LATVIJAS BANKA
EIROSISTĒMA

ISBN 978-9934-578-49-6

ANDREJS
ZLOBINS

INTO THE UNIVERSE OF UNCONVENTIONAL MONETARY POLICY: STATE-DEPENDENCE, INTERACTION AND COMPLEMENTARITIES

WORKING PAPER
5 / 2022

Latvijas Banka
K. Valdemāra iela 2A, Riga, LV-1050
Tel.: +371 67022300 info@bank.lv
http://www.bank.lv https://www.macroeconomics.lv

Into the Universe of Unconventional Monetary Policy: State-dependence, Interaction and Complementarities

Andrejs Zlobins[‡]

November 8, 2022

Abstract

This paper studies the interaction among non-standard monetary policy measures – the negative interest rate policy, forward guidance and quantitative easing – and their ability to substitute conventional policy rate setting when it is constrained by the effective lower bound. In this paper, the euro area serves as our laboratory since the European Central Bank has deployed all three unconventional measures in the past decade to bypass the binding effective lower bound constraint and stabilize the inflation trajectory towards the target. Our empirical setup makes use of a smooth-transition structural vector autoregression, while identification of monetary innovations is done via fusion of high frequency information with narrative sign restrictions, first introduced in Zlobins (2021b) and now further extended to isolate rate cuts in positive/negative territory, allowing to simultaneously identify the impact of both conventional and unconventional policy actions. Our findings show that unconventional measures can *substitute* the standard policy rate setting but their effectiveness is highly dependent on the overall policy mix and the state of the economy. However, the evidence also suggests that non-standard measures serve as *complements* to the conventional policy as they are particularly powerful in circumstances when standard policy rate setting loses its stabilization properties, for example, during market turbulence or when the risk of de-anchoring of inflation expectations is elevated.

Keywords: quantitative easing, negative interest rate policy, forward guidance, monetary policy, non-linearities

JEL codes: C54, E50, E52, E58

[‡]Monetary Policy Department, Latvijas Banka, K. Valdemāra iela 2A, Rīga, LV-1050, Latvija; e-mail: Andrejs.Zlobins@bank.lv. The author would like to thank the participants of an internal seminar held at Latvijas Banka, the 11th Nordic Econometric Meeting and the 4th Warsaw Money-Macro-Finance Conference for useful suggestions. I am also grateful to Mārtiņš Bitāns, Uldis Rutkaste, Boriss Siliverstovs and Kārlis Vilerts (all from Latvijas Banka) for valuable comments. The views expressed in this paper are those of the author and do not necessarily reflect the views of Latvijas Banka.

1 Introduction

Secular decline in equilibrium real interest rates observed over the last decades in the advanced economies has substantially reduced the space of conventional monetary policy (CMP). In light of persistently below-target inflation, central banks have significantly expanded their monetary toolboxes with several non-standard measures to recoup the reduced policy space. Namely, they have experimented with sub-zero policy rates, used communication as an outright policy tool to influence agents' expectations of the future rate path and embarked on large-scale asset purchases. However, the bulk of literature has studied the effects of these tools in isolation, omitting the complex interactions and complementarities between them. Recent theoretical contributions of Sims and Wu (2021) and Bonciani and Oh (2021) provide important exceptions, suggesting that a mix of non-standard measures can effectively substitute the conventional monetary policy when it faces a binding effective lower bound (ELB) constraint. Still, while both papers analyze the effects of unconventional monetary policy (UMP) measures within DSGE frameworks, the conclusions are somewhat contradictory as Sims and Wu (2021) suggest that quantitative easing (QE) is the most effective tool to stabilize the economy when the ELB is binding, while Bonciani and Oh (2021) advocate that it is optimal for the central bank to primarily rely on forward guidance (FG) with some adjustment to its balance sheet when standard policy rates are no longer able to provide the required monetary accommodation. This is likely affected by the respective approaches to mitigate the *forward guidance puzzle* (Del Negro et al. (2012)), thus calling for empirical investigation on the interaction between various non-standard measures as well as their ability to substitute standard policy rate setting when it faces the adverse consequences of the ELB constraint. An a additional aspect, which requires empirical evidence, is the potential state-dependency of QE as Karadi and Nakov (2021) provide theoretical arguments that central bank asset purchases are only effective when financial intermediaries face funding constraints, rendering QE to be an imperfect substitute for the policy rate at the ELB. This runs somewhat counter to the seminal papers of Gertler and Karadi (2011), Gertler and Karadi (2013) and Carlstrom et al. (2017) which quantify the effects of QE in a DSGE setup, assuming that it is always effective.

Existing empirical evidence on the interaction between different unconventional monetary policy tools is scarce, which is not surprising given the technical challenges associated with a precise identification of each tool, as they have usually been employed in unison. Rostagno et al. (2019)

focus on the ECB's experience with non-standard monetary policy tools and qualitatively discuss the complementarities between the measures but do not empirically test them. Rostagno et al. (2021) go further and propose a novel identification strategy to simultaneously pin down the effects of all three UMP measures deployed by the ECB and then track their real effects in a linear econometric setup, finding that QE has been the most effective tool, followed by the negative interest rate policy (NIRP), while the impact of the FG has been somewhat smaller. The overarching conclusion from these papers is that a mix of non-standard tools is more effective as the synergies between distinct instruments considerably reinforce their impact as opposed to if they would have been used as stand-alone tools. Still, the existing literature has devoted little attention to potential non-linear relationships between individual UMP tools or their effectiveness during different states of the economy.

Hence, we try to fill this gap in literature. We use the euro area as our laboratory since the ECB has (I) brought policy rate into negative territory, (II) provided guidance on the future path of rates and (III) deployed large-scale asset purchases. We contribute to the literature on the interaction of UMP measures as follows: first, we propose a novel approach to simultaneously identify the impact of both conventional and unconventional (NIRP, FG, QE) policy actions from high frequency surprises around the ECB Governing Council events by extending the approach introduced in Zlobins (2021b), namely via fusion of high frequency identification (HFI) with narrative sign restrictions. Second, we analyze the interaction among UMP instruments and their ability to substitute conventional policy rate setting in a non-linear fashion using a smooth-transition structural vector autoregression. Finally, we provide empirical comparison of macroeconomic effects generated by different monetary policy tools across various states of the economy.

Overall, our findings suggest that unconventional monetary policy measures can *substitute* the standard policy rate setting when it is subject to a binding ELB constraint, but they cannot be considered as perfect substitutes since their effectiveness is highly dependent on the overall policy mix and the state of the economy. For example, both NIRP and FG require an active QE programme to have the desired impact, while QE itself is more potent when financial intermediaries face funding constraints, as foreseen in Karadi and Nakov (2021). However, we argue that UMP tools can also be viewed as *complements* to conventional policy as they are particularly powerful in circumstances when CMP loses its stabilization properties, e.g. during market turbulence or when the risk of de-anchoring of inflation expectations is elevated.

The paper proceeds as follows. Section 2 reviews the relevant literature, while Section 3 describes the empirical framework, data and identification strategy used in our paper to pin down the interaction among monetary policy instruments as well as their state-dependent macroeconomic effects. Section 4 presents and discusses the results. Finally, Section 5 concludes.

2 Literature Review

While the deployment of various non-standard monetary policy measures by the ECB to combat persistently low inflation observed in the euro area for the better part of the last decade has produced a voluminous body of literature documenting their impact on the economy[1], most of the literature has studied the effects of these tools in isolation, omitting the complex interactions between them. Rostagno et al. (2019) and Rostagno et al. (2021) are important exceptions as they particularly focus on the complementarities between the different non-standard tools used by the ECB and conclude that a mutually reinforcing design of the tools significantly increase their impact on the economy compared to a case where they would have been used on a stand-alone basis.

These findings are well in line with theoretical predictions of Sims and Wu (2021) and Bonciani and Oh (2021). Both papers argue that a mix of unconventional monetary policy tools in the form of quantitative easing and forward guidance (and sub-zero policy rates in Sims and Wu (2021)) can provide sufficient monetary accommodation to pull out the economy from the liquidity trap even if the conventional monetary policy faces a binding ELB constraint. However, previous studies provide somewhat contradictory conclusions on the relative potency of different non-standard measures, rendering clear policy conclusions ambiguous and calling for an empirical investigation into this matter. In this regard, additional doubts are raised in Karadi and Nakov (2021), suggesting that QE cannot be considered as a perfect substitute for policy rate when it is constrained by the lower bound because asset purchases can only stabilize the economy when banks are subject to balance sheet constraints. This aspect also calls for empirical investigation as benchmark DSGE models used to study the macroeconomic effects of large-scale asset purchases assume that they are always effective, irrespective of the underlying state of the economy (see Gertler and Karadi (2011), Gertler and Karadi (2013) and Carlstrom et al. (2017)).

[1]See Altavilla et al. (2015), Andrade et al. (2016), Blattner and Joyce (2016), De Santis (2016), Garcia Pascual and Wieladek (2016), Koijen et al. (2016), Hartmann and Smets (2018), Eser et al. (2019), Gambetti and Musso (2020), Dedola et al. (2021), Zlobins (2021b) for the effects of QE, Altavilla et al. (2018), Klein (2020), Zlobins (2020), Altavilla et al. (2021), Demiralp et al. (2021) for the impact of NIRP and Coenen et al. (2017), Andrade and Ferroni (2021) and Zlobins (2021a) for evidence on the efficacy of FG.

This assumption though is questionable given the existing empirical evidence that the effects of (conventional) monetary policy are highly dependent on the state of the economy. For example, Aastveit et al. (2017) and Caggiano et al. (2017) study whether the prevailing level of uncertainty affects the transmission mechanism of conventional monetary policy actions in the US and find that they are substantially less powerful when uncertainty is high. Similar evidence for the euro area is provided by Hauzenberger et al. (2020), confirming that CMP is only effective during tranquil periods. In addition, they consider whether the uncertainty affects the potency of unconventional tools - FG and QE - and find that QE, in contrast to CMP and FG, is particularly effective during periods of high uncertainty. Falck et al. (2021), on the other hand, emphasize the role of anchored inflation expectations in the transmission of conventional rate cuts. They find that, when expectations are de-anchored, a rate cut can lead to a decrease in inflation, because firms interpret a rate cut as a signal that demand is decreasing, prompting them to lower their prices. We add to this literature by providing an empirical comparison of how the prevailing level of uncertainty or anchoring of inflation expectations affects the efficacy of CMP vs. UMP measures (NIRP, FG, QE).

Another important strand of the literature to which we contribute concerns the identification of monetary shocks as a precise measurement of the impact provided by individual monetary policy instrument is a prerequisite for the analysis of the interaction among them. A state-of-the-art high frequency identification of shocks has *de facto* become a benchmark approach to pin down the effects of monetary policy (see Gürkaynak et al. (2005), Gertler and Karadi (2015), Nakamura and Steinsson (2018), Altavilla et al. (2019), Jarociński and Karadi (2020), Swanson (2021) among others). Yet, the introduction of non-standard measures has complicated the task of quantifying the effects arising from each tool therefore most papers have employed the factor rotation approach of Swanson (2021) to single out the FG and QE disturbances alongside conventional policy shocks and this approach has also been applied by Altavilla et al. (2019) for the euro area. However, Rostagno et al. (2021) argue that this approach cannot capture the impact of NIRP as it propagates via different channels compared to a rate cut in positive territory, resembling an FG-type shock and thus complicating the identification of the impact stemming from a sub-zero policy rate cut. They propose a novel identification strategy to tell apart the effects of NIRP, FG and QE using an event study approach combined with forward curve counterfactuals, constructed using the information derived from rate options. In the next section, we propose an alternative method to pin down the effects of these unconventional policy innovations alongside conventional policy disturbances by augmenting high frequency surprises of the risk-free curve around the ECB policy events with narrative sign restrictions of Antolin-Diaz and Rubio-Ramirez (2018).

3 Empirical framework

In this section, we describe our non-linear econometric framework to pin down the interactions between non-standard monetary policy instruments deployed by the ECB over the last decade and their effectiveness over different states of the economy. In particular, we employ a smooth-transition structural vector autoregression (ST-SVAR) *a lá* Auerbach and Gorodnichenko (2012), which essentially generalizes the smooth-transition autoregressive model of Granger and Terasvirta (1993) for a multivariate case. The advantage of ST-SVAR over other non-linear VAR setups, e.g. threshold or Markov-switching vector autoregressions, is that it allows to utilize more information for the estimation of regime-specific impulse responses. The logistic function used in the estimation of ST-SVAR effectively assigns a probability of being in a particular regime at each point in time, sharpening the estimation of state-dependent impulse response functions (IRF)[2] as it is based on a larger set of observations. This aspect is particularly crucial for our application as the ECB has only deployed NIRP and QE post-2014, significantly shortening the relevant sample size over which the regime-specific IRFs can be computed.

Let y_t denote a vector of endogenous variables which evolve according to:

$$y_t = (1 - F(s_{t-1}))\left[\sum_{j=1}^{p} A_{1,j} y_{t-j}\right] + F(s_{t-1})\left[\sum_{j=1}^{p} A_{2,j} y_{t-j}\right] + u_t \tag{1}$$

where y_{t-j} is a set of endogenous variables, $A_{1,j}$ and $A_{2,j}$ are state-dependent SVAR coefficients related to the *j-th* lag and u_t denotes the vector of reduced-from residuals. Additionally, state-dependence in the propagation of structural innovations arises not only via differences in SVAR coefficients $A_{1,j}$ and $A_{2,j}$ but also via regime-specific variance-covariance matrices Ω_1 and Ω_2:

$$u_t \sim \; N(0, \Omega_t) \tag{2}$$

$$\Omega_t = (1 - F(s_{t-1}))\Omega_1 + F(s_{t-1})\Omega_2 \tag{3}$$

[2]When estimating state-dependent IRFs via STVAR, it is assumed that the economy stays in the same regime throughout the horizon as at the time of the shock. This implies that in some cases the estimated effects might appear large, especially when compared to the ones obtained from linear models.

While the state-dependence $F(s_t)$ is governed by the logistic transformation:

$$F(s_t) = \frac{exp(-\gamma s_t)}{1 + exp(-\gamma s_t)}, \gamma > 0, s_t \sim N(0,1) \tag{4}$$

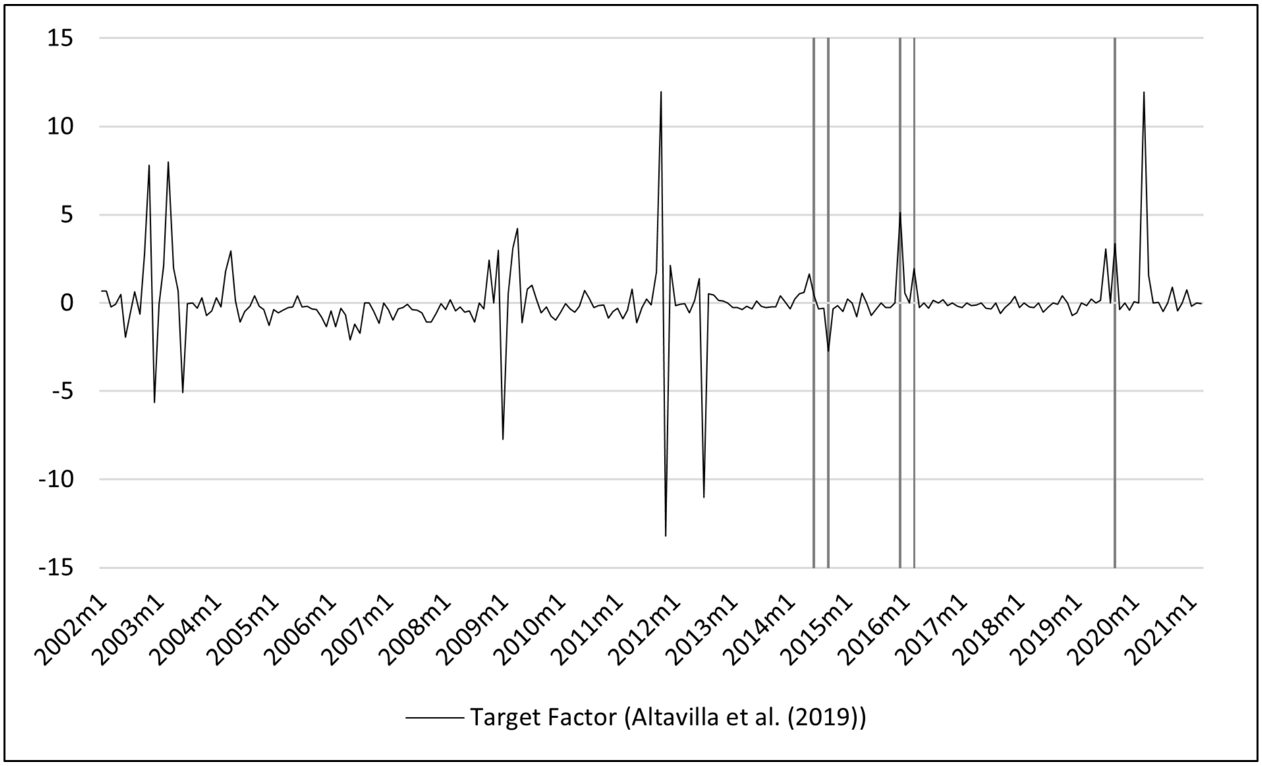
From equation 4 it follows that the logistic function depends on the state variable s_t and slope parameter γ. Each transition variable s_t (we describe them in the next section as we are interested in a multitude of states) is subject to the same transformation procedure as in Hauzenberger et al. (2020). First, the variable is detrended by regressing it on a linear trend term and then subtracting the fitted values from the original series. This allows to interpret the underlying changes in the state variable as deviations from a hypothetical long-run equilibrium. Second, the series are then standardized to have a zero mean and unit variance. Regarding the slope parameter γ, in all cases we set it to 5, implying a swift transition between states. While the choice of relatively large value for γ creates a risk that the transition between states is abrupt, in Appendix A3 we show that the logistic function indeed exhibits a smooth-transition rather than step-function behaviour. The ST-SVAR is estimated following the procedure outlined in Auerbach and Gorodnichenko (2012) and uses the Markov Chain Monte Carlo algorithm of Chernozhukov and Hong (2003). The lag order is set to 2, and the model includes a constant.

3.1 Data and identification strategy

The use of high frequency reactions of asset prices around central bank announcements has become a benchmark approach to pin down the effects of exogenous monetary policy shocks. However, the addition of several non-standard measures to the central bank toolkit over the last decade has complicated the task of fully capturing the monetary policy stance. Therefore, most papers have used the factor rotation approach of Swanson (2021) to capture the impact of FG and QE innovations alongside conventional policy shocks. Rostagno et al. (2021) note though that this methodology fails to disentangle the effects of a sub-zero policy rate cut as it propagates via different channels compared to a rate cut in positive territory. As shown in Figure 1, the Target factor of Altavilla et al. (2019) indeed fails to register rate cuts below zero.

Thus, we adopt the approach of Zlobins (2021b) in order to fully capture the monetary policy stance of the ECB as it has used NIRP alongside FG and QE since June 2014. The method combines HFI with narrative sign restrictions of Antolin-Diaz and Rubio-Ramirez (2018) which

Figure 1: **Target factor of Altavilla et al. (2019)**



Note: Vertical lines indicate dates when the DFR was cut into negative territory: in June 2014, September 2014, December 2015, March 2016 and September 2019.

allows to capture multiple monetary policy shocks in policy announcements and is now further extended to isolate rate cuts in positive/negative territory.

In the first step, we gather high frequency reactions of the risk-free yield curve and stock prices around the ECB policy announcements from the Euro Area Monetary Policy Event-Study Database (EA-MPD) of Altavilla et al. (2019). We use the press release window surprises for conventional policy shocks and press conference window reactions for all unconventional policy innovations. Then, we include high frequency surprises into the VAR and ensure that they do not depend on their own lags:

$$m_t = a_0 + \sum_{j=1}^{p} 0 \, m_{t-j} + \epsilon_t \tag{5}$$

where m_t are the high frequency reactions of the 3-month (both in the press release and press conference windows), 1-year and 10-year OIS rates and Eurostoxx 50 to ECB policy announcements. Our choice of the particular OIS maturities is motivated by the evidence from Altavilla et al. (2019) and Rostagno et al. (2021) showing that each instrument targets specific region of the yield curve. For instance, QE predominantly loads on the back-end of the term structure, while FG - on mediumterm maturities. Regarding the NIRP, we assume that it has the largest impact on short-term rates, similar to conventional policy, but instead of the press release, it primarily operates in the press conference window, given the resemblance to FG-type shock. Lane (2019) puts forth a similar point, arguing that the statement at the press conference that the ECB's Governing Council "expects the key ECB interest rates to remain at present or lower levels" amplifies the effects of NIRP as the lower bound itself essentially becomes a policy parameter. Besides, given the novelty of this measure, it is safe to assume that financial market participants reacted to sub-zero rate cuts with a lag. Indeed, Rostagno et al. (2019) chronicle the ECB's experience with NIRP, admitting that even the ECB realized the potential of sub-zero rate cuts after some time. The first cut in June 2014 was motivated by technical reasons warranted by adjustment to the rate corridor and only later developed into fully fledged policy tool as the synergies with FG and QE became more apparent. The VAR is estimated on a monthly basis from January 2002 to March 2021 with standard Bayesian techniques by specifying an independent Normal-Wishart prior.[3]

In the second step, we apply the following set of sign restrictions:

Table 1: **Set of traditional sign restrictions used to distinguish monetary policy instruments**

Shock	3-month OIS (press release)	3-month OIS (press conference)	1-year OIS	10-year OIS	Euro Stoxx 50
CMP	-				+
NIRP		-			+
FG			-		+
QE				-	+
Information		-	-	-	-

All restrictions are imposed to hold on impact only. In addition to identification of conventional and unconventional monetary policy disturbances, we also control for the effects of information shock following the logic put forth in Jarociński and Karadi (2020) and assuming that the release of central bank information during policy announcements entails a positive co-movement between interest rates and stock prices. However, given that policy shocks of Odyssean nature, induced by different monetary policy tools, move surprises in the same direction, pure sign restrictions alone are insufficient to clearly distinguish the effects of multiple monetary policy instruments. Mechanical orthogonalisation via zero restrictions, on the other hand, would be too restrictive as the ECB has often announced and/or recalibrated several instruments in its toolkit in the same meeting of

[3]We set the AR coefficient of the prior to 0, overall tightness λ_1=0.1, cross-variable weighting $\lambda_2 = 0.5$, lag decay $\lambda_3 = 1$ and block exogeneity shrinkage λ_5=0.001.

the Governing Council. Hence, we augment traditional sign restrictions with narrative information about the respective shocks, using the approach of Antolin-Diaz and Rubio-Ramirez (2018), which allows to implement narrative information by placing restrictions on the structural disturbances and historical decompositions in addition to sign restrictions on the impulse response functions and structural parameters, sharpening the inference. In particular, we supplement our identification strategy with the following narrative information to tell apart the effects of different monetary policy measures:

Narrative Sign Restriction I. *An expansionary CMP shock took place in November 2011.*

Narrative Sign Restriction II. *For November 2011, the CMP shock was the overwhelming driver of the unexpected movement in 3-month OIS (press release window).*

Narrative Sign Restriction III. *An expansionary NIRP shock took place in June 2014.*

Narrative Sign Restriction IV. *For June 2014, the NIRP shock was the overwhelming driver of the unexpected movement in 3-month OIS (press conference window).*

Narrative Sign Restriction V. *An expansionary FG shock took place in July 2013.*

Narrative Sign Restriction VI. *For July 2013, the FG shock was the overwhelming driver of the unexpected movement in 1-year OIS.*

Narrative Sign Restriction VII. *An expansionary QE shock took place in January 2015.*

Narrative Sign Restriction VIII. *For January 2015, the QE shock was the overwhelming driver of the unexpected movement in 10-year OIS.*

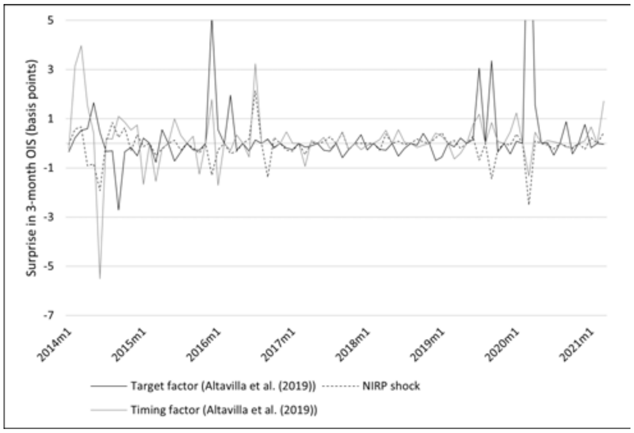
To sum up, for each of the four monetary policy shocks we identify, we restrict both the sign of the structural disturbance as well as the historical decomposition of the corresponding maturity OIS surprise on which the respective instrument primarily loads. For the unconventional instruments - NIRP, FG and QE - the choice of dates is straightforward as the selected Governing Council meetings are the ones in which the respective instruments were first officially announced. For a CMP shock, our choice of the specific date is motivated by the largest recorded easing surprise in 3-month OIS rate (in the press release window) in the considered sample period and the fact this conventional policy action was one the last before the ECB switched to a mix of unconventional policy tools, aiding the identification.

Figure 2d shows the obtained shock series using our approach and compares it against the updated factors of Altavilla et al. (2019)[4]. The figure demonstrates that our approach is able to

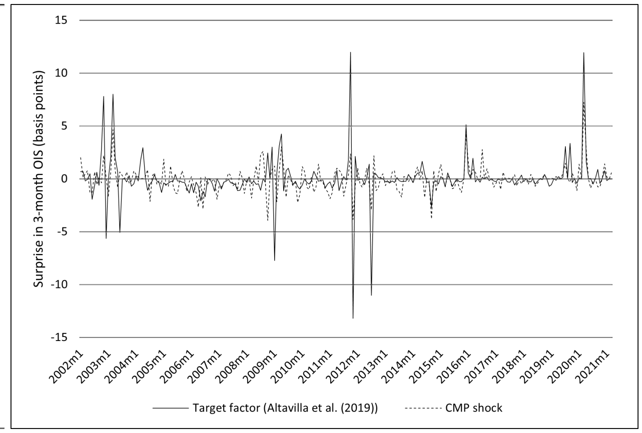
[4]We use codes from the website of Refet Gürkaynak: http://refet.bilkent.edu.tr/research.html

Figure 2: **Comparison of the identified shock series**

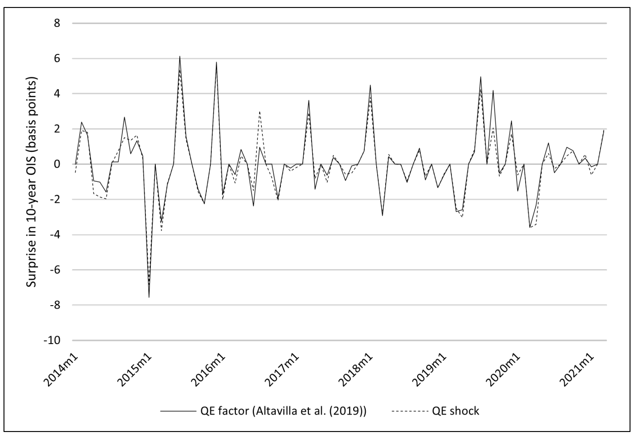
(a) NIRP shock



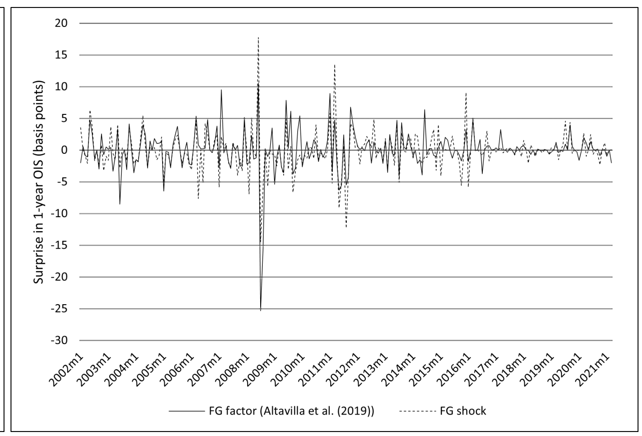
(b) CMP shock



(c) QE shock



(d) FG shock



effectively recover rate cuts below zero, generating NIRP shock series which is consistent with the actual use of this instrument in the euro area. In comparison with the Target factor of Altavilla et al. (2019), our shock series registers an easing on most dates when the Governing Council indeed decided to lower the Deposit Facility Rate (DFR) deeper into negative territory[5]. However, the shock series for CMP, FG and QE are broadly consistent with the benchmarks generated via the factor rotation approach.

The obtained shock series are then one-by-one plugged directly into the ST-SVAR, following the "internal instrument" VAR literature (Romer and Romer (2004), Ramey (2011), Barakchian and Crowe (2013), Plagborg-Møller and Wolf (2021)). IRFs to the policy shocks are then generated

[5] The ECB has cut the DFR into sub-zero territory five times since 2014: in June 2014, September 2014, December 2015, March 2016 and September 2019. Our approach only fails to register the easing of monetary policy stance in September 2014 which is likely driven by the disappointment of market participants regarding the policy decision to not launch (yet) a full-scale QE programme which was signalled by the Governor Mario Draghi in his speech at the central bank symposium in Jackson Hole in August of the same year, overshadowing the rate cut. This explanation is also backed by a considerable tightening surprise in our QE shock series for the same meeting, suggesting that this sentiment dominated during the press conference window of that particular Governing Council.

via Cholesky decomposition by ordering the shock series first as suggested by Plagborg-Møller and Wolf (2021). They also highlight that the "internal instrument" approach produces valid impulse responses even if the instrument is contaminated with measurement errors from other structural shocks, unrelated to the shock of interest. This gives it a clear advantage over the "external instrument" or the proxy SVAR approach of Stock and Watson (2012) and Mertens and Ravn (2013) which requires invertibility to hold. The rest of the endogenous variables included in the ST-SVAR are ordered as follows: real GDP, HICP, Eurostoxx 50, EONIA, 3-month Euribor 1-year forward rate and 10-year bond yield. We estimate the models over two distinct samples: January 2002–March 2021 (for CMP and FG shocks) and January 2014–March 2021 (for NIRP and QE shocks) so that the estimated parameters are consistent with the historical narrative about the use of these instruments in the euro area. The acute phase of Covid-19 shock (March-June 2020) is dropped from the sample to alleviate the impact of outliers on inference because Lenza and Primiceri (2020) show that the extreme volatility in the data from March to June 2020 has a considerable impact on the parameter estimates and shock volatilities, thus implying serious consequences for identification in the VAR models. As one of the remedies to mitigate the undesirable effects on the parameter stability, they suggest that a simple exclusion of them from the sample is a viable solution for structural analysis.

Before turning to the non-linear analysis of interactive relationships between different monetary policy instruments, we first examine the obtained shock series in a linear framework using a constant parameter Bayesian VAR with a Normal-Wishart prior[6]. Figure A2 shows that the IRFs to CMP, FG and QE shocks are both quantitatively and qualitatively similar to the ones generated using the respective factors of Altavilla et al. (2019), while the NIRP innovation, which is unique to our approach, produces macroeconomic effects of similar magnitude and sign as a conventional policy rate cut.

4 Results

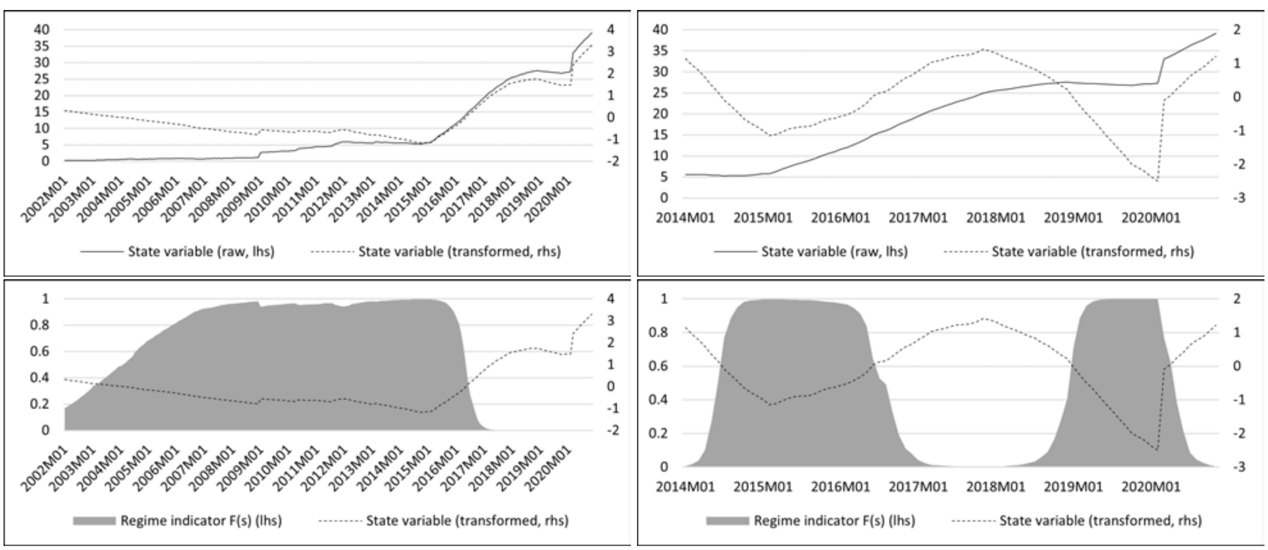
We start our analysis of the interaction among the instruments used by the ECB by looking at the role of QE as it arguably has been the cornerstone of the policy response to help stabilize the path of inflation towards the target in light of persistent deflationary pressures since 2013 and

[6]Identically to the ST-SVAR, we estimate the linear SVARs using 2 lags and employ the algorithm of Giannone et al. (2015) to set hyper-parameters in an optimal fashion and thus maximise the marginal likelihood. IRFs are also generated using the "internal instrument" approach as described above.

binding ELB constraint. In particular, we study the interlinkages between QE, FG and NIRP[7] by using the Eurosystem's asset holdings relative to the euro area nominal GDP as the switching variable s_t[8]. Figure 3 shows both the raw and transformed, as described in the previous section, state variable based on the Eurosystem's asset holdings as a proxy to pin down active/inactive QE regimes displayed in the lower part of figure. In this case, values of regime indicator F(s) close to zero indicate an active phase of QE, while values close to 1 - a period without an active QE. Overall, the state variable tracks the developments of QE regimes fairly well, indicating active QE regime after the announcement of the APP in 2015 and the PEPP in 2020 and the passive regime during 2019 as net purchases under the APP were briefly paused. We replicate the identification of states for two sample periods: January 2002-March 2021 and January 2014-March 2021 since the FG shock is assumed to be active for the full sample, whilst the NIRP shock - only for post-2014.

Figure 3: **ECB asset holdings as the switching variable s_t**

(a) January 2002-March 2021 (b) January 2014-March 2021



The set of impulse responses in Figure 4 show the reaction of macroeconomic variables to FG shock both when it is accompanied with an active asset purchase programmme as well as when QE is passive. The findings suggest that an active QE programme is essential for FG to exhibit a strong macroeconomic impact as the effects on output and inflation are substantially more forceful compared to a situation when FG announcements are not backed by asset purchases. Also, the response of financial market variables has the expected sign (see Euro Stoxx 50) and is more

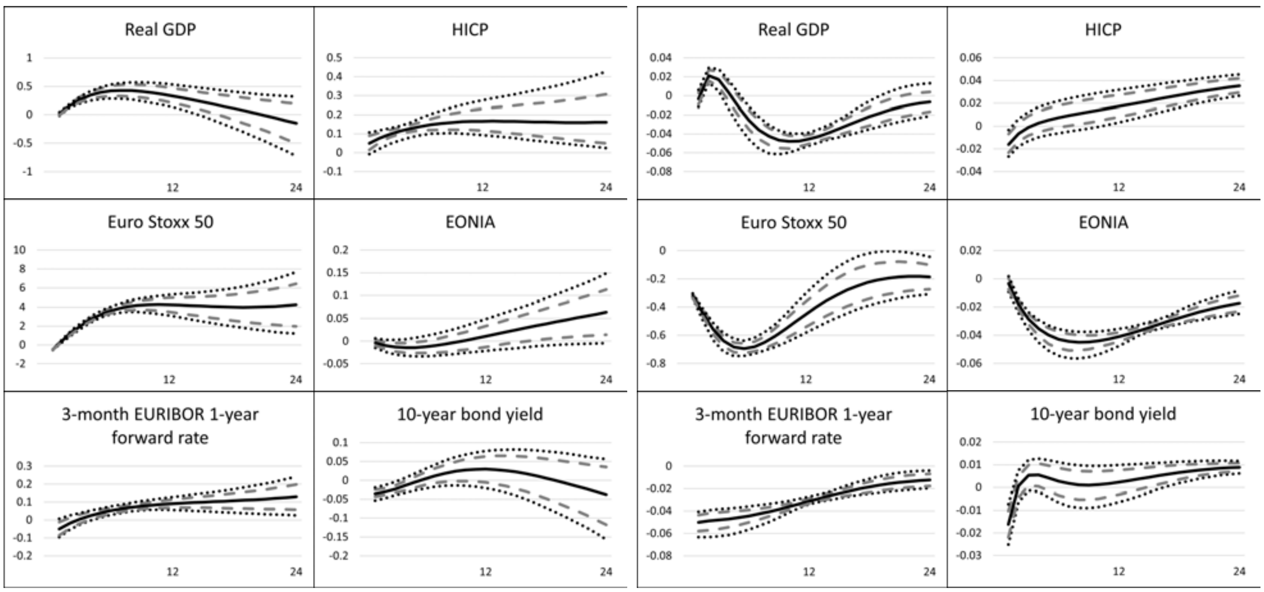
[7]We do not consider the CMP shock as the ECB has only deployed large-scale asset purchases when its policy has been in negative territory.

[8]Results remain robust also when using a flow measure - net purchases made under the APP and the PEPP - instead of stock of asset holdings, see results in Figures A4-A6.

persistent (see the 10-year bond yield) in a regime when QE is active, suggesting that the signalling properties of QE (see Bauer and Rudebusch (2014), Bhattarai et al. (2015) among others) also have important implications for the transmission of FG as the asset purchases considerably strengthen the signal to the financial market participants regarding the future policy path, thus enhancing the credibility of FG announcements.

Figure 4: **Interaction between QE and FG**

(a) QE active (b) QE inactive

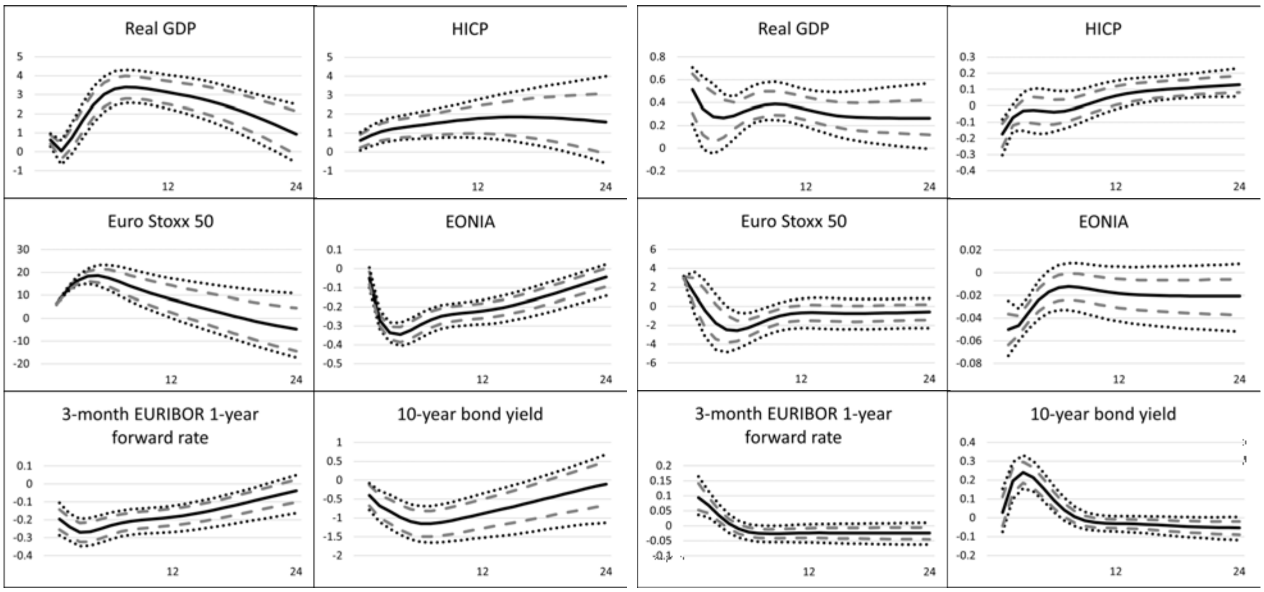


Note: Figures show impulse response functions from a ST-SVAR to the FG shock, normalized to generate a 5 bps drop in the 3-month EURIBOR 1-year forward rate. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Figure 5 documents that an active QE programme is also a prerequisite for NIRP to have the desired effects. The results show that when a rate cut into negative territory is used in tandem with an active asset purchase programme, it generates higher impact on both financial and macroeconomic variables. These findings are in line with the qualitative conclusions of Rostagno et al. (2019), suggesting that the additional liquidity, provided to the banking sector via purchases of securities by the central bank, helps to push the overnight interest rate towards the DFR. Our empirical evidence from the euro area thus contradicts the theoretical predictions of Sims and Wu (2021), who suggest that a cut into negative territory is contractionary if the balance sheet of the central bank is as large as the ECB's one. They argue that the larger the central bank's balance sheet, the more reserves the banking sector is required to hold which, in turn, are subject to negative policy rates, reducing bank profitability and willingness to lend. Instead, our findings are in line with the bank-level evidence of Ryan and Whelan (2021), suggesting that the banking system has actively managed the excess reserves generated by the ECB's QE as the negative deposit rate acted as disincentive to hold them, encouraging financial intermediaries to rebalance excess holdings primarily towards new purchases of debt securities.

Figure 5: **Interaction between QE and NIRP**

(a) QE active (b) QE inactive



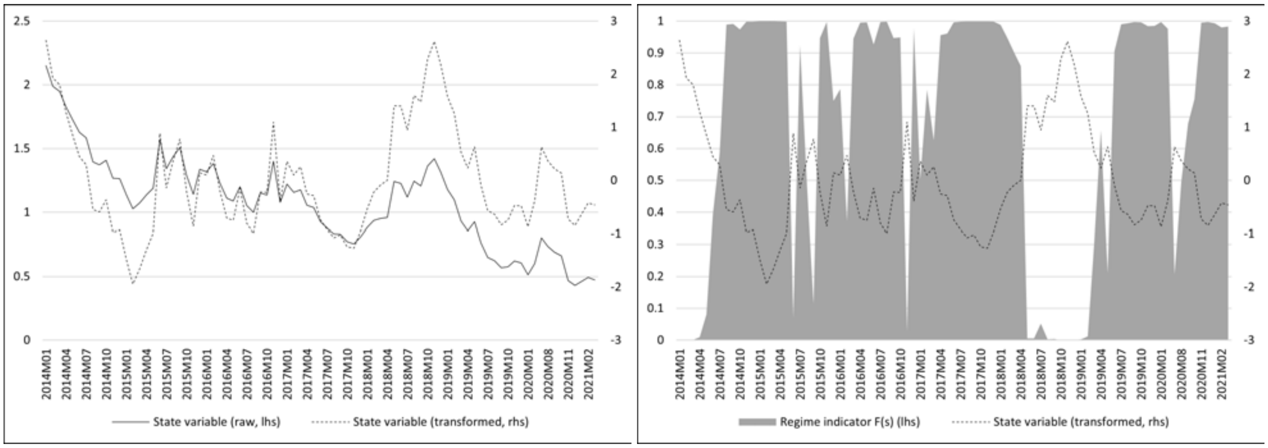
Note: Figures show impulse response functions from a ST-SVAR to the NIRP shock, normalized to generate a 5 bps drop in the EONIA. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Given the evidence that both FG and NIRP require an active QE programme to have the intended effects, it is important to test the state-dependency of the ECB's asset purchases as the Karadi and Nakov (2021) argue that they are more effective when financial intermediaries are subject to funding constraints. To empirically test this theoretical prediction, we employ bank bond spread against the German Bund of Gilchrist and Mojon (2018) as the proxy for banks' balance sheet constraints. Figure 6 shows the evolution of this variable over the period in which the ECB has actively deployed large-scale asset purchases together with the identified states when funding constraints are binding (F(s) values close to 0)/non-binding (F(s) values close to 1).

The results in Figure 7 demonstrate that the effectiveness of QE indeed depends on the underlying state of the economy as it generates a significantly larger impulse when banks are experiencing balance sheet constraints. As panel (a) shows, the ECB's asset purchases exert a more persistent impact on the term structure and interest rate expectations as well as produce longer-lived effects on output and prices compared to a case in panel (b), which shows IRFs for a state when funding constraints are loose. In the next subsection we investigate whether this finding holds when using

Figure 6: **Euro area bank bond spread as the switching variable s_t**

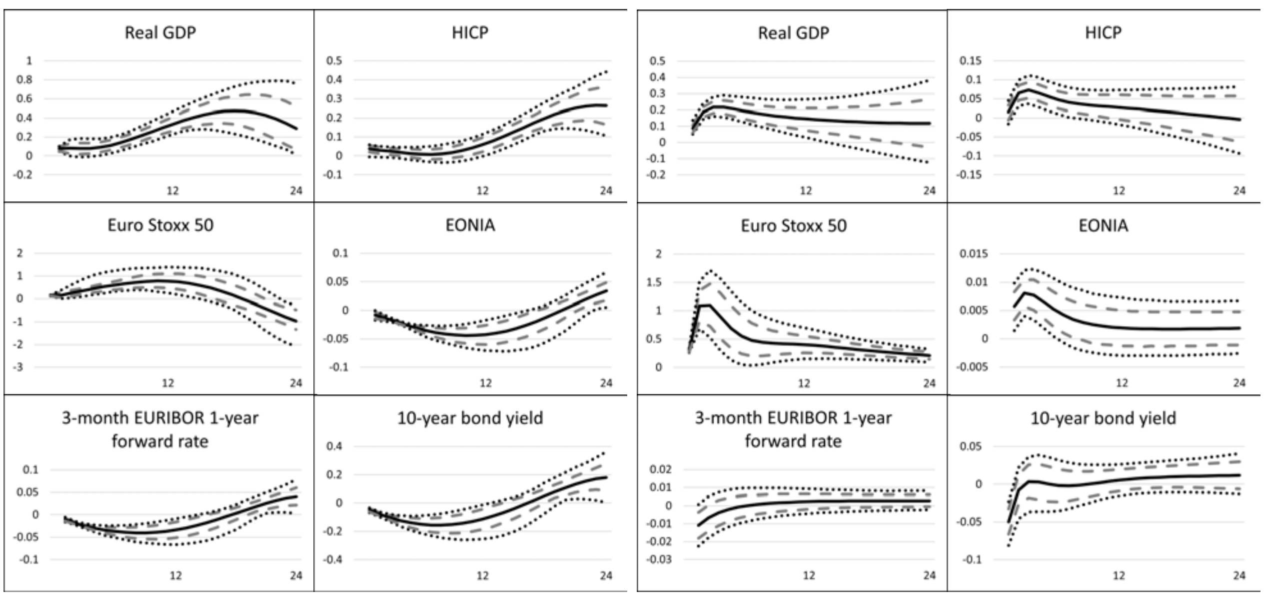
January 2014-March 2021



a broader measure of financial stress and provide results for the state-dependent effects of other monetary policy instruments.

Figure 7: **The role of bank funding constraints in the propagation of QE shock**

(a) Constraints are binding (b) Constraints are not binding



Note: Figures show impulse response functions from a ST-SVAR to the QE shock, normalized to generate a 5 bps drop in the 10-year bond yield. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

4.1 State-dependence of monetary policy shocks

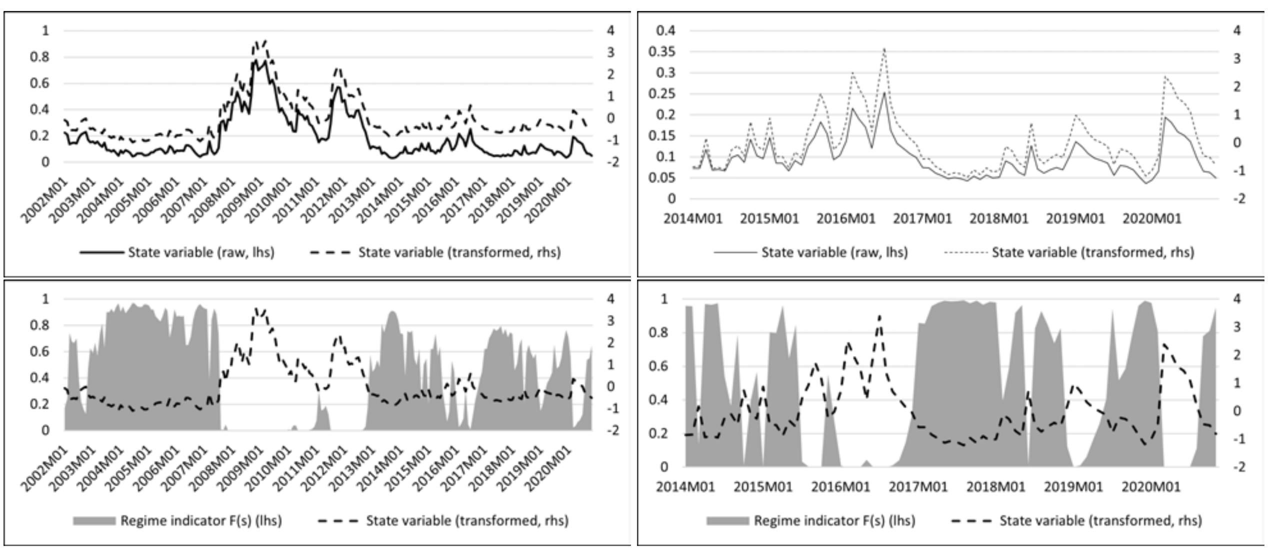
In this subsection we explore and compare the non-linear transmission mechanism of conventional monetary policy vs. three unconventional tools employed by the ECB - QE, NIRP and FG - in times of a high/low financial distress and when inflation expectations are anchored/de-anchored.

The impact of prevailing uncertainty levels in the economy on the monetary transmission mechanism have previously been explored in Aastveit et al. (2017) and Caggiano et al. (2017). They provide empirical evidence from the US, suggesting that monetary policy is significantly less powerful during the regimes of high uncertainty. These papers argue that this result is mainly driven by the response of investment due to non-convex adjustment costs, as predicted by "real-options" theory (Bernanke (1983), Dixit and Pindyck (1994)). In essence, under high uncertainty, firms and households postpone their spending decisions on investment goods, awaiting better information on macroeconomic outlook and putting less weight on the level of prevailing interest rates in the decision-making process, thus making conventional monetary policy less effective.

For the euro area, similar analysis is performed in Hauzenberger et al. (2020), which in addition to CMP, also considers whether the prevailing levels of uncertainty affect the potency of unconventional tools - QE and FG - in the same vein using the newspaper-based index of economic policy uncertainty (EPU) developed by Baker et al. (2016). They confirm that conventional rate cuts are substantially less effective when uncertainty is high, as does the forward guidance, while quantitative easing on the other hand is particularly powerful during periods of elevated uncertainty.

Figure 8: **CISS as the switching variable** s_t

(a) January 2002-March 2021 (b) January 2014-March 2021

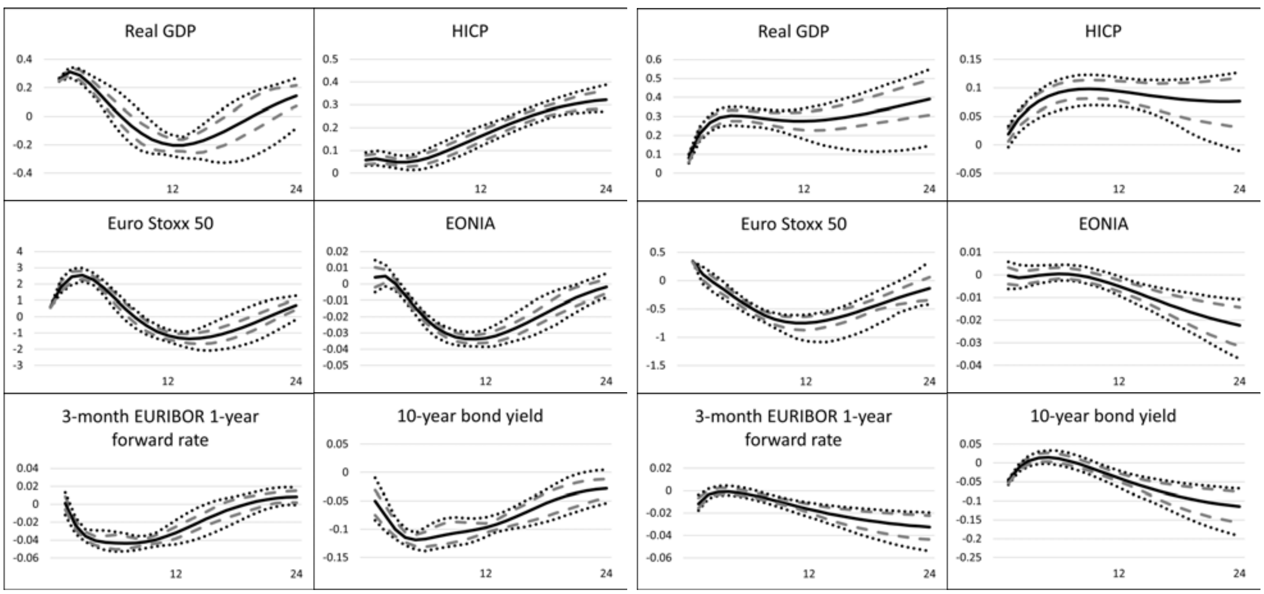


We extend the literature by providing the results for the effectiveness of NIRP and focus on the financial uncertainty as we employ the CISS index of Kremer et al. (2012), which captures disruptions in financial intermediation, equity, bond, money and foreign exchange markets. Figure

8 shows the dynamics of this variable over time as well as the identified states of low (F(s) values close 0)/high (F(s) values close to 1) levels of financial distress. The identified states of high uncertainty correspond well with the narrative as it correctly identifies the collapse of Lehman Brothers and the following Great Recession (2008-2009), the European sovereign debt crisis (2010-2012), Brexit (2016 and 2019), US-China trade tensions (2019) and the Covid-19 outbreak (2020). Results in Figure 9 confirm the findings of Hauzenberger et al. (2020) regarding the amplified effect of quantitative easing during periods of market turmoil as panel (a) shows that the QE innovation exerts more pronounced effect on all financial variables and generates more inflationary pressures as a result.

Figure 9: **Financial stress: QE shock**

(a) High stress (b) Low stress

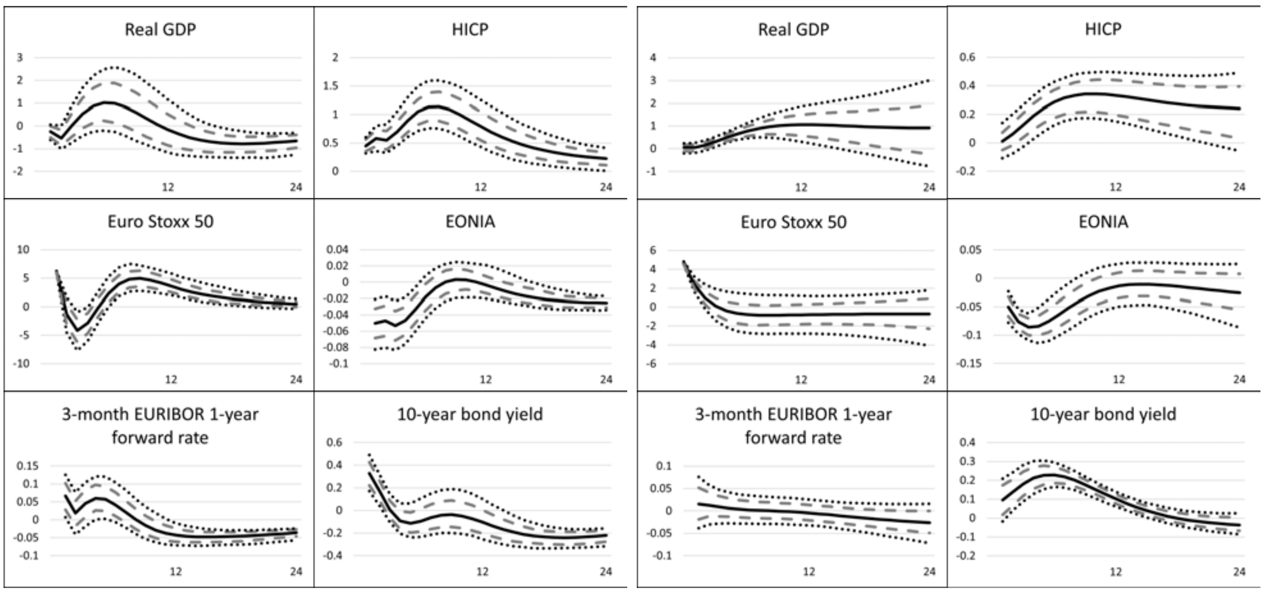


Note: Figures show impulse response functions from a ST-SVAR to the QE shock, normalized to generate a 5 bps drop in the 10-year bond yield. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

In addition, evidence in Figure 10 suggests that a rate cut into negative territory can further complement the monetary response during turbulent periods as it produces a significantly higher macroeconomic impact compared to times with low levels of financial frictions. These results also confirm the findings of Rostagno et al. (2021) that a cut into negative territory has different effects on the economy compared to conventional policy easing, resembling an FG-type shock although one that is fully credible. Indeed, Figure 11 documents that, during elevated uncertainty, a pure verbal commitment to keep rates low is not sufficient for effective macroeconomic stabilisation. Panel (b) indicates that forward guidance only has significant impact on output and prices when the financial stress level is low. Thus, our results suggest that when financial markets are in turmoil and financial fragmentation risks are high, an (unconventional) central bank action is mandatory to limit the adverse consequences of financial volatility for real economy via the financial accelerator mechanism (Bernanke et al. (1996)).

Figure 10: **Financial stress: NIRP shock**

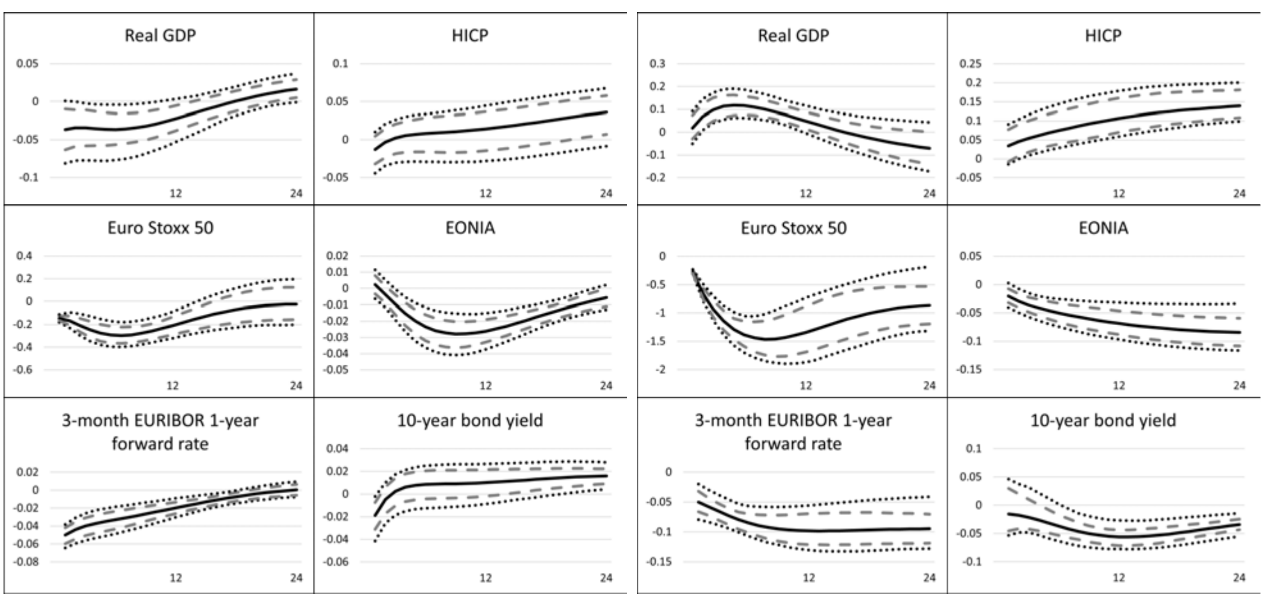
(a) High stress (b) Low stress



Note: Figures show impulse response functions from a ST-SVAR to the NIRP shock, normalized to generate a 5 bps drop in the EONIA. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Figure 11: **Financial stress: FG shock**

(a) High stress (b) Low stress

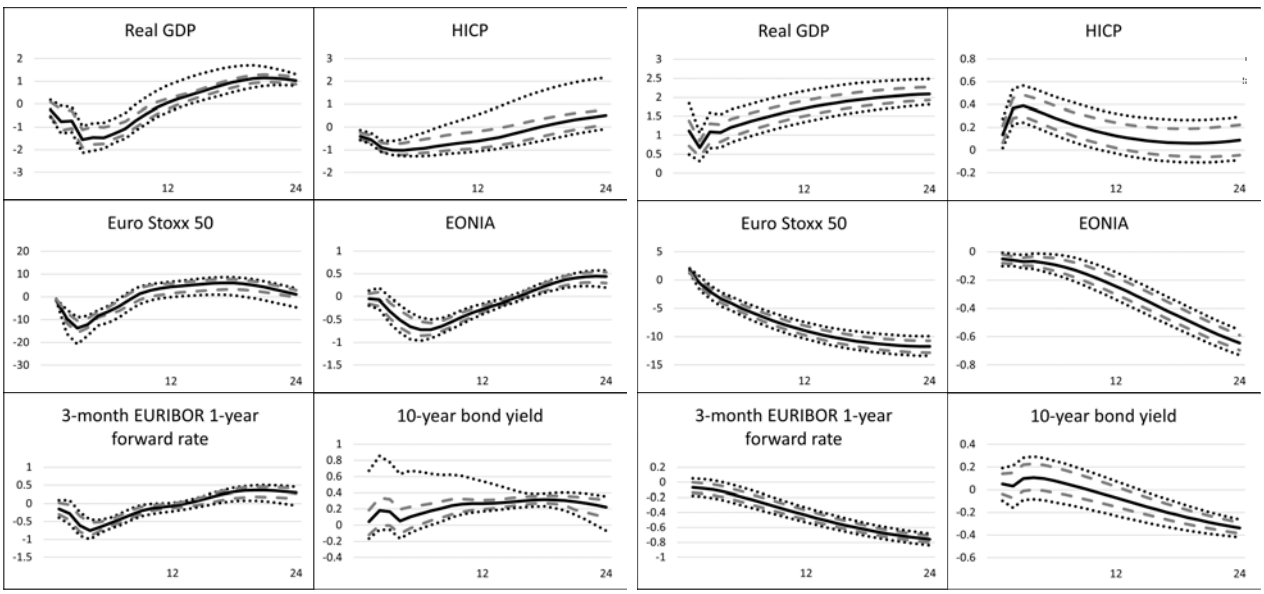


Note: Figures show impulse response functions from a ST-SVAR to the FG shock, normalized to generate a 5 bps drop in the 3-month EURIBOR 1-year forward rate. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Moreover, Figure 12 confirms limited power of conventional monetary policy during the state of high uncertainty as IRFs suggest that it generates significantly higher impact on output and only stabilizes inflation dynamics when the level of financial frictions is low. Hence, by looking at the effectiveness of different monetary policy instruments over varying levels of financial stress, our study provides important policy lessons as the unconventional tools - particularly QE and NIRP - are an important part of the central bank toolkit and complement the traditional policy rate setting as it loses stabilization properties.

Figure 12: **Financial stress: CMP shock**

(a) High stress (b) Low stress



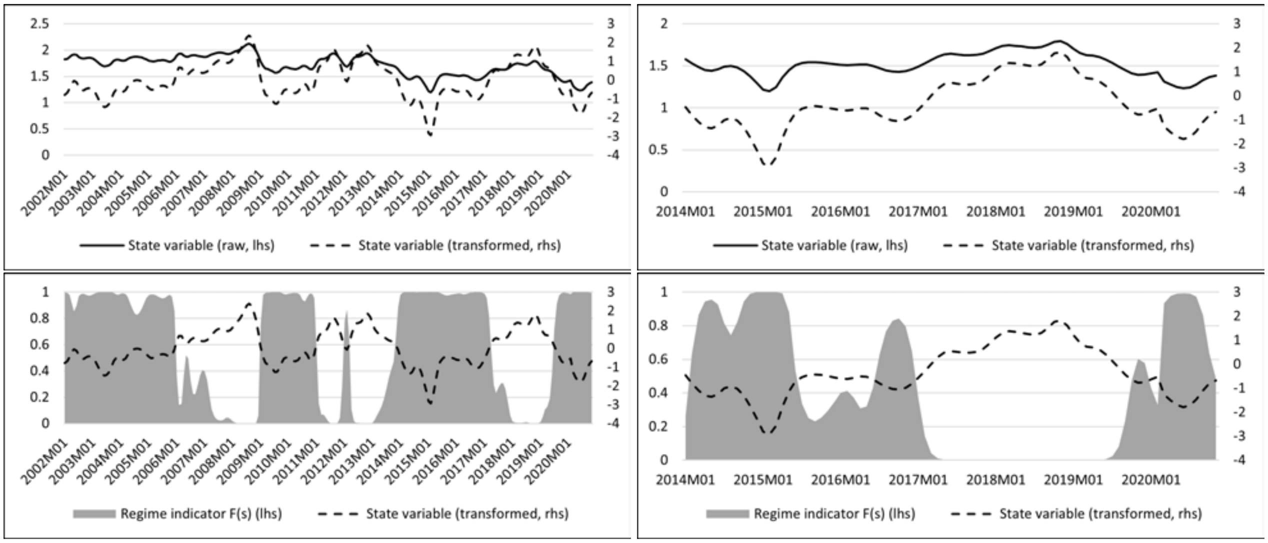
Note: Figures show impulse response functions from a ST-SVAR to the CMP shock, normalized to generate a 5 bps drop in the EONIA. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Next, we study the importance of anchored inflation expectations for the efficacy of monetary policy. Inflation expectations play an important role in the monetary transmission mechanism since they affect the current price and wage setting and *ex-ante* real interest rates and, in a broader sense, they proxy the credibility of a central bank to maintain the price stability (see Andrade et al. (2016), Baumann et al. (2021)). Moreover, Falck et al. (2021) provide a novel empirical evidence from the US that disagreement about inflation expectations is highly relevant for the transmission of conventional monetary policy. Using smooth-transition local projections, they show that when disagreement is high, i.e. inflation expectations are de-anchored, the effects of a rate cut flip relative to conventional wisdom as it leads to a decrease in inflation.

They also rationalize this empirical phenomenon in the New Keynesian DSGE model with

Figure 13: **SPF 2-years ahead inflation expectations as the switching variable s_t**

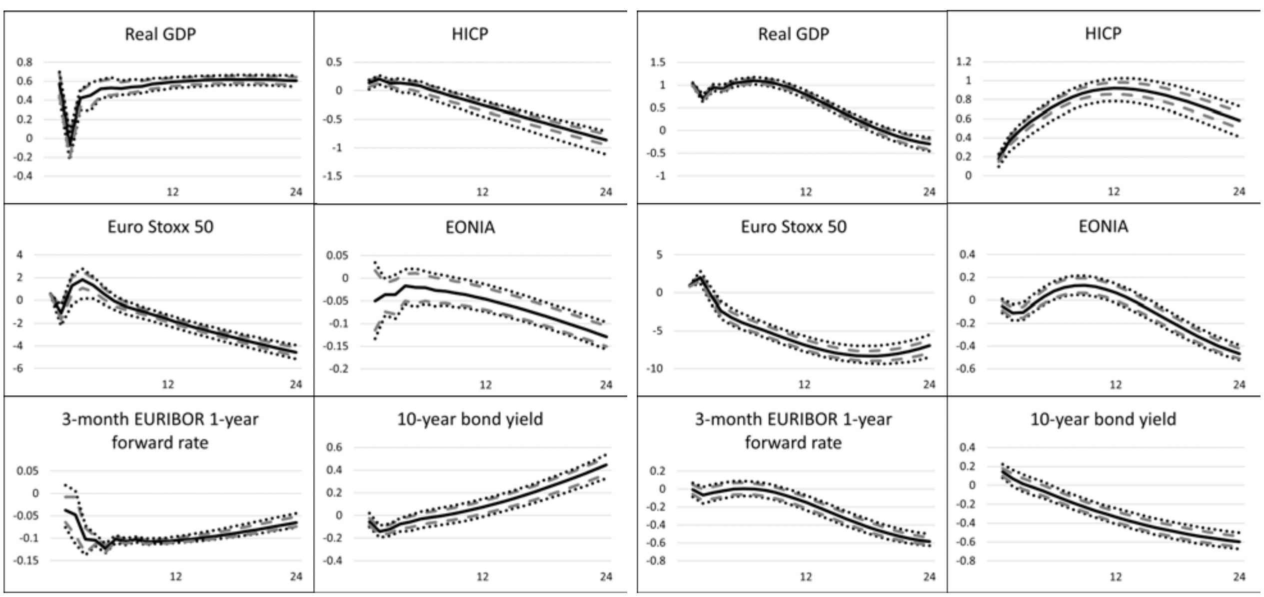
(a) January 2002-March 2021 (b) January 2014-March 2021



dispersed information and argue that this outcome is driven by the signalling channel of monetary policy. In particular, during high disagreement regime, firms interpret a rate cut as a signal that demand is decreasing, prompting them to lower their prices.

Figure 14: **Inflation expectations: CMP shock**

(a) Elevated risk of de-anchored expectations (b) Anchored expectations

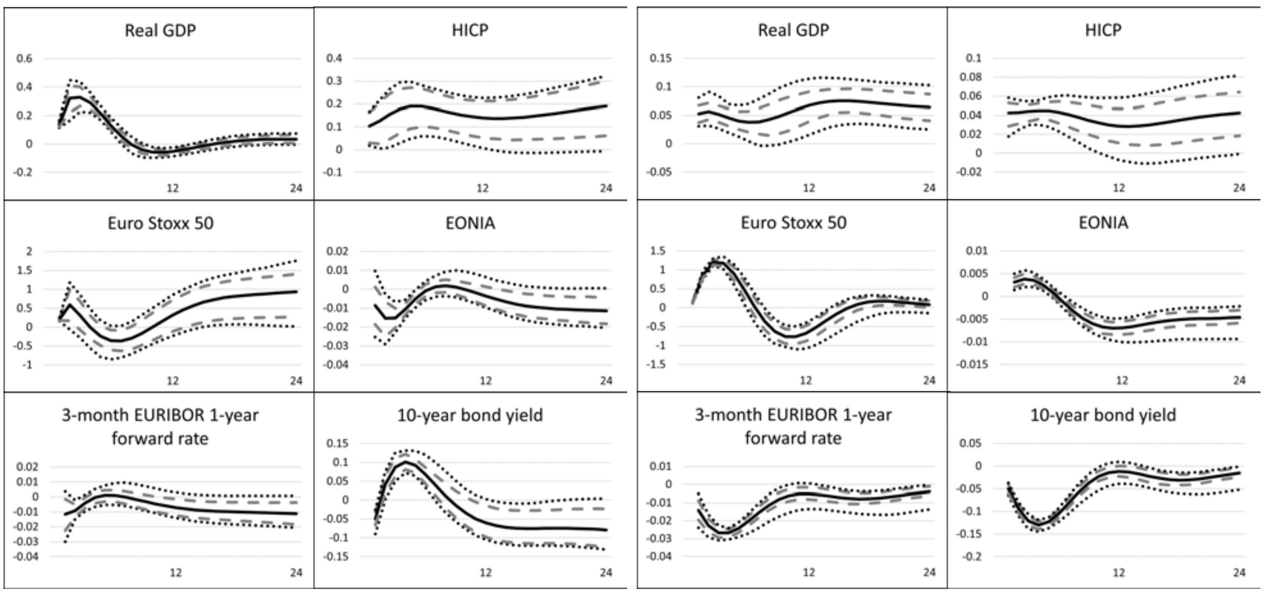


Note: Figures show impulse response functions from a ST-SVAR to the CMP shock, normalized to generate a 5 bps drop in the EONIA. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

However, the literature lacks evidence from the euro area as well as whether this finding also applies to non-standard monetary instruments, which have been specifically introduced to avert the de-anchoring of inflation expectations[9]. Therefore, we provide evidence on the interaction between the anchoring of inflation expectations and monetary policy in the euro area by using the SPF 2-years-ahead inflation expectations as the s_t[10], shown in Figure 13. The identified states of anchored (F(s) values close to 0)/elevated risk of de-anchored (F(s) values close to 1) inflation expectations are in line with the observed narrative in the euro area, suggesting a significant de-achoring before the announcement of the APP in January 2015 as well as during the Covid-19 pandemic and the Great Recession.

Figure 15: **Inflation expectations: QE shock**

(a) Elevated risk of de-anchored expectations (b) Anchored expectations



Note: Figures show impulse response functions from a ST-SVAR to the QE shock, normalized to generate a 5 bps drop in the 10-year bond yield. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

The results in Figure 14 confirm that the findings of Falck et al. (2021) hold also for the euro area as the conventional policy easing induces deflationary pressures when expectations are at risk of being de-anchored, suggesting the dominance of the signalling effects in firms' pricing decisions. Also, it is likely that this finding regarding the impairment of CMP, when inflation expectations are not firmly anchored, reflects the notion of ZLB since agents expect diminishing returns of monetary policy as the policy rate approaches zero.

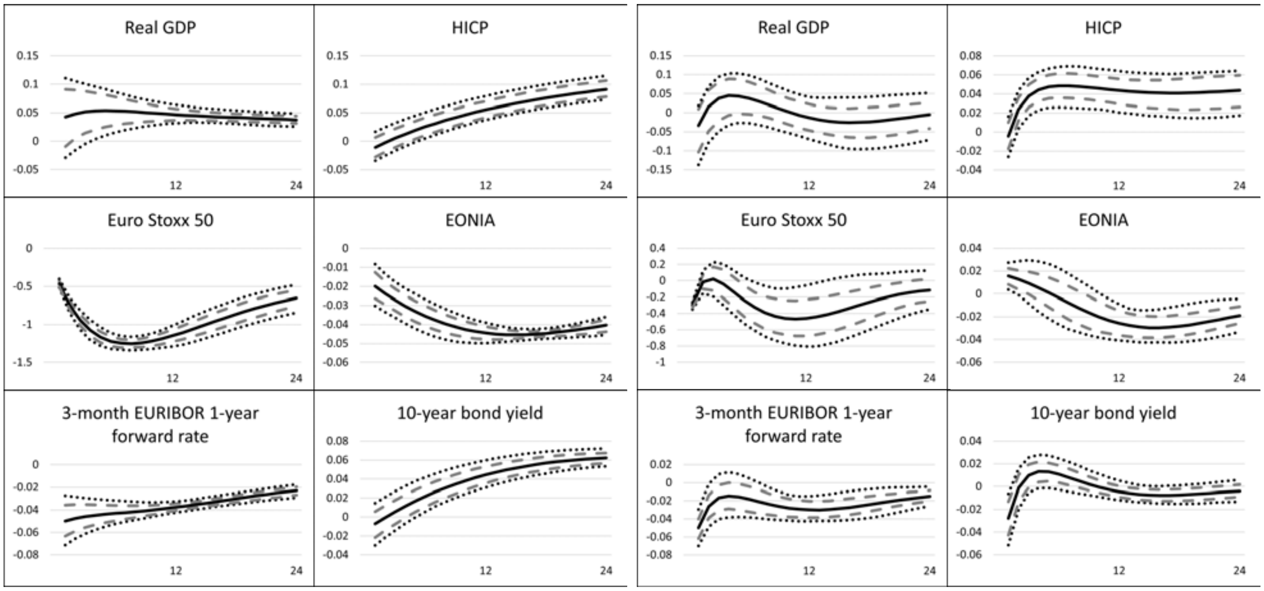
The introduction of non-standard measures, designed specifically to bypass the ZLB and provide

[9] Draghi (2019) points out the de-achoring of inflation expectations as the main motivation for launching the APP in 2015.

[10] We also employ the gap of SPF 2-years-ahead inflation expectations from the ECB inflation target as the switching variable. We assume the target of 1.9% throughout given that our sample ends in March 2021, i.e. before the announcement of symmetric 2% target in July 2021 as the outcome of the strategy review. The results remain qualitatively robust, see Figures A7-A11.

Figure 16: **Inflation expectations: FG shock**

(a) Elevated risk of de-anchored expectations (b) Anchored expectations



Note: Figures show impulse response functions from a ST-SVAR to the FG shock, normalized to generate a 5 bps drop in the 3-month EURIBOR 1-year forward rate. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

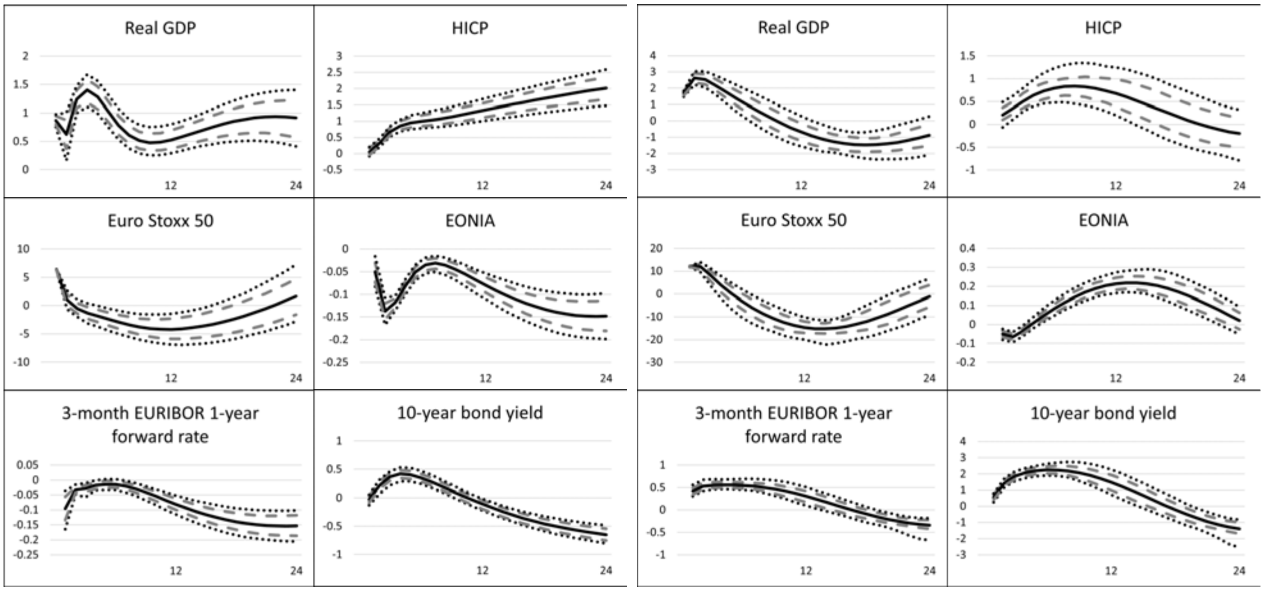
additional monetary accommodation to help lift the economy out of the low inflation state, appears to have played a major role in re-anchoring inflation expectations back towards the target. The findings in Figure 15 demonstrate that QE has been instrumental to restore credibility as it is substantially more powerful in situations when expectations are not firmly anchored, as evidenced by the impulse responses of real GDP and, more importantly, HICP in panel (a).

Similar conclusions emerge also when considering IRFs to the FG and NIRP shocks in Figures 16 and 17. As panels (a) in both Figures suggest, FG and NIRP produce markedly higher impact on inflation when expectations are at risk of being disconnected from the central banks' objective.

These results yield several conclusions. First, the ECB's strategy to employ a mix of UMP tools, instead of relying on single instrument, to stave off deflationary pressures and re-anchor inflation expectations is justified, especially given the self-reinforcing effects between the UMP tools as demonstrated in the previous subsection. Second, unconventional monetary policy instruments serve as complements to conventional policy rate setting as they are particularly powerful in circumstances when CMP loses its stabilization properties.

Figure 17: **Inflation expectations: NIRP shock**

(a) Elevated risk of de-anchored expectations (b) Anchored expectations



Note: Figures show impulse response functions from a ST-SVAR to the NIRP shock, normalized to generate a 5 bps drop in the EONIA. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

5 Conclusions

In this paper, we have investigated the ability of unconventional monetary policy instruments - quantitative easing, forward guidance and negative interest rates - to substitute conventional policy rate setting when it faces a binding ELB constraint and provided empirical evidence on the interplay between them as well their impact over different states of the economy. To pin down the effects of the ECB's monetary policy tools, we propose a novel approach in the literature which allows us to simultaneously identify the impact of both conventional and unconventional (NIRP, FG, QE) policy actions from high frequency surprises around the ECB Governing Council events by augmenting the high frequency identification with narrative sign restrictions. We then employ a smooth-transition structural vector autoregression to track the state-dependent transmission of monetary shocks to the economy.

Overall, our findings suggest that unconventional monetary policy measures can *substitute* the standard policy rate setting when it is subject to the ELB constraint but they cannot be considered as perfect substitutes since their effectiveness is highly dependent on the overall policy mix and the state of the economy. In particular, both NIRP and FG require an active QE programme to have the desired impact. Regarding the interaction between QE and NIRP, the excess liquidity generated by the central bank asset purchases in the money markets pushes the overnight rate towards the DFR, amplifying the effects of a sub-zero rate cut. While for FG, the signalling properties of QE - i.e. by embarking on large-scale asset purchases the central bank signals that policy rates will stay low for a prolonged period of time - considerably enhance the credibility of FG announcements. However, QE itself is subject to non-linearities as it is more potent in conditions when financial frictions are high, e.g. when financial intermediaries face funding constraints and when general financial uncertainty dominates in the markets.

At the same time, we argue that non-standard monetary policy tools can also be viewed as *complements* to conventional policy as they are particularly powerful in circumstances when CMP loses its stabilization properties, e.g. during market turbulence or when the risk of de-anchoring of inflation expectations is elevated.

To sum up, this paper contributes to the empirical literature on the interaction among unconventional monetary policy tools by exploring the ECB's deployment of QE, FG and NIRP in the past decade to bypass the ELB and stabilize the inflation trajectory towards the target. Our results illustrate that synergies between distinct instruments reinforce the impact of monetary response as opposed to a case had they been used as stand-alone tools. In addition, the findings on the state-dependency of different tools advocates for inclusion of non-standard measures in the standard monetary toolkit as they allow the central bank to stabilize the economy in circumstances when conventional tools are no fit for purpose.

References

Aastveit, K. A., G. Natvik, and S. Sola (2017). Economic uncertainty and the influence of monetary policy. *Journal of International Money and Finance 76*, 50–67.

Altavilla, C., M. Boucinha, and J.-L. Peydró (2018). Monetary policy and bank profitability in a low interest rate environment. *Economic Policy 33*(96), 531–586.

Altavilla, C., L. Brugnolini, R. S. Gürkaynak, R. Motto, and G. Ragusa (2019). Measuring euro area monetary policy. *Journal of Monetary Economics 108*, 162–179.

Altavilla, C., L. Burlon, M. Giannetti, and S. Holton (2021). Is there a zero lower bound? the effects of negative policy rates on banks and firms. *Journal of Financial Economics*.

Altavilla, C., G. Carboni, and R. Motto (2015). Asset purchase programmes and financial markets: Lessons from the euro area. Working Paper No. 1864, ECB.

Andrade, P., J. Breckenfelder, F. De Fiore, P. Karadi, and O. Tristani (2016). The ECB's asset purchase programme: an early assessment. Working Paper No. 1956, ECB.

Andrade, P. and F. Ferroni (2021). Delphic and odyssean monetary policy shocks: Evidence from the euro area. *Journal of Monetary Economics 117*, 816–832.

Antolin-Diaz, J. and J. F. Rubio-Ramirez (2018). Narrative sign restrictions for SVARs. *American Economic Review 108*(10), 2802–2829.

Auerbach, A. J. and Y. Gorodnichenko (2012). Measuring the Output Responses to Fiscal Policy. *American Economic Journal: Economic Policy 4*(2), 1–27.

Baker, S., N. Bloom, and S. Davis (2016). Measuring economic policy uncertainty. *The Quarterly Journal of Economics 131*(4), 1593–1636.

Barakchian, M. S. and C. Crowe (2013). Monetary policy matters: Evidence from new shocks data. *Journal of Monetary Economics 60*(8), 950–966.

Bauer, M. D. and G. D. Rudebusch (2014). The signaling channel for Federal Reserve bond purchases. *International Journal of Central Banking 10*(3), 233–289.

Baumann, U., M. Darracq Pariès, T. Westermann, M. Riggi, E. Bobeica, A. Meyler, B. Böninghausen, F. Fritzer, R. Trezzi, and J. a. Jonckheere (2021). Inflation expectations and their role in Eurosystem forecasting. Occasional Paper No. 264, ECB.

Bernanke, B., M. Gertler, and S. Gilchrist (1996). The Financial Accelerator and the Flight to Quality. *The Review of Economics and Statistics 78*(1), 1–15.

Bernanke, B. S. (1983). Irreversibility, Uncertainty, and Cyclical Investment. *The Quarterly Journal of Economics 98*(1), 85–106.

Bhattarai, S., G. B. Eggertsson, and B. Gafarov (2015). Time consistency and the duration of government debt: A signalling theory of quantitative easing. Working Papers No. 21336, NBER.

Blattner, T. S. and M. A. S. Joyce (2016). Net debt supply shocks in the euro area and the implications for QE. Working Paper No.1957, ECB.

Bonciani, D. and J. Oh (2021). Optimal monetary policy mix at the zero lower bound. Working Papers 945, Bank of England.

Caggiano, G., E. Castelnuovo, and G. Nodari (2017). Uncertainty and Monetary Policy in Good and Bad Times. CESifo Working Paper Series 6630, CESifo.

Carlstrom, C. T., T. S. Fuerst, and M. Paustian (2017). Targeting long rates in a model with segmented markets. *American Economic Journal: Macroeconomics 9*(1), 205–242.

Chernozhukov, V. and H. Hong (2003). An MCMC approach to classical estimation. *Journal of Econometrics 115*(2), 293–346.

Coenen, G., M. Ehrmann, G. Gaballo, P. Hoffmann, A. Nakov, S. Nardelli, E. Persson, and G. Strasser (2017). Communication of monetary policy in unconventional times. Working Paper No. 2080, ECB.

De Santis, R. A. (2016). Impact of the asset purchase programme on euro area government bond yields using market news. Working Paper No. 1939, ECB.

Dedola, L., G. Georgiadis, J. Gräb, and A. Mehl (2021). Does a big bazooka matter? Quantitative easing policies and exchange rates. *Journal of Monetary Economics 117*, 489–506.

Del Negro, M., M. Giannoni, and C. Patterson (2012). The forward guidance puzzle. Staff Reports 574, Federal Reserve Bank of New York.

Demiralp, S., J. Eisenschmidt, and T. Vlassopoulos (2021). Negative interest rates, excess liquidity and retail deposits: Banks' reaction to unconventional monetary policy in the euro area. *European Economic Review 136*.

Dixit, A. K. and R. S. Pindyck (1994). *Investment under Uncertainty*. Princeton University Press.

Draghi, M. (2019). Debate about the annual report. Speech at plenary debate of the European Parliament about the ECB's annual report 2017. Available at: https://www.bis.org/review/r190116b.pdf.

Eser, F., W. Lemke, K. Nyholm, S. Radde, and A. L. Vladu (2019). Tracing the impact of the ECB's asset purchase programme on the yield curve. Working Paper No. 2293, ECB.

Falck, E., M. Hoffmann, and P. Hürtgen (2021). Disagreement about inflation expectations and monetary policy transmission. *Journal of Monetary Economics 118*, 15–31.

Gambetti, L. and A. Musso (2020). The effects of the ECB's expanded asset purchase programme. *European Economic Review 130*.

Garcia Pascual, A. I. and T. Wieladek (2016). The European Central Bank's QE: A new hope. Discussion Paper No. DP11309, CEPR.

Gertler, M. and P. Karadi (2011). A model of unconventional monetary policy. *Journal of Monetary Economics 58*(1), 17–34.

Gertler, M. and P. Karadi (2013). QE 1 vs. 2 vs. 3. . . : A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool. *International Journal of Central Banking 9*(1), 5–53.

Gertler, M. and P. Karadi (2015). Monetary policy surprises, credit costs, and economic activity. *American Economic Journal: Macroeconomics 7*(1), 44–76.

Giannone, D., M. Lenza, and G. E. Primiceri (2015). Prior Selection for Vector Autoregressions. *The Review of Economics and Statistics 97*(2), 436–451.

Gilchrist, S. and B. Mojon (2018). Credit risk in the euro area. *Economic Journal 128*(608), 118–158.

Granger, C. W. J. and T. Terasvirta (1993). *Modelling Non-Linear Economic Relationships*. Oxford University Press.

Gürkaynak, R. S., B. Sack, and E. Swanson (2005). Do actions speak louder than words? The response of asset prices to monetary policy actions and statements. *International Journal of Central Banking 1*(1).

Hartmann, P. and F. Smets (2018). The first twenty years of the European Central Bank: Monetary policy. Working Paper No. 2219, ECB.

Hauzenberger, N., M. Pfarrhofer, and A. Stelzer (2020). On the effectiveness of the European Central Bank's conventional and unconventional policies under uncertainty. Mimeo. Available at: https://arxiv.org/pdf/2011.14424.pdf.

Jarociński, M. and P. Karadi (2020). Monetary policy surprises – the role of information shocks. *American Economic Journal: Macroeconomics 12*(2), 1–43.

Karadi, P. and A. Nakov (2021). Effectiveness and addictiveness of quantitative easing. *Journal of Monetary Economics 117*, 1096–1117.

Klein, M. (2020, March). Implications of negative interest rates for the net interest margin and lending of euro area banks. Working Papers No. 848, Bank for International Settlements.

Koijen, R. S. J., F. Koulischer, B. Nguyen, and M. Yogo (2016). Quantitative easing in the euro area: The dynamics of risk exposures and the impact on asset prices. Document de Travail No. 601, Banque de France.

Kremer, M., M. Lo Duca, and D. Holló (2012). CISS - a composite indicator of systemic stress in the financial system. Working Paper No. 1426, ECB.

Lane, P. R. (2019). The yield curve and monetary policy. Speech at the Centre for Finance and the Department of Economics at University College London. Available at: https://www.ecb.europa.eu/press/key/date/2019/html/ecb.sp191125~b0ecc8e6f0.en.html.

Lenza, M. and G. E. Primiceri (2020). How to estimate a VAR after March 2020. Working Paper No. 2461, ECB.

Mertens, K. and M. O. Ravn (2013). The dynamic effects of personal and corporate income tax changes in the United States. *American Economic Review 103*(4), 1212–1247.

Nakamura, E. and J. Steinsson (2018). High-frequency identification of monetary non-neutrality: The information effect. *The Quarterly Journal of Economics 133*(3), 1283–1330.

Plagborg-Møller, M. and C. K. Wolf (2021). Local projections and VARs estimate the same impulse responses. *Econometrica 89*(2), 955–980.

Ramey, V. A. (2011). Identifying government spending shocks: It's all in the timing. *The Quarterly Journal of Economics 126*(1), 1–50.

Romer, C. D. and D. H. Romer (2004). A new measure of monetary shocks: Derivation and implications. *American Economic Review 94*(4), 1055–1084.

Rostagno, M., C. Altavilla, G. Carboni, W. Lemke, R. Motto, S. G. A., and J. Yiangou (2019). A tale of two decades: the ECB's monetary policy at 20. Working Paper No. 2346, ECB.

Rostagno, M., C. Altavilla, G. Carboni, W. Lemke, R. Motto, and A. Saint Guilhem (2021). Combining negative rates, forward guidance and asset purchases: identification and impacts of the ECB's unconventional policies. Working Paper No. 2564, ECB.

Ryan, E. and K. Whelan (2021). Quantitative easing and the hot potato effect: Evidence from euro area banks. *Journal of International Money and Finance 115*.

Sims, E. and E. Wu (2021). Evaluating central banks' tool kit: Past, present, and future. *Journal of Monetary Economics 118*, 135–160.

Stock, J. H. and M. W. Watson (2012). Disentangling the channels of the 2007-09 recession. *Brookings Papers on Economic Activity 43*(1), 81–156.

Swanson, E. T. (2021). Measuring the effects of Federal Reserve forward guidance and asset purchases on financial markets. *Journal of Monetary Economics 118*, 32–53.

Zlobins, A. (2020). ZLB and Beyond: Real and Financial Effects of Low and Negative Interest

Rates in the Euro Area. Working Paper No. 2020/06, Latvijas Banka.

Zlobins, A. (2021a). Macroeconomic effects of the ECB's forward guidance. *Empirical Economics 61*(5), 2587–2611.

Zlobins, A. (2021b). On the time-varying effects of the ECB's asset purchases. Working Paper No. 2021/02, Latvijas Banka.

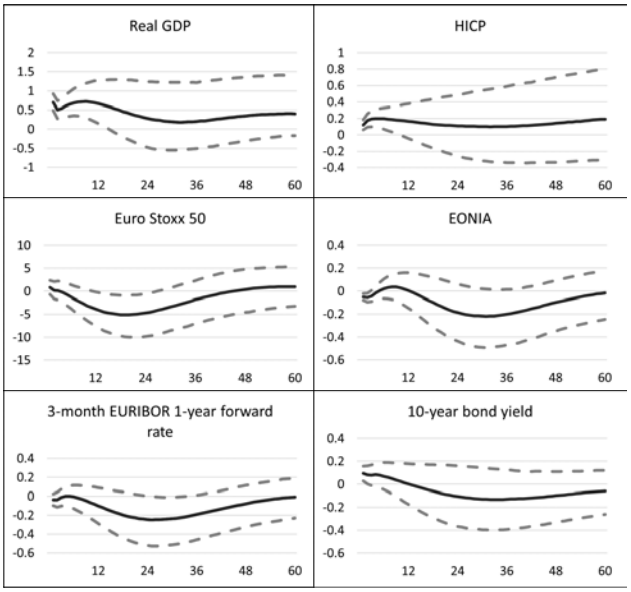
Appendix

Table A1: **Dataset description and transformations**

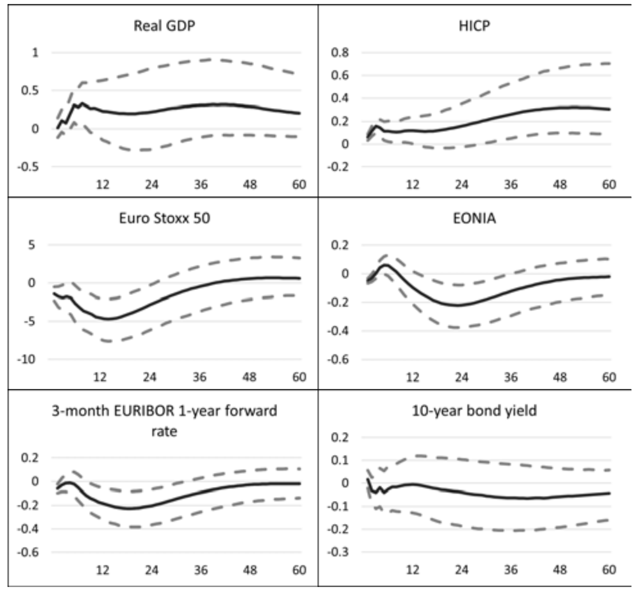
Block	Variable	Description	Data source
Baseline model	Real GDP	Real GDP index. 2015=100. Monthly series are obtained by performing the Litterman temporal disaggregation procedure using the industrial production index as indicator series.	Author's calculations based on the Eurostat data
	HICP	All-items HICP. 2015=100.	ECB
	Euro Stoxx 50	Dow Jones Euro Stoxx 50 price index.	ECB
	EONIA	Money market interest rate.	Eurostat
	1-year forward rate	3-month EURIBOR 1-year forward rate.	Bloomberg
	10-year bond yields	10-year government benchmark bond yield.	ECB
Switching variables	ECB asset holdings	Securities of euro area residents denominated in euro held by the Eurosystem scaled by 2015 nominal GDP.	Author's calculations based on the ECB and Eurostat data
	Euro area bank bond spread	Spread of euro area bank bond yields with respect to German Bund.	Gilchrist and Mojon (2018)
	CISS	Composite Indicator of Systemic Stress.	ECB
	Inflation expectations	Survey of Professional Forecasters 2-years-ahead inflation expectations.	ECB

Figure A2: **Linear IRFs to the obtained shock series**

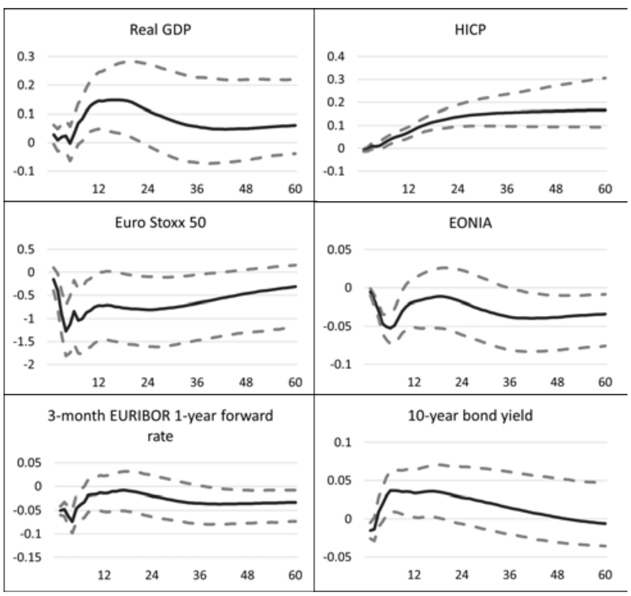
(a) CMP shock



(b) Target factor of Altavilla et al. (2019)



(c) FG shock



(d) FG factor of Altavilla et al. (2019)

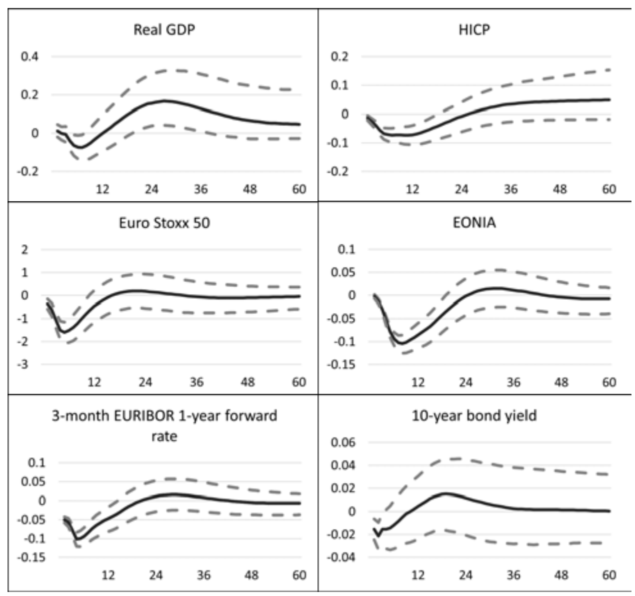
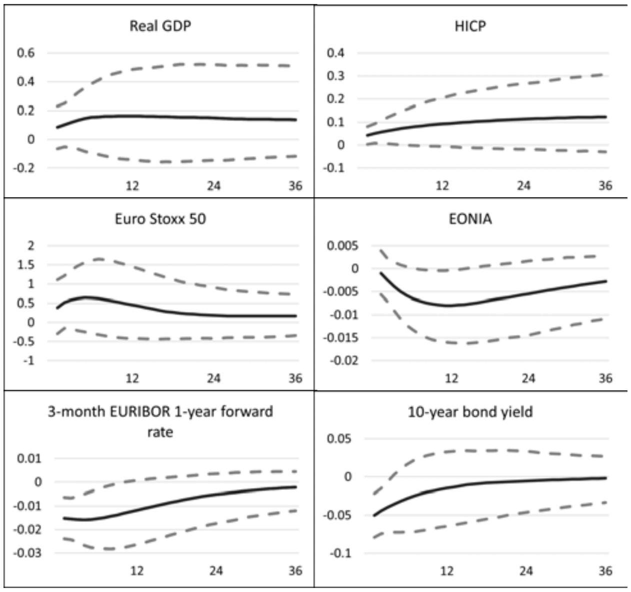
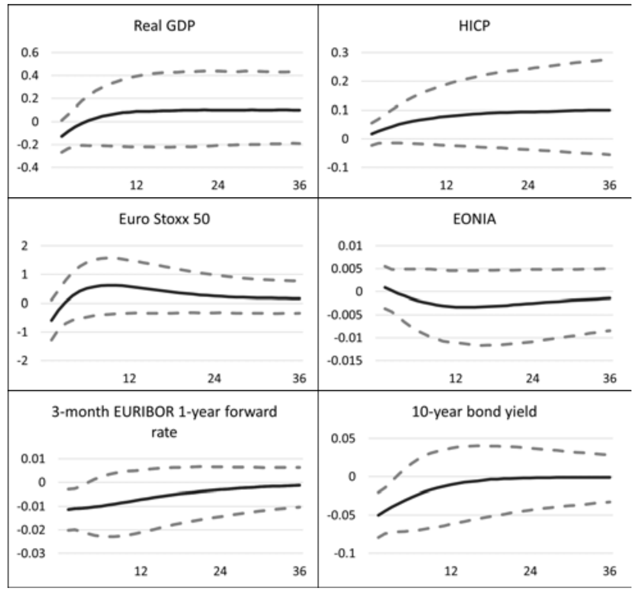


Figure A2: **Linear IRFs to the obtained shock series (cont.)**

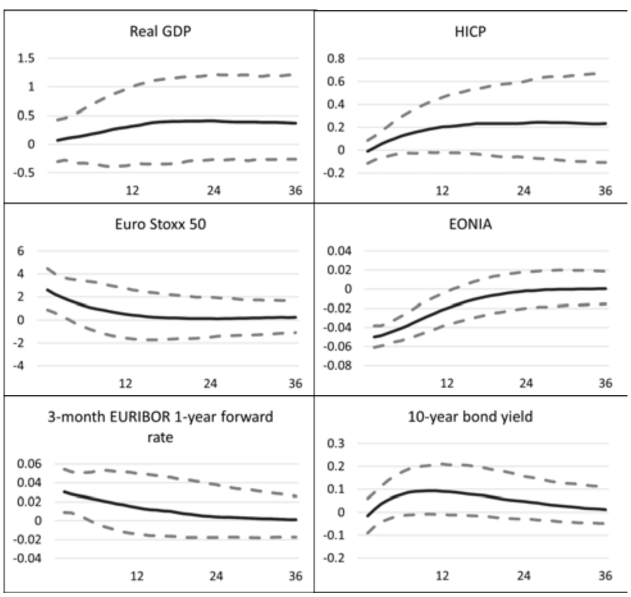
(e) QE shock



(f) QE factor of Altavilla et al. (2019)



(g) NIRP shock

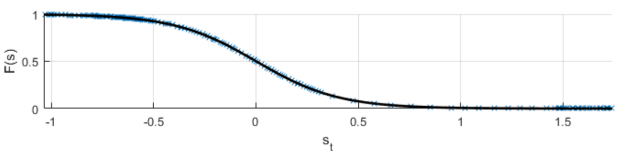


Note: Figures show impulse response functions from a linear SVAR to the policy shocks, in all cases normalized to generate a 5 bps drop in the policy proxy (EONIA for CMP and NIRP shocks, 3-month EURIBOR 1-year forward rate for FG disturbance and 10-year bond yield for QE innovation. The solid line shows the median response, while the dashed region denotes the 68% credible sets.

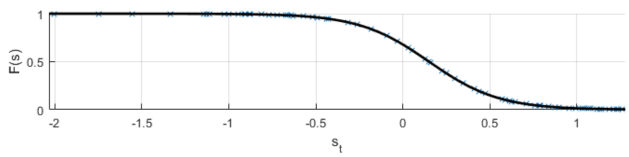
Figure A3: **Transition functions**

ECB asset holdings as the switching variable s_t

(a) January 2002-March 2021

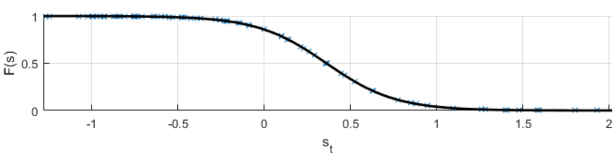


(b) January 2014-March 2021



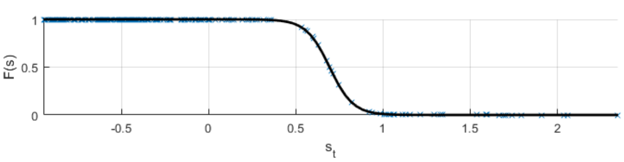
Euro area bank bond spread as the switching variable s_t

(c) January 2014-March 2021

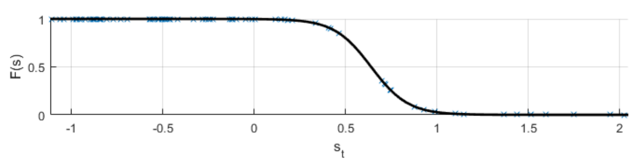


CISS as the switching variable s_t

(d) January 2002-March 2021

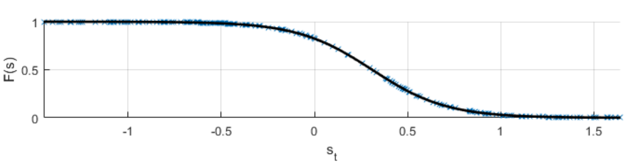


(e) January 2014-March 2021

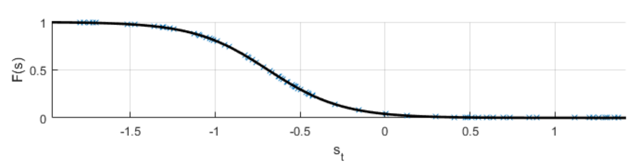


SPF 2-years-ahead inflation expectations as the switching variable s_t

(f) January 2002-March 2021

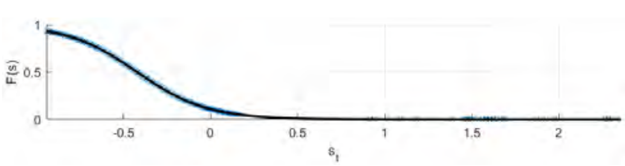


(g) January 2014-March 2021

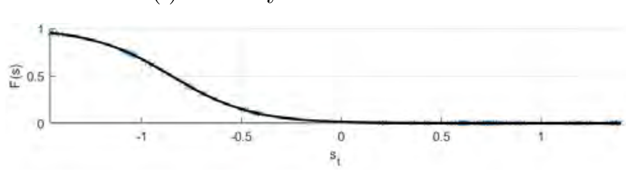


Net purchases under the APP and the PEPP as the switching variable s_t

(h) January 2002-March 2021

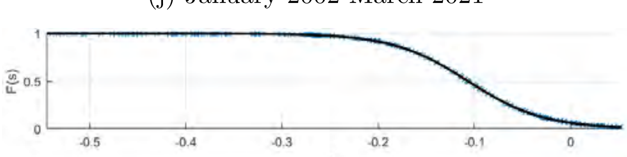


(i) January 2014-March 2021



Gap of SPF 2-years-ahead inflation expectations from the ECB target as the switching variable s_t

(j) January 2002-March 2021



(k) January 2014-March 2021

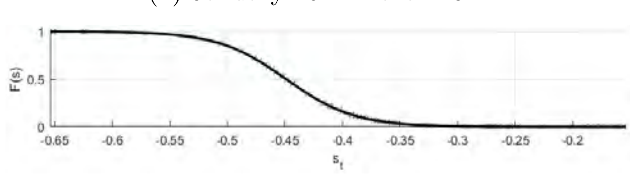


Figure A4: **Net purchases under the APP and the PEPP as the switching variable s_t**

(a) January 2002-March 2021 (b) January 2014-March 2021

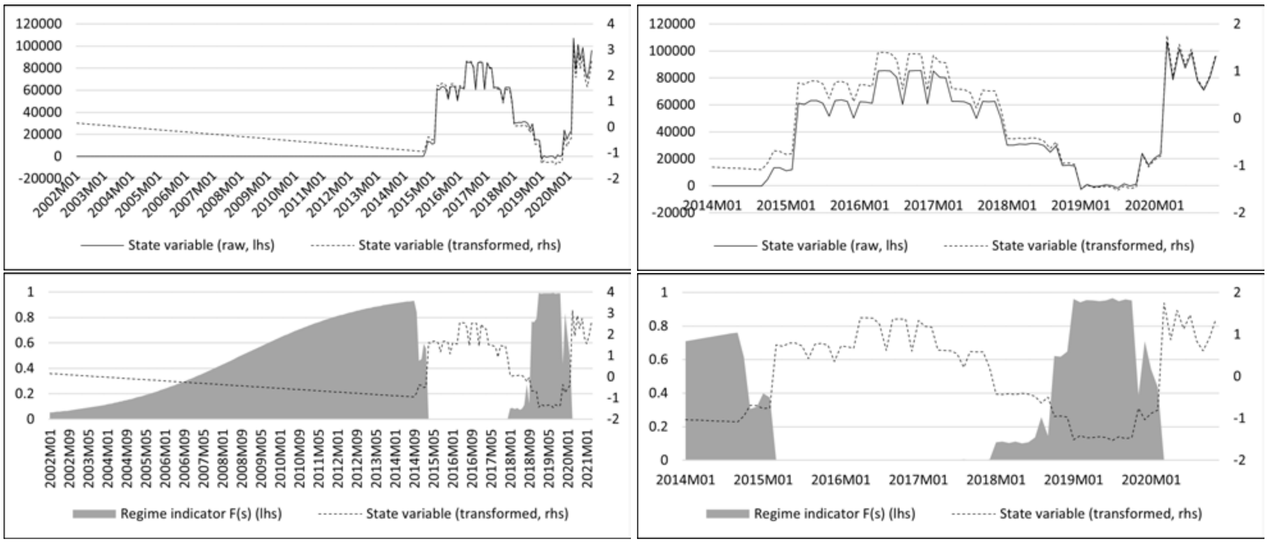
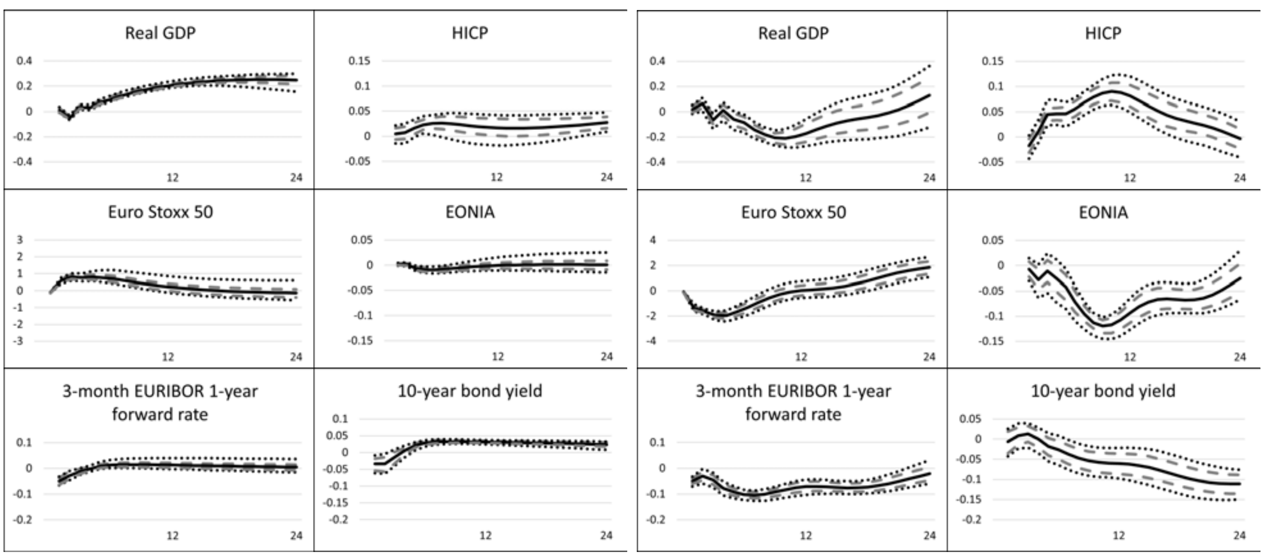


Figure A5: **Interaction between QE and FG(with net purchases as the s_t)**

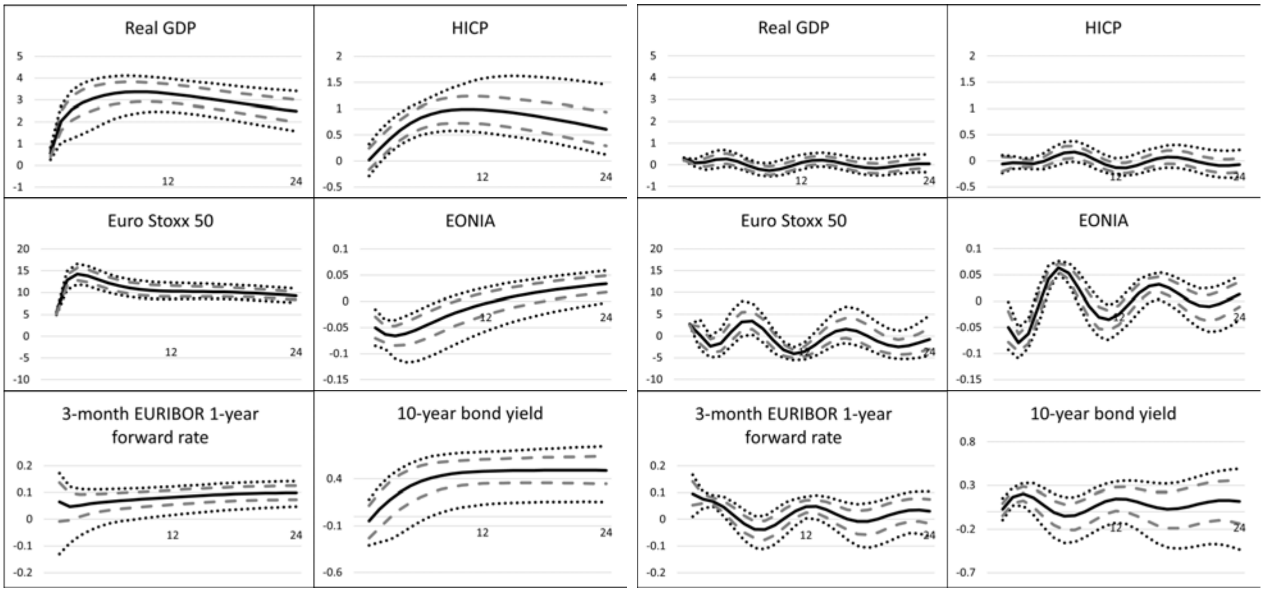
(a) QE active (b) QE inactive



Note: Figures show impulse response functions from a ST-SVAR to the FG shock, normalized to generate a 5 bps drop in the 3-month EURIBOR 1-year forward rate. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Figure A6: **Interaction between QE and NIRP(with net purchases as the s_t)**

(a) QE active (b) QE inactive



Note: Figures show impulse response functions from a ST-SVAR to the NIRP shock, normalized to generate a 5 bps drop in the EONIA. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Figure A7: **Gap of SPF 2-years-ahead inflation expectations from the ECB target as the switching variable s_t**

(a) January 2002-March 2021 (b) January 2014-March 2021

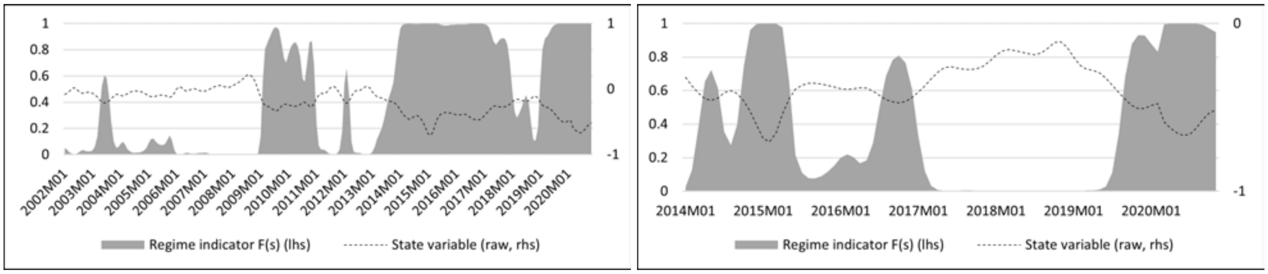
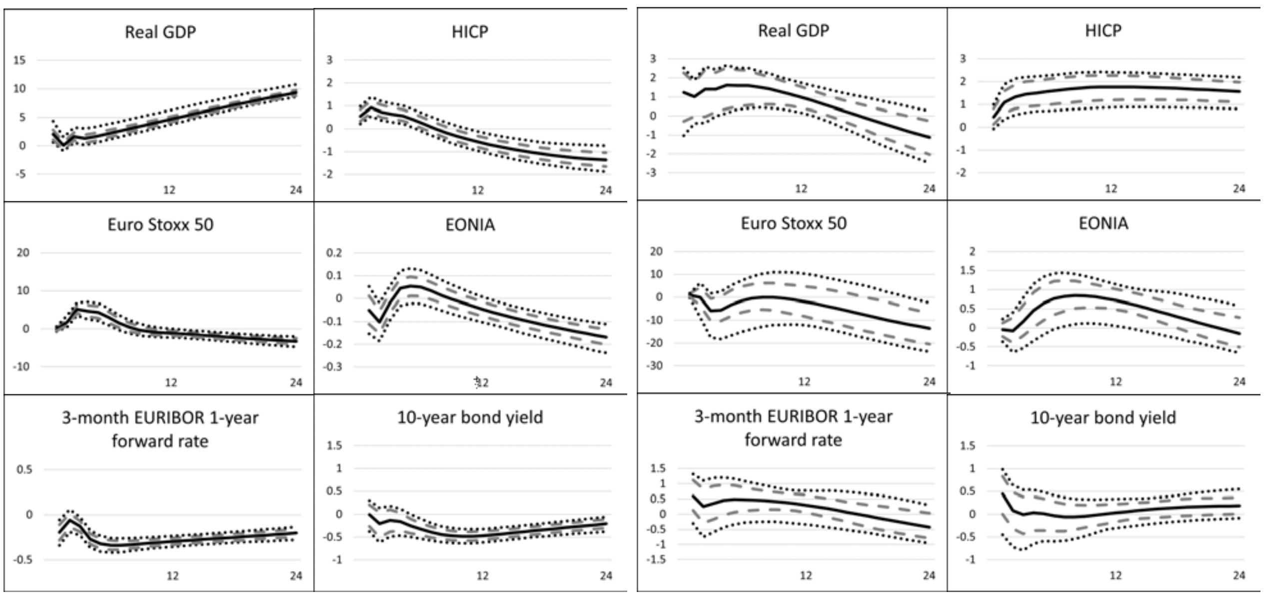


Figure A8: **Inflation expectations: CMP shock (with gap from the ECB target as the switching variable s_t)**

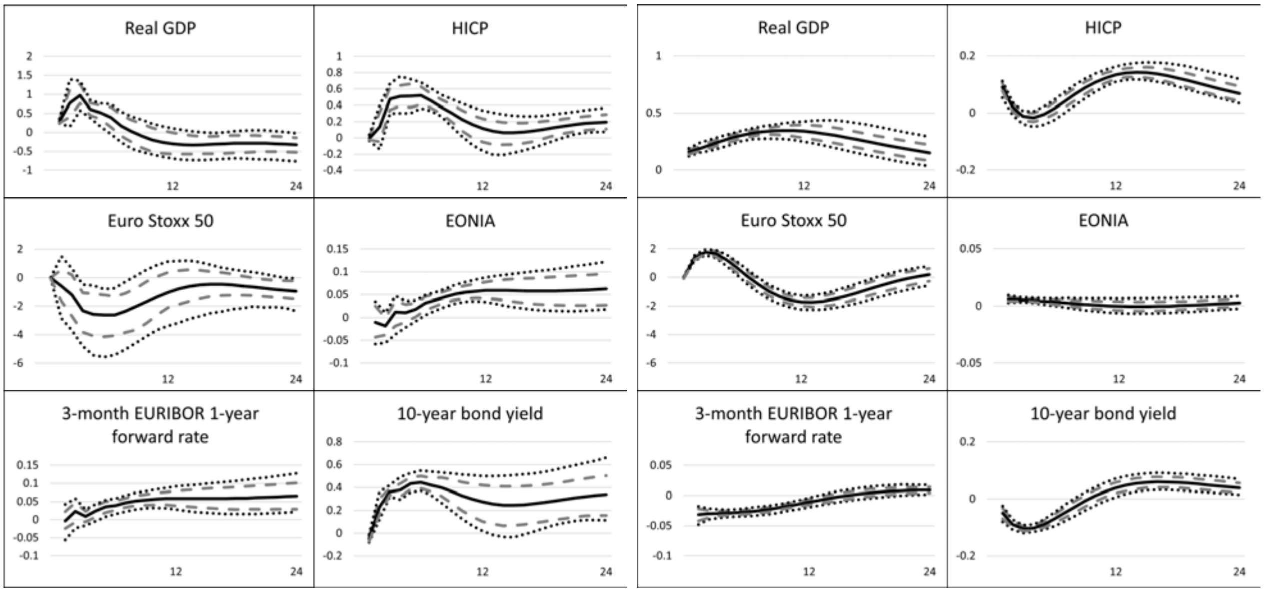
(a) Elevated risk of de-anchored expectations (b) Anchored expectations



Note: Figures show impulse response functions from a ST-SVAR to the CMP shock, normalized to generate a 5 bps drop in the EONIA. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Figure A9: **Inflation expectations: QE shock (with gap from the ECB target as the switching variable s_t)**

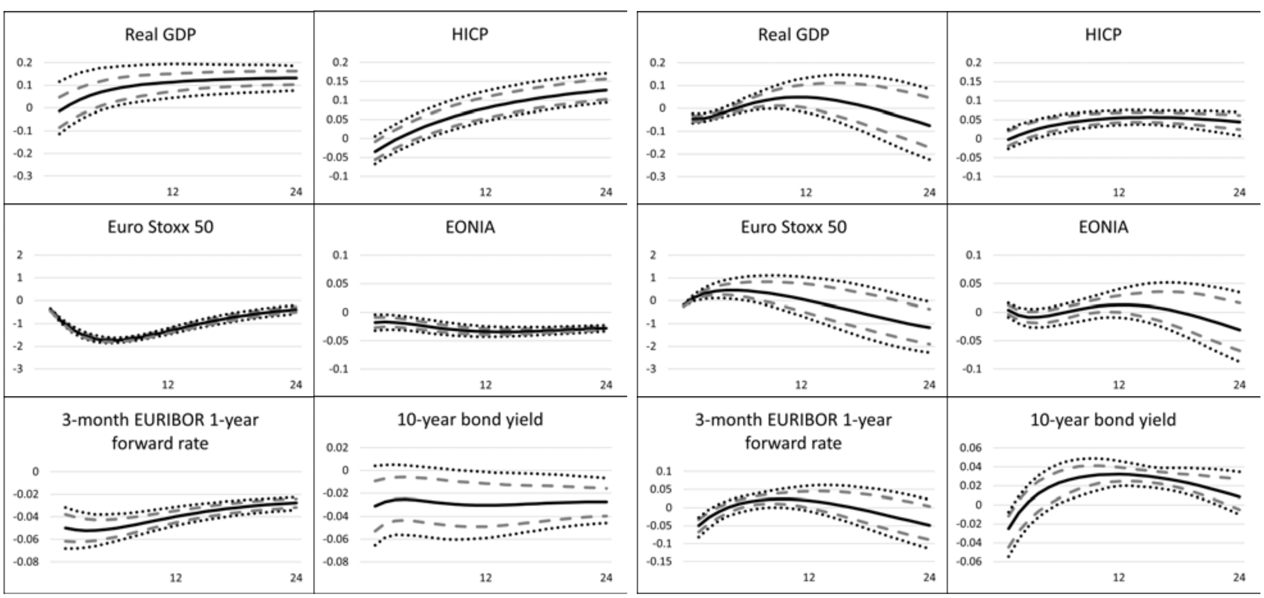
(a) Elevated risk of de-anchored expectations (b) Anchored expectations



Note: Figures show impulse response functions from a ST-SVAR to the QE shock, normalized to generate a 5 bps drop in the 10-year bond yield. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Figure A10: **Inflation expectations: FG shock (with gap from the ECB target as the switching variable s_t)**

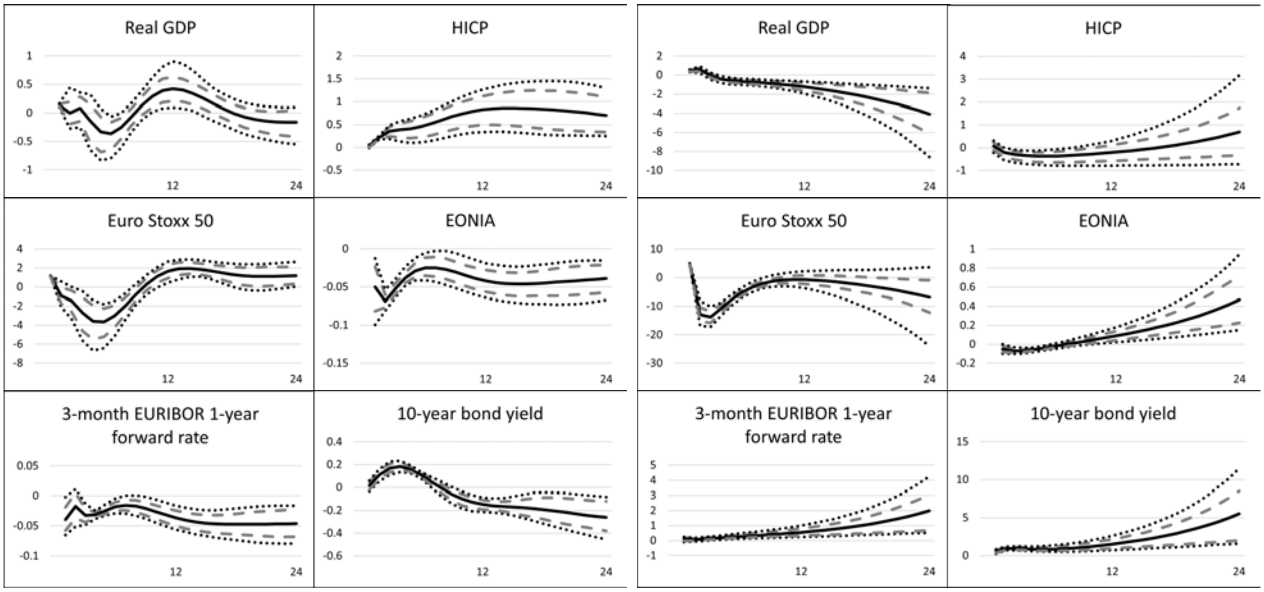
(a) Elevated risk of de-anchored expectations (b) Anchored expectations



Note: Figures show impulse response functions from a ST-SVAR to the FG shock, normalized to generate a 5 bps drop in the 3-month EURIBOR 1-year forward rate. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.

Figure A11: **Inflation expectations: NIRP shock (with gap from the ECB target as the switching variable s_t)**

(a) Elevated risk of de-anchored expectations (b) Anchored expectations



Note: Figures show impulse response functions from a ST-SVAR to the NIRP shock, normalized to generate a 5 bps drop in the EONIA. The solid line shows the median response, while the dashed and dotted regions denote the 68% and 90% credible sets.