macro-financial environment at time  $t$ . We then define the potential outcome  $y_{t,h}(z)$  as the value that the observed outcome variable  $y_{t+h}$  would have taken if  $MaPP_t = z$  for all possible values  $z$ . We first define the causal effect of setting  $\Delta MaPP_t = 1$  relative to some benchmark value  $\Delta MaPP_t = 0$  on conditional quantiles of  $y_t$  as:

$$\mathbb{Q}_\tau(y_{t,h}(1)|\mathbf{x}_t, \Delta MaPP_t) - \mathbb{Q}_\tau(y_{t,h}(0)|\mathbf{x}_t, \Delta MaPP_t) \quad (4)$$

This equates to our causal effect of interest, capturing how macroprudential policies affect the entire distribution of future GDP growth outcomes conditional on the current macro-financial environment. We never observe counterfactual outcomes and so the quantiles in equation (4) cannot be estimated directly. One route to identification is the following assumption:

**Conditional Independence (CI)**  $y_{t,h}(z) \perp \Delta MaPP_t | \mathbf{x}_t$  for all  $z$

This states that potential outcomes are fully independent of policy conditional on  $\mathbf{x}_t$ . This can be understood as a slightly weaker assumption than the claim that potential outcomes are unconditionally independent of policy, i.e.:

**Unconditional Independence (UI)**  $y_{t,h}(z) \perp \Delta MaPP_t$  for all  $z$

In effect, CI allows that our narrative measure  $\Delta MaPP_t$  is not fully exogenous, but that the set of conditioning variables  $\mathbf{x}_t$  successfully captures all confounding factors that simultaneously drive our narrative-based measure and the outcome variable. Under CI,  $\beta^h(\tau)$  in our baseline quantile regression (1) is equal to the causal effect of interest from equation (4). To see this, note that under CI, we can write the causal effect of interest in terms of observable conditional quantiles:

$$\begin{aligned} & \mathbb{Q}_\tau(y_{t,h}(1)|\mathbf{x}_t, \Delta MaPP_t) - \mathbb{Q}_\tau(y_{t,h}(0)|\mathbf{x}_t, \Delta MaPP_t) \\ &= \mathbb{Q}(y_{t+h}|\mathbf{x}_t, \Delta MaPP_t = 1) - \mathbb{Q}(y_{t+h}|\mathbf{x}_t, \Delta MaPP_t = 0) \end{aligned}$$

Since our quantile regression from equation (1) provides a direct estimate of the right-hand side of this equation, under CI, the coefficient  $\beta^h(\tau)$  identifies the causal effect of interest.

An alternate estimation strategy in the literature on the quantile treatment effects of macroprudential policies employs a two-step estimation strategy. This amounts to estimating an OLS

regression of the policy variable on potential confounding factors and then a quantile regression of the outcome variable on the residual from the first-stage. Defining  $\epsilon_t$  as the OLS residual from the first-stage, the coefficient of interest from this two-step procedure  $\beta_{2S}^h(\tau)$  is estimated via the following quantile regression:

$$\mathbb{Q}(y_{t+h}|\epsilon_t) = \alpha_{2S}^h(\tau) + \epsilon_t \beta_{2S}^h(\tau) \quad \tau \in (0, 1) \quad (5)$$

The key insight from [Lloyd and Manuel \(2023\)](#) is that, while such an approach is valid for estimating causal effects under CI in an OLS setting, in quantile regression this two-step approach can suffer from a form of quantile-regression omitted variable bias. Intuitively, although  $\epsilon_t$  is uncorrelated with  $X_t$  by construction, this is insufficient for partialling out the effect of  $x_t$  on  $y_t$  across all conditional quantiles. In particular, they show that the difference between the coefficient from our one-step quantile regression  $\beta^h(\tau)$  and the two-step coefficient  $\beta_{2S}^h(\tau)$  can be expressed as:

$$\beta_{2S}^h(\tau) = \beta^h(\tau) + \phi_1(\tau) \frac{\mathbb{E}[w_\tau \epsilon_t \mathbf{x}_t']}{\mathbb{E}[w_\tau \epsilon_t^2]}$$

where the second term amounts to the formula for omitted-variable bias for quantile regression ([Angrist et al., 2006](#)) with  $w_\tau = \int_0^1 f_{u^{Hyb}}[u(\epsilon_t \beta(\tau) - \mathbf{x}_t' \phi(\tau) - \epsilon_t \beta_{hyb}(\tau)) | \epsilon_t, \mathbf{x}_t'] du/2$  and additional terms are defined from the following “hybrid” quantile regression:

$$y_{t+h} = \alpha_{Hyb}^h(\tau) + \epsilon_t \beta_{Hyb}^h(\tau) + \phi(\tau) \mathbf{x}_t' + u_\tau^{Hyb} \quad \tau \in (0, 1)$$

## C Sensitivity Checks

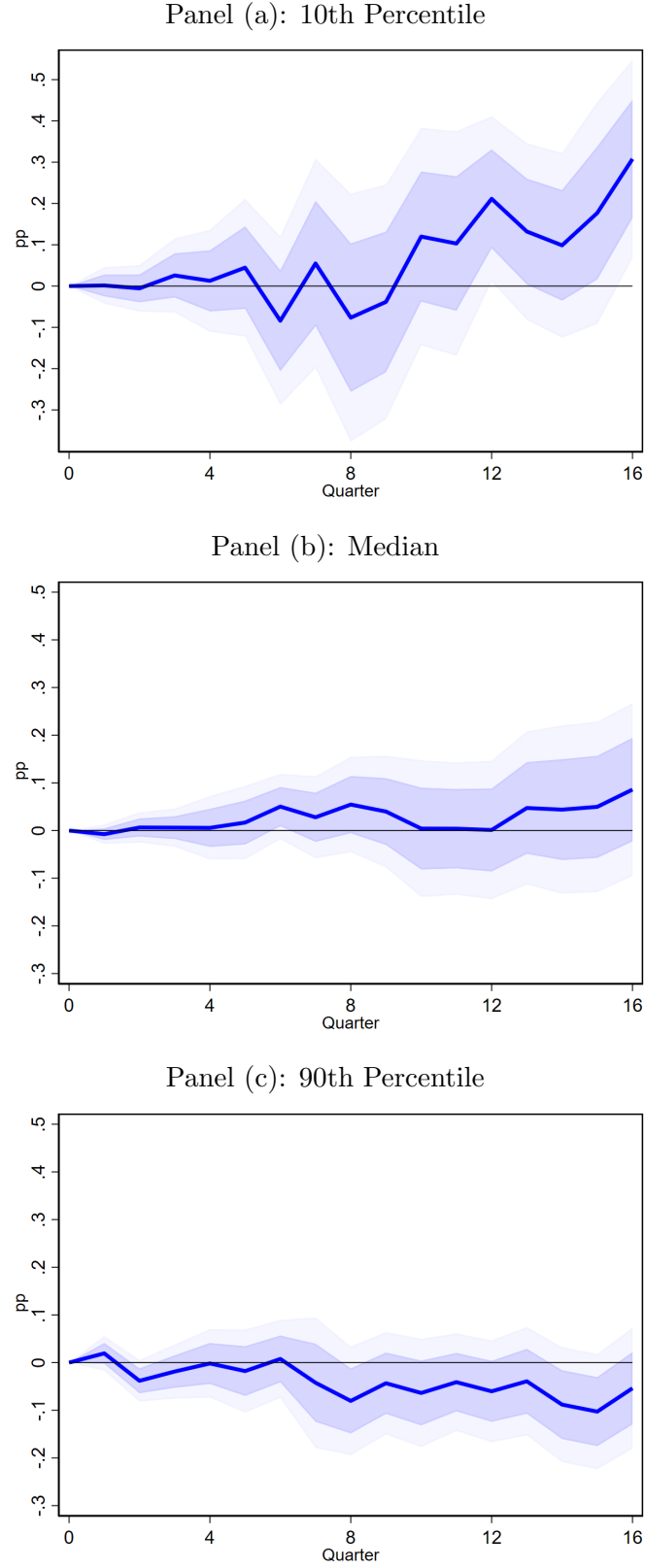
In this appendix, we present our findings from all the robustness exercises described in Section 3.2.

Table B.1: Baseline and Robustness estimation results: GDP-growth distribution

$\tau = 0.1$								
	Baseline	No Implementation Lag	Expectation Data	Alternative Macroprudential Index	Control-augmented: FCI	Control-augmented: Monetary Policy	Subsample: Excluding GFC	Alternative CFE
$h = 4$	0.02 (0.04)	0.01 (0.07)	0.04 (0.04)	0.02 (0.06)	0.01 (0.06)	0.01 (0.04)	0.03 (0.06)	0.01 (0.04)
$h = 8$	0.15** (0.08)	-0.08 (0.17)	0.15** (0.08)	-0.03 (0.12)	0.14** (0.07)	0.11** (0.06)	0.02 (0.16)	0.10* (0.08)
$h = 12$	0.25*** (0.09)	0.21* (0.13)	0.24** (0.10)	0.18** (0.11)	0.18** (0.07)	0.20*** (0.06)	0.18* (0.12)	0.21** (0.11)
$h = 16$	0.32*** (0.08)	0.31** (0.13)	0.31*** (0.08)	0.27** (0.12)	0.19** (0.08)	0.25*** (0.08)	0.22** (0.10)	0.25** (0.14)
$\tau = 0.5$								
	Baseline	No Implementation Lag	Expectation Data	Alternative Macroprudential Index	Control-augmented: FCI	Control-augmented: Monetary Policy	Subsample: Excluding GFC	Alternative CFE
$h = 4$	0.03* (0.03)	0.01 (0.04)	0.04** (0.03)	0.02 (0.03)	0.00 (0.03)	0.01 (0.03)	-0.00 (0.03)	0.02 (0.04)
$h = 8$	0.05* (0.04)	0.05* (0.05)	0.06** (0.04)	0.03 (0.06)	0.01 (0.04)	0.03 (0.03)	0.00 (0.04)	0.02 (0.05)
$h = 12$	0.02 (0.05)	0.00 (0.09)	0.03 (0.04)	-0.04 (0.06)	-0.01 (0.05)	-0.01 (0.04)	-0.00 (0.05)	0.01 (0.05)
$h = 16$	0.06* (0.06)	0.09 (0.11)	0.05 (0.05)	0.00 (0.07)	0.05 (0.06)	0.02 (0.05)	0.09** (0.06)	0.04 (0.07)
$\tau = 0.9$								
	Baseline	No Implementation Lag	Expectation Data	Alternative Macroprudential Index	Control-augmented: FCI	Control-augmented: Monetary Policy	Subsample: Excluding GFC	Alternative CFE
$h = 4$	-0.00 (0.03)	-0.00 (0.04)	-0.00 (0.03)	-0.00 (0.04)	0.01 (0.03)	-0.01 (0.03)	-0.01 (0.04)	0.03 (0.07)
$h = 8$	-0.05* (0.04)	-0.08* (0.07)	-0.06* (0.04)	-0.08* (0.07)	-0.02 (0.05)	-0.05* (0.04)	-0.05* (0.04)	-0.04 (0.05)
$h = 12$	-0.07* (0.05)	-0.06* (0.06)	-0.07* (0.05)	-0.15** (0.06)	-0.14** (0.06)	-0.09* (0.06)	-0.13** (0.06)	-0.11** (0.05)
$h = 16$	-0.14*** (0.05)	-0.05 (0.08)	-0.09* (0.07)	-0.19** (0.08)	-0.13*** (0.05)	-0.12** (0.06)	-0.12* (0.09)	-0.11** (0.06)

Notes: This table presents coefficient estimates reflecting the change in the  $\tau$ -th percentile of annual average real output growth at horizon  $h = 4, 8, 12$  and  $16$ , following a tightening macroprudential policy activation. Coefficient estimates of fixed effects and controls not reported. Sample period is 1990Q1-2017Q4. Standard errors are based on bootstrap with 500 replications and show in parenthesis.  $\hat{p} < 0.32$ , \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

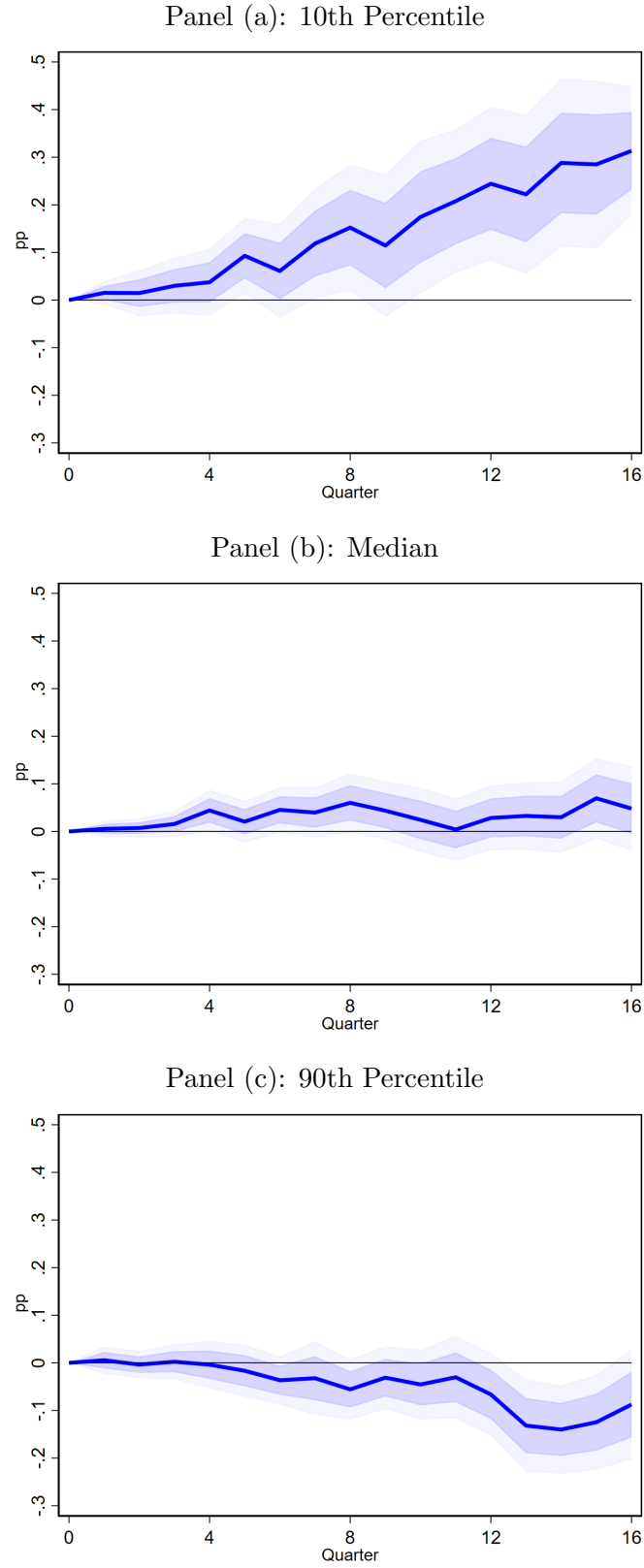
Figure B.2: **Lags in Policy Implementation.** Impulse Response of Quantiles of the GDP-Growth Distribution to Macroprudential Policy Tightenings.



*Notes:* Excluding policies with implementation lag according to the 90 days threshold of [Mertens and Ravn \(2012\)](#). Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence interval based on bootstrap 500 replications.

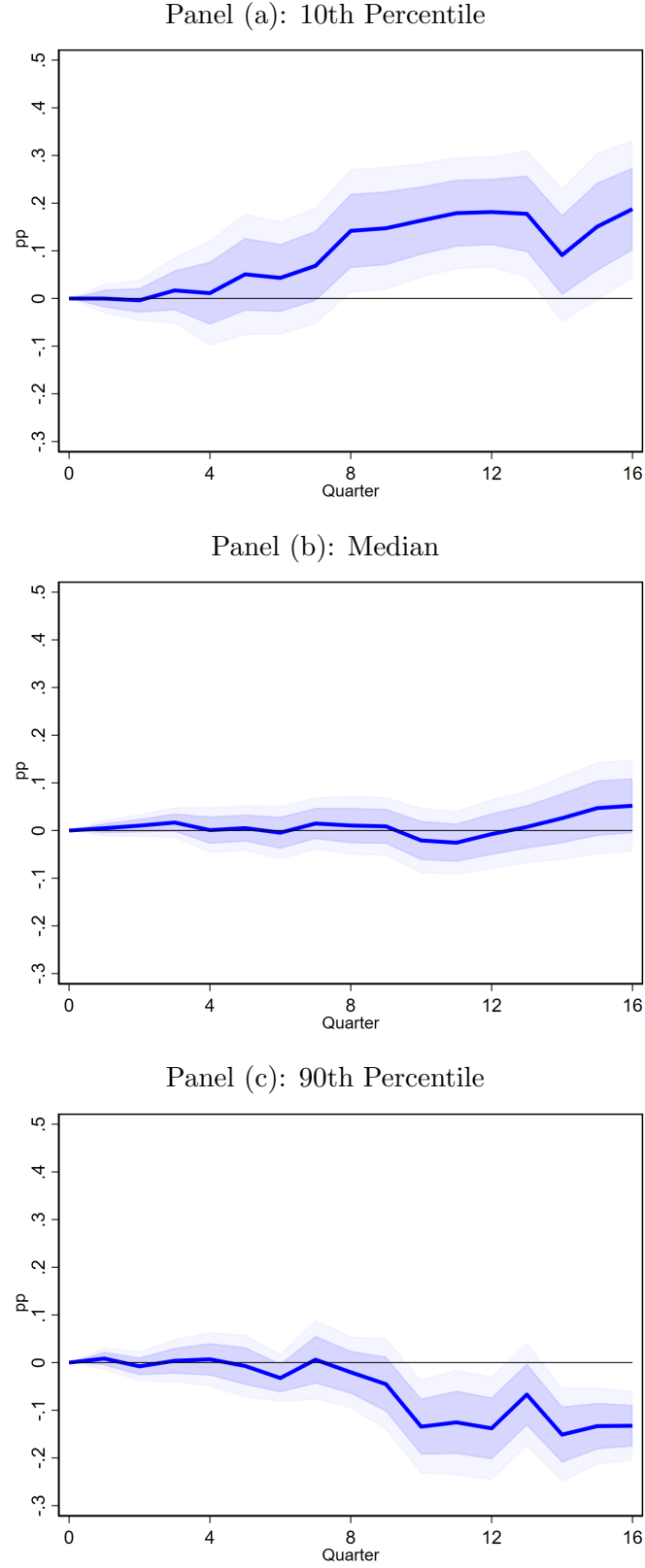


Figure B.3: **Accounting for expectations.** Impulse Response of Quantiles of the GDP-Growth Distribution to Macroprudential Policy Tightenings.



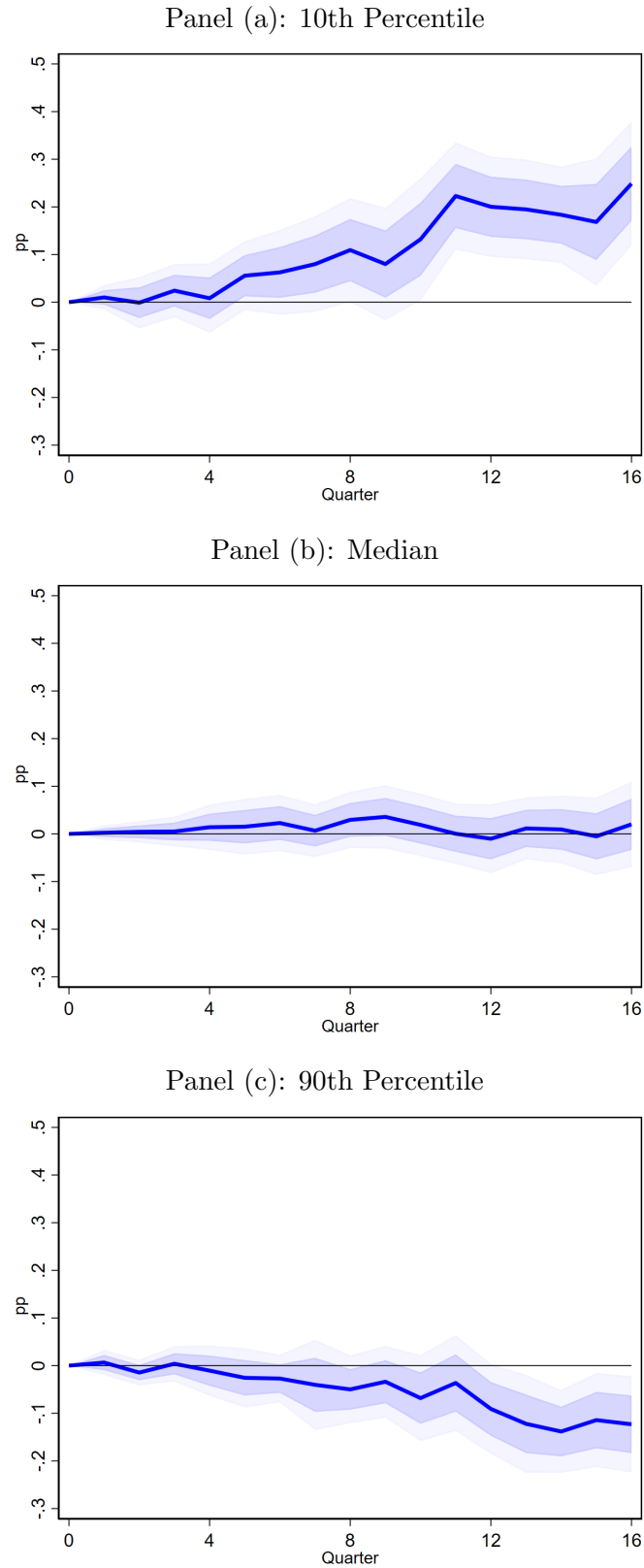
*Notes:* GDP growth forecast as an additional control. Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence interval based on bootstrap 500 replications.

Figure B.4: **Alternative Controls: Financial Conditions Index (FCI)**. Impulse Response of Quantiles of the GDP-Growth Distribution to Macroprudential Policy Tightenings.



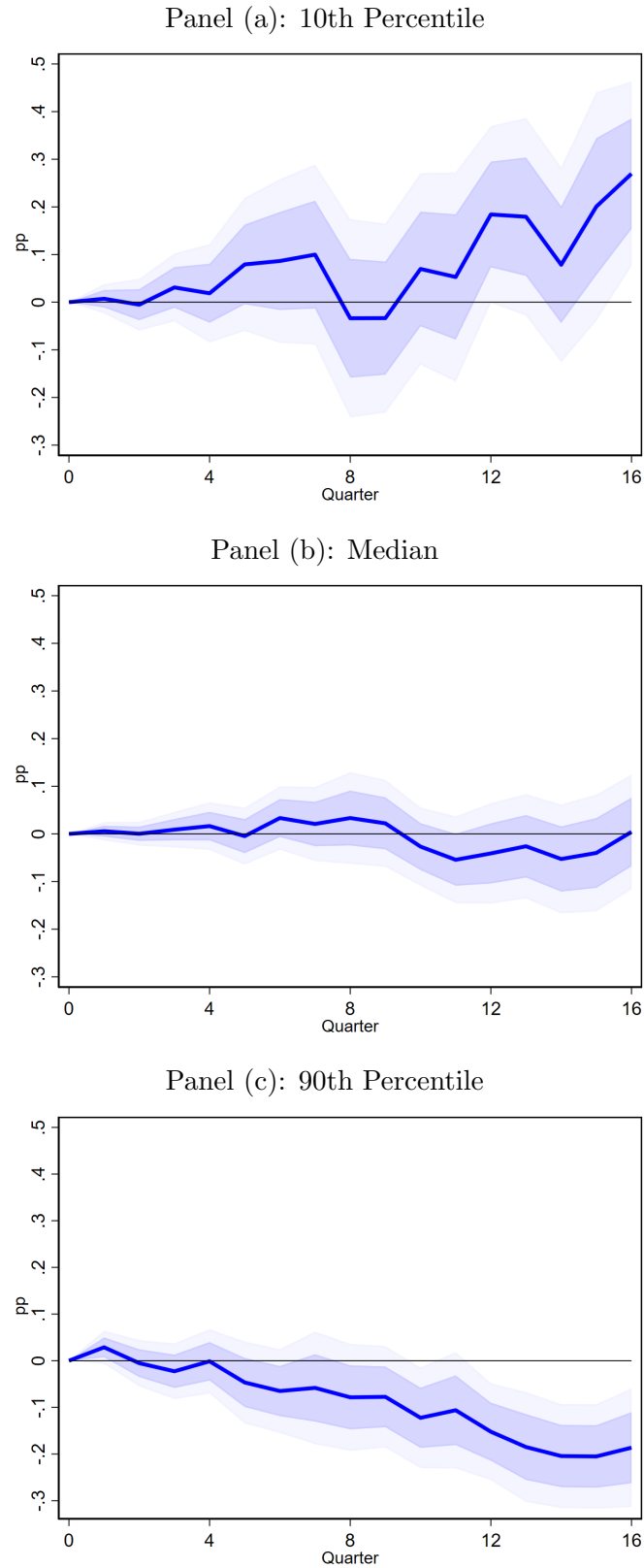
*Notes:* Control-augmented quantile local projections: Financial Condition Index (FCI). Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence interval based on bootstrap 500 replications.

Figure B.5: **Alternative Controls: Monetary Policy.** Impulse Response of Quantiles of the GDP-Growth Distribution to Macroprudential Policy Tightenings.



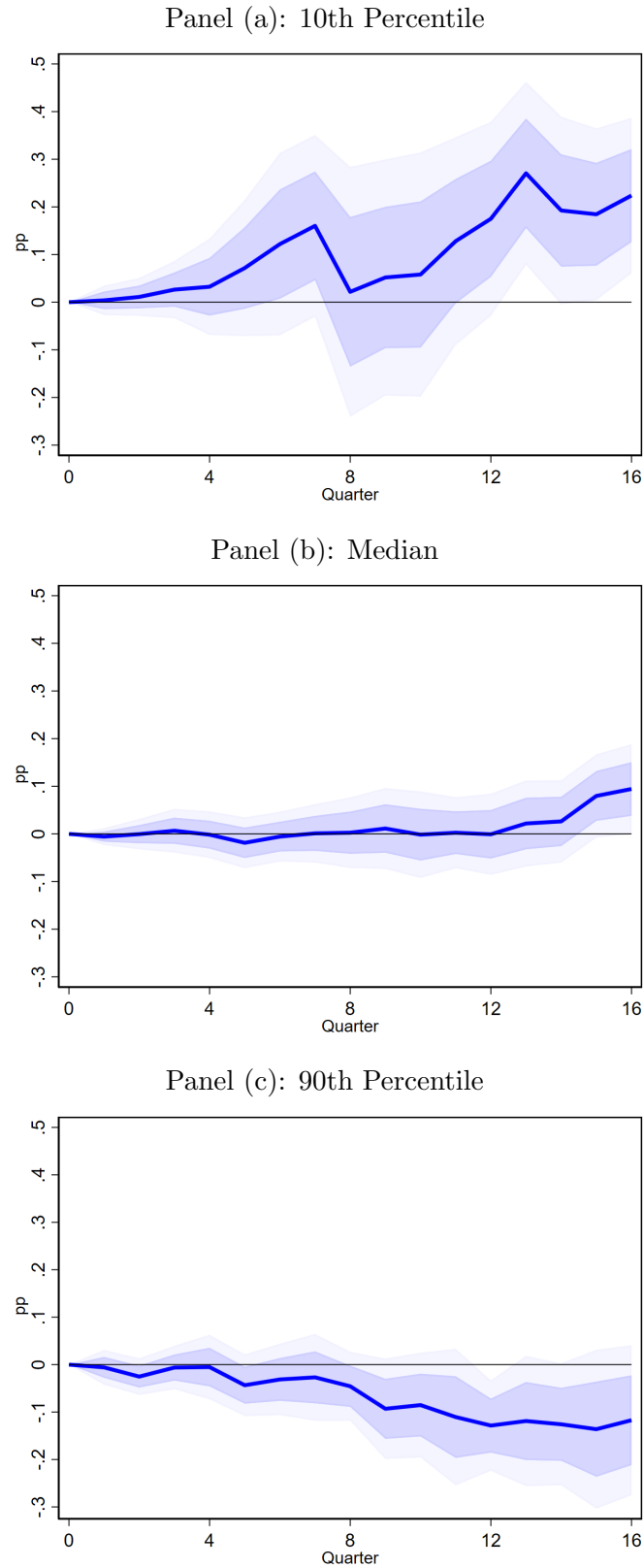
*Notes:* Control-augmented quantile local projections: Short-term interest rate. Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence interval based on bootstrap 500 replications.

Figure B.6: **Alternative Macroprudential Policy Index.** Impulse Response of Quantiles of the GDP-Growth Distribution to Macroprudential Policy Tightenings.



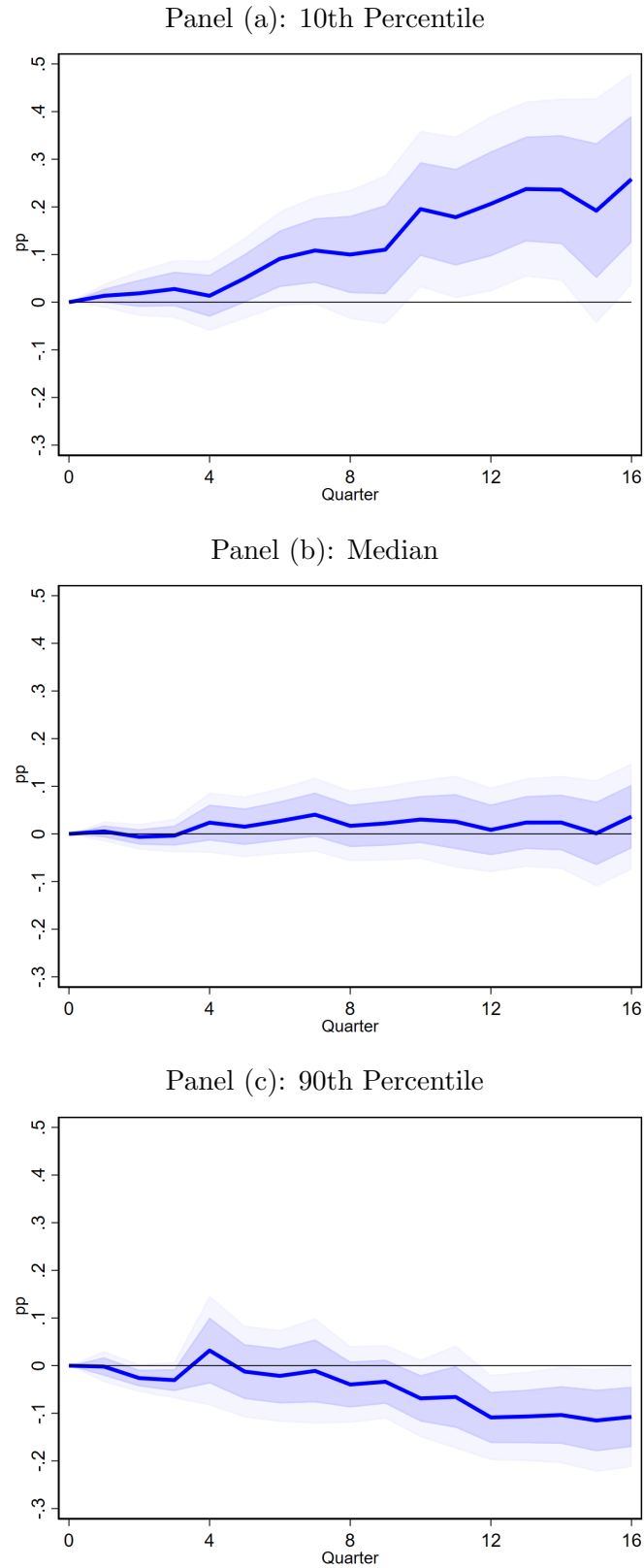
*Notes:* Alternative Macroprudential Policy Index. Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence interval based on bootstrap 500 replications.

Figure B.7: **Subsample: Excluding the Great Financial Crisis (GFC)**. Impulse Response of Quantiles of the GDP-Growth Distribution to Macroprudential Policy Tightenings.



*Notes:* Subsample: Excluding the Great Financial Crisis (GFC). Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1985Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence interval based on bootstrap 500 replications.

Figure B.8: **Alternative country fixed-effects.** Impulse Response of Quantiles of the GDP-Growth Distribution to Macroprudential Policy Tightenings.



*Notes:* Machado and Santos Silva (2019) country fixed-effects. Estimated change in the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence interval based on bootstrap 500 replications.

## D Additional Results

### D.1 Financial Conditions

Financial conditions have been shown to play an important role in explaining observed growth vulnerability dynamics (Adrian et al., 2019, 2022). We therefore study whether the financial conditions channel can be a driver of the positive effects that macroprudential policy exercises on the tails of the GDP-growth distribution. To do so, we follow Adrian et al. (2019, 2022) and use a domestic financial condition index (FCI) to measure financial conditions in the economy.<sup>25</sup> We then explore the extent to which macroprudential policy has an asymmetric impact on future financial conditions quantiles using local projections. We therefore now use the annual change in the FCI as our dependent variable in this specification, i.e.,  $\Delta y_{i,t+h}$  is the annual change in the FCI over  $h$  quarters.

Coefficient estimates from the estimated impulse response and standard errors are shown in Table B.2, and Figure B.9. We focus again on the 10th, 50th and 90th percentiles. We find there is a drop in the FCI (a loosening of financial conditions) over the medium-term in response to a tightening macroprudential policy shock. This effect appears most pronounced in the right-tail (at the 2- and 3-year horizon particularly), pointing to a role for tighter macroprudential policy in reducing the probability and severity of a sharp tightening in financial conditions in the medium-term.

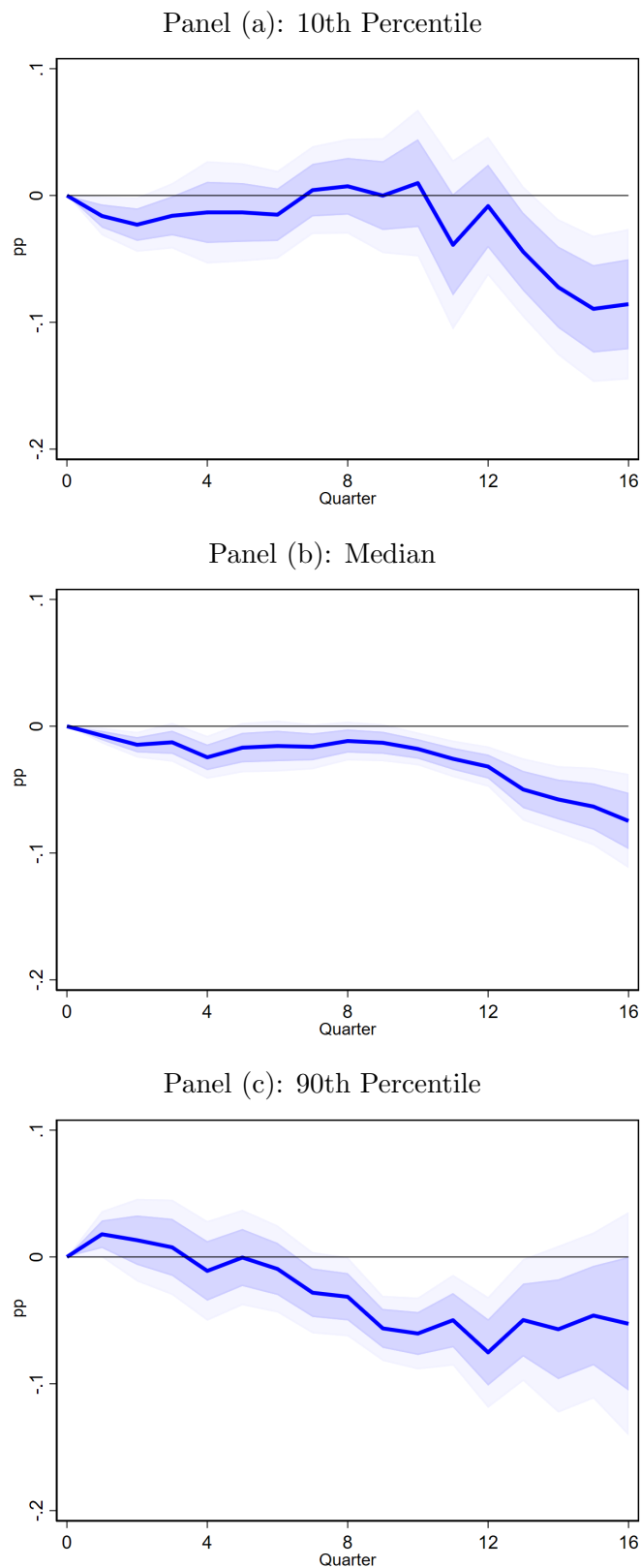
Table B.2: Coefficient estimates for  $\beta^h(\tau)$  from regression of financial conditions change on narrative measure of macroprudential policy and controls

	$h = 4$	$h = 8$	$h = 12$	$h = 16$
PANEL A: Quantile-Regression Estimates				
$\tau = 0.1$	-0.01 (0.02)	0.01 (0.02)	-0.01 (0.03)	-0.09** (0.04)
$\tau = 0.5$	-0.02** (0.01)	-0.01 <sup>^</sup> (0.01)	-0.03*** (0.01)	-0.07*** (0.02)
$\tau = 0.9$	-0.01 (0.02)	-0.03** (0.02)	-0.08*** (0.03)	-0.05 <sup>^</sup> (0.05)
PANEL B: OLS-Regression Estimates				
OLS	-0.02** (0.01)	0.00 (0.01)	-0.01 <sup>^</sup> (0.01)	-0.04*** (0.01)

Notes: Panel A presents coefficient estimates for the causal effects of a 1-unit tightening in macroprudential policy on the  $\tau$ -th percentile of annual average financial conditions change at horizon  $h = 4, 8, 12, 16$ . Panel B presents corresponding estimates from OLS regressions. Coefficient estimates for the fixed effects and controls are not reported. Sample period is 1990Q1-2017Q4, for 12 advanced economies. Standard errors are based on bootstrap with 500 replications and are shown in parenthesis with: <sup>^</sup>  $p < 0.32$ , \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

<sup>25</sup>The financial conditions index provides a weekly estimate of domestic financial conditions in money markets, debt and equity markets, and the traditional and shadow banking systems. Adrian, Boyarchenko, and Giannone (2019) show that the conditional quantile function is more sensitive to the overall FCI than other standard measures of financial conditions such as equity volatility, term spread or credit spread.

Figure B.9: Impulse Response of Quantiles of the Financial Conditions Index (FCI) Distribution to Macroprudential Policy Tightenings



*Notes:* Estimated change in the  $\tau$ -th percentile of annual average financial conditions change at horizon  $h = 1, 2, \dots, 16$ , following a tightening macroprudential policy activation. Sample period is 1990Q1-2017Q4. Shaded areas denote the 90% (light blue) and 68% (dark blue) confidence intervals based on bootstrap with 500 replications.



## D.2 Heterogeneity: Lender- and Borrower-Based Macroprudential Policy

Table B.3 presents the dynamic response of GDP-growth to lender- and borrower-based macroprudential policy tightenings, from Section 3, in tabular form.

Table B.3: Coefficient estimates  $\beta^h(\tau)$  from baseline specification: regression of GDP growth on lender- and borrower-based narrative measure macroprudential policy and controls

	$h = 4$	$h = 8$	$h = 12$	$h = 16$
PANEL A: Quantile-Regression Estimates for Lender-based Macroprudential Policy				
$\tau = 0.1$	0.02 (0.06)	0.13 <sup>^</sup> (0.11)	0.22** (0.09)	0.31*** (0.10)
$\tau = 0.5$	0.02 (0.02)	0.06** (0.03)	0.03 (0.04)	0.09** (0.05)
$\tau = 0.9$	-0.00 (0.03)	-0.05 <sup>^</sup> (0.04)	-0.06 <sup>^</sup> (0.05)	-0.09** (0.05)
PANEL B: Quantile-Regression Estimates for Borrower-based Macroprudential Policy				
$\tau = 0.1$	-0.00 (0.28)	-0.13 (0.45)	0.32 (0.49)	0.26 (0.56)
$\tau = 0.5$	-0.20** (0.11)	-0.22 <sup>^</sup> (0.16)	-0.28 <sup>^</sup> (0.18)	-0.30 (0.32)
$\tau = 0.9$	-0.26 <sup>^</sup> (0.16)	-0.60** (0.32)	-0.69 <sup>^</sup> (0.44)	-0.85 <sup>^</sup> (0.57)

*Notes:* This table presents coefficient estimates for the causal effects of a 1-unit tightening in lender- and borrower-based macroprudential policy on the  $\tau$ -th percentile of annual average real GDP growth at horizon  $h = 4, 8, 12, 16$ . Coefficient estimates for the fixed effects and controls are not reported. Sample period is 1990Q1-2017Q4, for 12 advanced economies. Standard errors are based on bootstrap with 500 replications and are shown in parenthesis with: <sup>^</sup>  $p < 0.32$ , \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

### D.3 House Prices

Table B.4 presents the results for house prices, from Section 4.3, in tabular form.

Table B.4: Coefficient estimates for  $\beta^h(\tau)$  from regression of house-price growth on narrative measure of macroprudential policy and controls

	$h = 4$	$h = 8$	$h = 12$	$h = 16$
PANEL A: Quantile-Regression Estimates				
$\tau = 0.1$	-0.11 (0.12)	-0.11 (0.16)	-0.15 (0.24)	-0.02 (0.33)
$\tau = 0.5$	-0.08 <sup>^</sup> (0.07)	-0.24 <sup>^</sup> (0.17)	-0.31 <sup>^</sup> (0.24)	-0.18 (0.29)
$\tau = 0.9$	0.03 (0.14)	0.05 (0.18)	-0.05 (0.23)	-0.06 (0.34)
PANEL B: OLS-Regression Estimates				
OLS	-0.04 (0.07)	-0.16 <sup>^</sup> (0.14)	-0.20 <sup>^</sup> (0.19)	-0.18 (0.24)

*Notes:* Panel A presents coefficient estimates for the causal effects of a 1-unit tightening in macroprudential policy on the  $\tau$ -th percentile of annual average real house-price growth at horizon  $h = 4, 8, 12, 16$ . Panel B presents corresponding estimates from OLS regressions. Coefficient estimates for the fixed effects and controls are not reported. Sample period is 1990Q1-2017Q4, for 12 advanced economies. Standard errors are based on bootstrap with 500 replications and are shown in parenthesis with: <sup>^</sup>  $p < 0.32$ , \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .