ONLINE APPENDIX

Measuring Monetary Policy in the Euro Area Using SVARs with Residual Restrictions

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Contents

A. ECB Press Releases

A representative example of a press release by the ECB Governing Council, keeping interest rates unchanged, reads as follows:

"At today's meeting the Governing Council of the ECB decided that the minimum bid rate on the main refinancing operations and the interest rates on the marginal lending facility and the deposit facility will remain unchanged at 3.25%, 4.25% and 2.25% respectively.

The President of the ECB will comment on the considerations underlying these decisions at a press conference starting at 2.30 p.m. today." (ECB Governing Council, 2002)

A representative example of a press release announcing interest rate changes reads as follows:

"At today's meeting the Governing Council of the ECB took the following monetary policy decisions:

1. *The interest rate on the main refinancing operations of the Eurosystem will be decreased by 25 basis points to 0.75%, starting from the operation to be settled on 11 July 2012.*
2. *The interest rate on the marginal lending facility will be decreased by 25 basis points to 1.50%, with effect from 11 July 2012.*
3. *The interest rate on the deposit facility will be decreased by 25 basis points to 0.00%, with effect from 11 July 2012.*

The President of the ECB will comment on the considerations underlying these decisions at a press conference starting at 2.30 p.m. CET today." (ECB Governing Council, 2012)

B. Daily EONIA

Figure B shows the daily development of *EONIA* in the four months of the largest interest rate surprises, which are used to identify the effects of monetary policy shocks in the baseline model. These months include two restrictive shocks (November 2008, October 2011) and two expansive shocks (October 2008, November 2011).

Notice first that the upward spikes, which can be observed in each month, coincide with the end of ECB reserve maintenance periods. Banks are required to maintain a certain amount of reserves with the ECB on average over these periods. Those which conceivably fall short of these requirements compete for central bank money at the end of the period, driving *EONIA* up. This technical effect is reversed on the following day, when the new period starts. In the four months at hand, the reserve maintenance periods lasted until October 7, 2008, November 11, 2008,

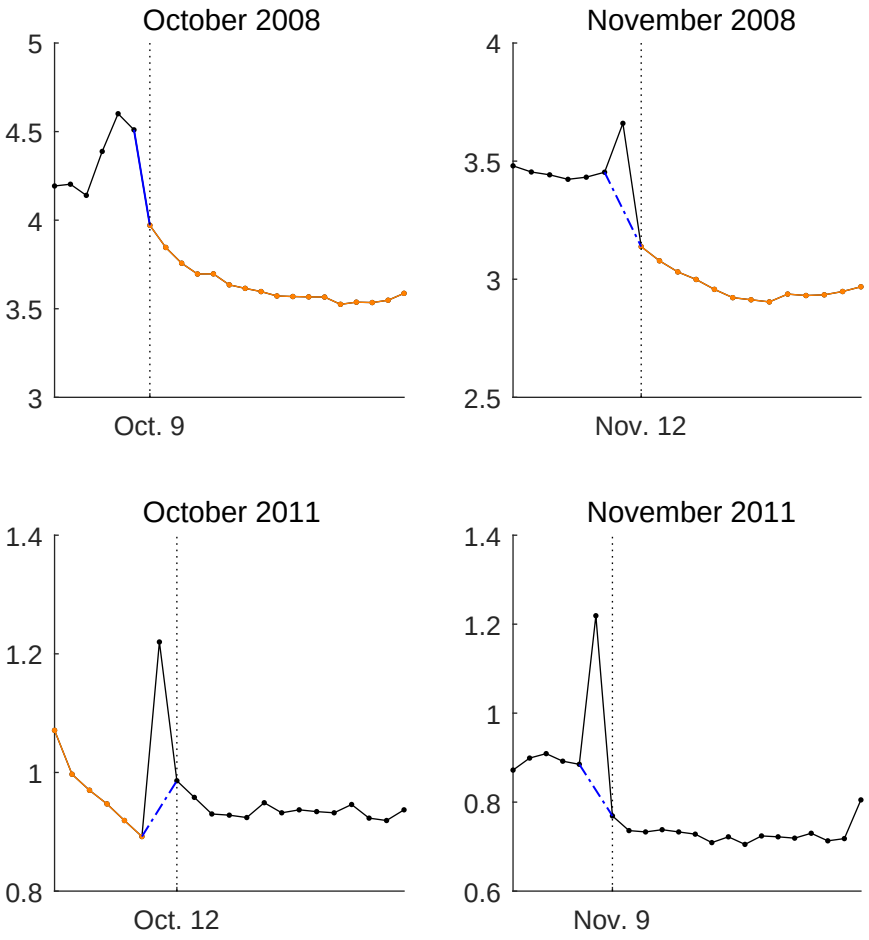

FIGURE B. DAILY EONIA

Note: Vertical dotted lines mark days on which new ECB interest rates came into force. Blue lines illustrate the effects of ECB interest rate changes. Orange line segments mark periods where *EONIA* was trending downwards for reasons unrelated to ECB interest rate decisions.

October 11, 2011, and November 8, 2011, respectively, which exactly matches the dates of the spikes.[1]

Apart from these technical effects, *EONIA* is of course affected by ECB decisions, specifically at the time the new policy rates come into effect. In all four months under consideration, these dates coincide with the start of a new maintenance period, except for October 2008, when the new interest rates came into effect a day later. Assessing the impact of the new ECB rates on *EONIA* therefore requires a correction for the technical reversal that has occurred contemporaneously.

Hence, the effect of new ECB interest rates on *EONIA* is approximately equal to the difference between the change of *EONIA* on the first day of a new maintenance period and its increase on the last day of the previous period. This effect is illustrated

[1]See `https://www.ecb.europa.eu/press/calendars/reserve`.

in Figure B by the blue, dashed-dotted lines. In October 2008, where the reversal had already taken place before the new policy rates came into effect, the decline of *EONIA* from October 8, 2008 to October 9, 2008 is considered as the policy effect.

As a market-determined rate, *EONIA* also moves in the absence of monetary policy changes, which is illustrated in Figure B by the orange line segments. For most of the time in October and November 2008, *EONIA* was on a downward trend. The same holds true for the first week of October 2011. Merely in November 2011, *EONIA* changed only the day the new ECB interest rates came into effect (November 9, 2011).[2] This observation, together with the fact that there was a large monetary policy surprise in that month, motivates our magnitude restriction, which states that at least half of the unexplained movement of *EONIA* was due to the monetary policy shock.

C. Further Interest Rate Surprises

In this appendix, we provide narrative accounts on eleven interest rate surprises that are next in size to the four events used to identify the SVAR (see Section III.D). We then extend our baseline identification strategy by additional sign restrictions on the structural residuals at the corresponding dates.

C.1 Narrative Analysis

November 2002 (+). The day before the ECB Governing Council meeting on November 7, 2002, the Fed had lowered interest rates by 50 basis points, thereby raising expectations on the ECB, given the weakening of the world economy. The ECB, however, left interest rates unchanged. *"Alan cuts, Wim refuses to follow,"* commented The Economist (2002a) in an allusion to the then Fed chairman, Alan Greenspan, and the ECB's president, Wim Duisenberg, who declared at the press conference that there was an extensive discussion for and against a rate cut (ECB, 2002). The Economist (2002a) commented that *"the ECB's stance is hard to understand. Partly it reflects the ECB's single-minded focus on inflation,"* referring to the still elevated level of consumer price inflation.

However, the interest rate decision presumably had a political economy background, too. It can be interpreted as an attempt by the still young central bank to demonstrate and thus consolidate its independence. In the run-up to the meeting, politicians from Germany, France and other countries urged the bank to cut rates in order to support the economy. With respect to these pleas, Ernst Welteke, president of the German Bundesbank, and member of the ECB Governing Council, said some days before the meeting: *"In such a situation, it is more difficult for us to reduce*

[2]There were also two technical spikes; one due to the expiration of the maintenance period on November 8 and a smaller spike at the end of the month, which was due to banks' money operations to balance their books. End-of-month spikes also occur regularly and are reversed the following day.

interest rates. The people and financial markets would get the impression that we are giving in to political pressure" (Der Spiegel, 2002, translation by the authors).

While a substantial share of financial market participants did obviously not expect interest rates to remain unchanged, this does not mean that nobody expected it. In an article posted in the morning of November 7, just before the meeting of the Governing Council, the Frankfurter Allgemeine Zeitung (2002) noted that *"analysts had recently pointed out that the ECB would probably not be forced to take action and therefore the key rates would probably not change despite the Fed's decision. According to the experts, the desire expressed by politicians for lower interest rates and the recent discussion about the EU Stability Pact will delay a rate cut in the euro area at least until December"* (translation by the authors). This was exactly what happened. Indeed, our baseline model estimates do not suggest that this interest rate decision was a significant policy rule deviation (see Section III.D).

December 2002 (–). After the cautious decision in November, a rate cut seemed urgently needed. *"As the ECB prepared to cut euro-area interest rates on December 5th, the first change in 13 months, the only question in bank watchers' minds, after so much official semaphoring, was the size of the cut,"* i.e., 25 or 50 basis points, according to The Economist (2002b). The newspaper also conjectured that *"boldness has not been one of the characteristics of the European Central Bank. So few people expect the bank to throw caution to the wind and announce a cut of half a percentage point in European interest rates"* (The Economist, 2002c).

This seemed all the more likely since *"central bankers have proved resistant to outside pressure before"* (The Economist, 2002c), alluding to the ECB's reluctance to cut interest rates the month before. Furthermore, inflation was still above target, something that was repeatedly pointed out by the chief economist of the ECB, Otmar Issing (Handelsblatt, 2002). The ECB, however, relented in the face of slowing growth and opted for a significant rate cut, i.e., a reduction of policy rates by 50 basis points. Financial markets might well have perceived this decision as an indication of a worsening economy, i.e., a negative information shock. This interpretation is supported by the estimates of our baseline model, which do not point to an expansive monetary policy shock at this date (see Section III.D).

March 2003 (+). In a speech at a G7 summit of finance ministers and central bank governors in Paris two weeks before the ECB Governing Council meeting on March 6, 2003, president Duisenberg said that uncertainties had increased lately and that the perspective for an economic recovery was no longer supported by the most recent data available to the bank (The Guardian, 2003). Importantly, *"this weaker outlook, as we see it, should contribute to lower inflationary pressure. And as you know, price stability is our aim."*

Many market participants interpreted this assessment, together with similar statements of other members of the Governing Council, as evidence for a substantial rate cut, given that policy rates had been unchanged for two consecutive months. *"Why so small?,"* The Economist (2003) and, according to the newspaper, many economists asked after the ECB announced its decision to cut interest rates by only

25 basis points. *"The European Central Bank (...) thus disappointed the stock markets in particular, which had expected a 0.5-point cut after various hints in recent weeks"* (Neue Zürcher Zeitung, 2003a, translation by the authors).

June 2003 (–). At that time, a substantial interest rate cut was considered necessary by many observers and it was indeed implemented. *"When the ECB cut interest rates by half a percentage point to 2% on Thursday, it did not come as a surprise to the markets. The cut had been predicted by economists for weeks and called for by the financial community, the International Monetary Fund and government officials,"* the Neue Zürcher Zeitung (2003b) noted. The Handelsblatt (2003) confirmed that *"the sharp cut in the key interest rate by the ECB to a historic low of 2.0 percent came as no surprise to anyone. Experts, financial markets and politicians had been calling loudly for monetary easing at this level"* (both translations by the authors).

However, the strong reaction of the financial markets suggests that a lot of skepticism about the ECB's willingness to implement something that was considered a broad consensus had built up. *"Even though most forecasters had agreed that a 50 basis point cut was the best outcome, the ECB's record of extreme caution had led many to fear a different outcome,"* the British Broadcasting Corporation (2003) noted. *"But in the event, the smoke signals emanating from Frankfurt turned out to be accurate."* So it seems that financial markets were surprised by a policy move that a broad public had demanded.

Mid-2003 to mid-2008. The five years preceding the global financial crisis, from mid-2003 to mid-2008, were a period of almost perfect foresight by financial markets, no significant surprise occurred. Each of the nine interest rate hikes, one in late 2005, five in 2006, two in 2007, and another one in 2008, each of them amounting to 25 basis points, were well anticipated in timing and magnitude.

December 2008 (+). Similarly to November 2008 (see Section I.B), expectations of the ECB's behavior were strongly affected by the Bank of England's immediately preceding interest rate decision. So, although the Governing Council on December 4, 2008, decided to cut interest rates by 75 basis points, this was less than the 100 basis points bank rate cut by the BoE. *"Indeed, there are many who believe that the ECB has been too hesitant, and these critics point to the more decisive monetary policy measures taken by central banks in the Anglo-Saxon countries in particular"* (Neue Zürcher Zeitung, 2008, translation by the authors).

The Handelsblatt (2008) noted that *"hopes of a 1.00 percentage point cut in the key interest rate by the European Central Bank (ECB) drove the markets significantly upwards (...) When the ECB cut the key interest rate by 'only' 0.75 percentage points, this initially led to disappointment among investors"* (translation by the authors). The Financial Times (2008) asserted that while *"the ECB's move was still the biggest in its history (...) there had been hopes of even bigger reductions."*

January 2009 (–). Media reports predominantly concluded that the monetary policy decision of January 15, 2009, was too hesitant. Referring to the cut of the

main refinancing rate by 50 basis points, The Economist (2009a) assessed that *"the ECB is not hurrying to cut interest rates—mostly for the wrong reasons."* The Financial Times (2009a) asserted that *"the European Central Bank is not cutting rates fast enough"* and that *"this, at least, is what markets believe."*

This was, however, not exactly what markets believed. As described in Section I.B, the change from a flexible-rate bidding procedure to fixed-rate full allotment in October 2008 led to an immediate and substantial increase of excess liquidity, which made the ECB's corridor system, with short-term money market rates normally fluctuating around the main refinancing rate, essentially a floor system, with market rates hovering just above the deposit facility rate.

In the January meeting, the Governing Council not only decided to cut the main refinancing rate by 50 basis points, but also to restore the width of the corridor of standing facility rates from 100 to 200 basis points. This implied that the deposit facility rate fell by another 50 basis points, from 2.00% to 1.00% overall. This decrease, not the 50 basis points decrease of the main refinancing rate, was the relevant rate cut and closely followed by *EONIA*. When the decisions came into effect a week later, the Financial Times (2009b) re-assessed that *"overnight market rates moved sharply lower, as the full force of last week's interest rate decision came into effect."*

March 2009 (+). Although the Handelsblatt (2009a) noted that *"it was not really a surprise anymore that the European Central Bank lowered the key interest rate to the historic low of 1.5 percent today,"* (translation by the authors) it obviously was a surprise to financial markets. A potential reason for this could be the interaction with the Bank of England, again. The BoE had cut its interest rate by 50 basis points in February and another 50 basis points in March. The ECB, instead, lowered rates by 'only' 50 basis points in March, while it had not changed them in February.

The Financial Times (2009c) commented on the supposedly contrasting responses of the two central banks to economic developments as follows: *"The Bank of England and the European Central Bank interest rate-setting committees both met on Thursday. They face similar economic crises but gave very different answers to the problems facing them. The UK central bank is acting in proportion to the severity of the crisis. The eurozone's monetary authority is doing far too little."*

April 2009 (+). *"A big cut is what markets had expected. Instead, the ECB trimmed its main rate by just 25 basis points to 1.25 per cent,"* the Financial Times (2009d) commented the ECB's interest rate decision of April 2, 2009. The Neue Zürcher Zeitung (2009) reported that *"only 4 of the 55 bank economists polled by the Bloomberg news agency had expected the ECB to cut interest rates by 25 basis points. The markets had predominantly expected a larger step of 50 basis points"* (translation by the authors). The Economist (2009b) agreed that *"there will be much wailing and gnashing of teeth at the news that the European Central Bank decided to cut interest rates by a quarter, rather than a half, of a percentage point today."*

The Handelsblatt (2009b) explained that *"due to the rapidly deteriorating economic outlook and falling inflation rates, most experts had expected an easing of half a percentage point"* and that the decision may have been motivated by the ECB's reluctance to adopt a zero-interest policy. *"The decision (...) delays the inevitable move to a zero-interest policy. (...) For some time now, it has been clear to all market participants that the ECB cannot maintain its reluctance to lower key rates"* (translation by the authors).

However, stock markets surged that day. The Neue Zürcher Zeitung (2009) correspondingly headlined: *"Stock market fireworks despite ECB decision"* (translation by the authors). Accordingly, the evidence for a (restrictive) monetary policy shock as given by our model estimates is weak (see Section III.D).

July 2012 (–). The surprising rate cut in November 2011 (see Section I.B) was followed by another cut in December 2011, which had been expected. Subsequently, rates were kept unchanged until July 5, 2012.

At this meeting, all three policy rates were cut by 25 basis points. According to media reports, the rate cut per se was not surprising but its uniformity across the different facility rates, in particular the deposit rate, was. *"As expected, the ECB has cut its main refinancing rate by 25 basis points to 0.75% and the marginal lending facility (emergency funds) by 25 basis points to 1.50%. In a less expected move they also cut the deposit rate to zero,"* noted the Financial Times (2012) and concluded: *"It's clear the ECB has gone into experimental mode."*

This perceived mode shift also surprised financial markets. The Handelsblatt (2012) quoted a money market trader in Frankfurt as saying that *"the reduction in the interest rate on the deposit facility comes as a complete surprise to us. I am curious how the money market will deal with it. After all, many had recommended that the ECB should not cut the interest rate to zero"* (translation by the authors).

Most economists, however, would probably not associate this month with the interest rate decision of July 5, but rather with an event that occurred later: On July 26, 2012, Mario Draghi delivered a speech at a conference in London, in which he pledged that *"within our mandate, the ECB is ready to do whatever it takes to preserve the euro"* (Draghi, 2012). This strong commitment is widely regarded as an important contribution to ending the euro area crisis. However, given its occurrence at the end of July and with *EONIA* defined as monthly average, a relevant shock on the interest rate or on other macroeconomic variables in the same month can be ruled out. Hence, it could not have caused the large monetary policy shock reported by our model. This reassures us that our identification strategy captures conventional monetary policy shocks.

September 2014 (–). Corresponding to the instrument of forward guidance introduced in July 2013, the Governing Council in August 2014 announced that interest rates *"would remain unchanged for an extended period of time"* (ECB, 2014). But only a month later, at its next meeting on September 4, 2014, the Governing Council decided to cut interest rates by 10 basis points. *"Draghi intervention on rates and*

bonds startles markets. Thursday's rate cuts (...) took analysts by surprise," the Financial Times (2014) headlined.

Moreover, in June that year, when the deposit rate had been cut to below zero, the ECB had indicated that the lower bound was reached. *"Speaking on that occasion, Mario Draghi, the bank's president, said that 'for all practical purposes, we have reached the lower bound.' (...) Today he insisted that whatever he might have said in June the ECB had now definitely reached the lower bound"* (The Economist, 2014). Draghi also conceded that the interest rate decision was not unanimous.

December 2015 (+). *"Draghi has over promised and under delivered."* This quote, cited by the British Broadcasting Corporation (2015), sums up the situation on December 3, 2015. As consumer price inflation had remained well below its target for several years, *"Mario Draghi had sent strong signals in recent weeks that he and his colleagues on the ECB's governing council were prepared to 'do what we must to raise inflation as quickly as possible'"* (The Guardian, 2015).

An investor, quoted by Handelsblatt (2015), suggested that *"Draghi had deliberately raised expectations too high in order to exert pressure on the Governing Council"* (translation by the authors). The newspaper maintained that the views in the Governing Council must have diverged considerably. In the end, *"many in the markets had been looking for a bigger reduction in the deposit rate"* (Financial Times, 2015) than from -0.20% to only -0.30%.

The Wall Street Journal (2015) concluded that *"the ECB's moves were a major disappointment from a central bank whose actions have typically exceeded investors' expectations"*—interestingly, a view that differs dramatically from the perception of the ECB in the early years of its existence.

C.2 Extended Identification

This appendix shows the results from an estimation with an extended identification strategy, which uses fourteen sign restrictions (see Subsection III.D). Specifically, we set the following sign restrictions on top of the residual restrictions imposed in the baseline specification (Section II.B):

$$\begin{aligned}
&\hat{w}_{1,2002m11} > 0 \quad \text{(SR5)}, && \hat{w}_{1,2009m03} > 0 \quad \text{(SR10)},\\
&\hat{w}_{1,2003m03} > 0 \quad \text{(SR6)}, && \hat{w}_{1,2009m04} > 0 \quad \text{(SR11)},\\
&\hat{w}_{1,2003m06} < 0 \quad \text{(SR7)}, && \hat{w}_{1,2012m07} < 0 \quad \text{(SR12)},\\
&\hat{w}_{1,2008m12} > 0 \quad \text{(SR8)}, && \hat{w}_{1,2014m09} < 0 \quad \text{(SR13)},\\
&\hat{w}_{1,2009m01} < 0 \quad \text{(SR9)}, && \hat{w}_{1,2015m12} > 0 \quad \text{(SR14)}.
\end{aligned}$$

Figure C.2 shows that the impulse responses of our model variables hardly change compared with the baseline specification, only the exchange rate appreciates more pronouncedly (but less than in the standard high-frequency VAR). This result supports our narrative reading of these further interest rate surprises. In particular, it says that also those surprises, for which the baseline model is unclear (November

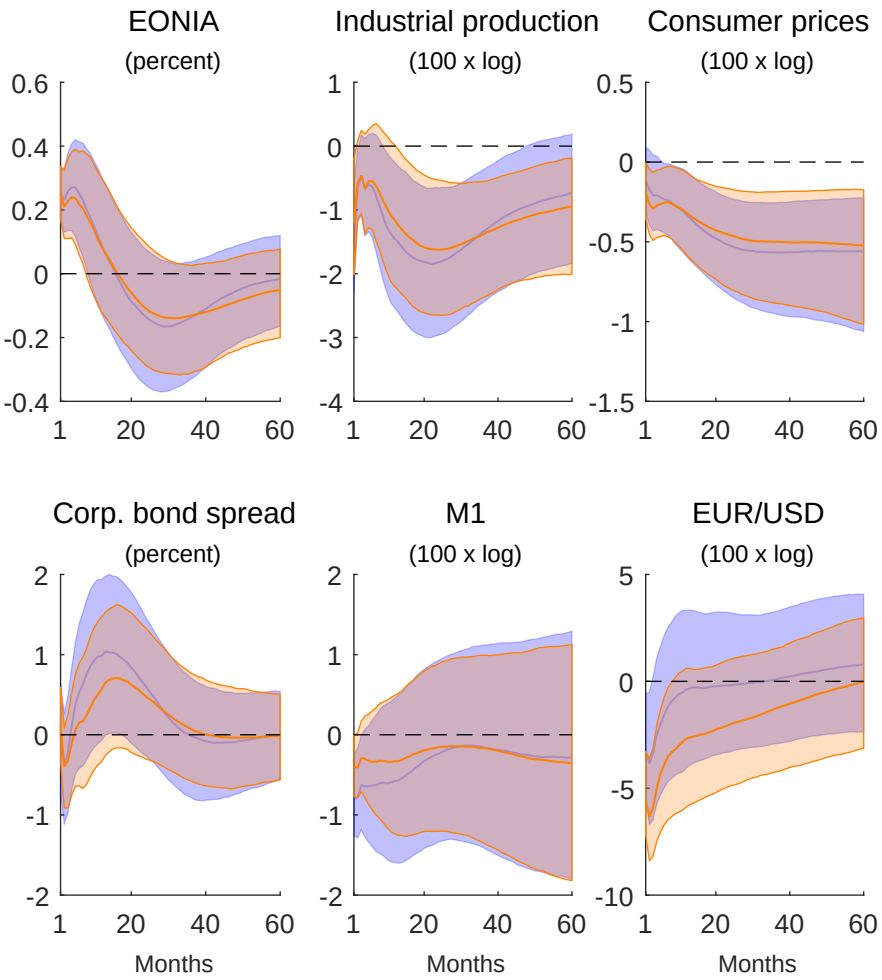

FIGURE C.2. IMPULSE RESPONSES, EXTENDED IDENTIFICATION

Note: Impulse responses obtained with extended identification (SR1−SR14 and MR) in orange, impulse responses from our baseline model in blue. Solid lines are median estimates, shaded areas correspond to 68% credible sets. The monetary policy shock has been normalized to have an impact of 25 basis points on *EONIA*.

2002, April 2009) or contradicting (March 2003), can be regarded—at least to a large extent—as monetary policy shocks.

D. Robustness

In this appendix, we provide several robustness checks to our baseline model. In Subsection D.1 we show that focusing on the subsample, in which policy rates were strictly positive, does not change our results. In Subsection D.2 we drop the magnitude restriction for November 2011 and find that this blurs the estimated effects of monetary policy shocks significantly.

In Subsection D.3 we show that replacing the independent prior by its conjugate counterpart does not affect our results. Finally, in Subsections D.4 and D.5 we show that our results are robust to replacing industrial production by real GDP and to replacing consumer prices by core consumer prices.

D.1 Short Sample

Evidence suggests that in the considered sample period, ranging from 1999 to 2019, a lower bound on the ECB policy rate has not been reached. After the deposit facility rate had been reduced to zero in July 2012—a decision which is included in our set of interest rate surprises—it was further lowered several times; to -0.10% in June 2014, to -0.20% in September 2014, to -0.30% in December 2015 (which even constituted an unexpectedly restrictive interest rate decision), to -0.40% in March 2016, and to -0.50% in September 2019.

Still, given the conventional view of a (zero) lower bound and presumptions of monetary policy working differently below it (see, e.g., Ulate, 2021), we examine whether restricting the sample to the period of positive policy rates would change our results. It does not. Specifically, cutting the sample at June 2012, i.e., a month prior to the reduction of the deposit facility rate to zero, leaves the results virtually unchanged, as the impulse responses in Figure D.1 show.

D.2 The Role of the Magnitude Restriction

In this robustness check, we examine the role of the magnitude restriction. It turns out that it is eminent. Figure D.2.1 compares the results with and without the magnitude restriction for November 2011. The credible sets increase significantly and the baseline results become strongly blurred. Nonetheless, several of the basic results of Section III.A are preserved. This means that the sign restrictions SR1$-$SR4 (see Section II.B) contain important information on monetary policy shocks.

Figure D.2.2, in turn, shows that an identification strategy using only the sign and magnitude restriction for November 2011 narrows down the credible sets. However, it does not suffice to recover all properties of the effects of monetary policy shocks that we obtain from the baseline model, specifically the unambiguous effects on output, money, and the exchange rate.

D.3 Conjugate Prior

Figure D.3 shows that using a conjugate prior instead of an independent prior and, hence, refraining from a different shrinkage parameter for the variance of coefficients of own lags and lags of other variables in the model equations, leaves the basic results from Section III.A intact. The only notable difference is that real output responds slightly stronger than in the baseline model.

D.4 GDP

In this appendix, we consider real GDP as a measure of economic activity instead of industrial production. Monthly data of real GDP are obtained by interpolation using industrial production data and the method proposed by Chow and Lin (1971). As Figure D.4 shows, interpolated GDP itself responds similarly to industrial production, though the credible set turns out to be wider. The results for the other variables in the model are hardly affected.

D.5 Core Inflation

What happens, when we replace consumer prices by core consumer prices to account for different inflation dynamics in the consumption basket? Qualitatively nothing, Figure D.5 shows that the basic results from Section III.A are largely unchanged. Core consumer prices themselves respond gradually to a monetary policy shock.

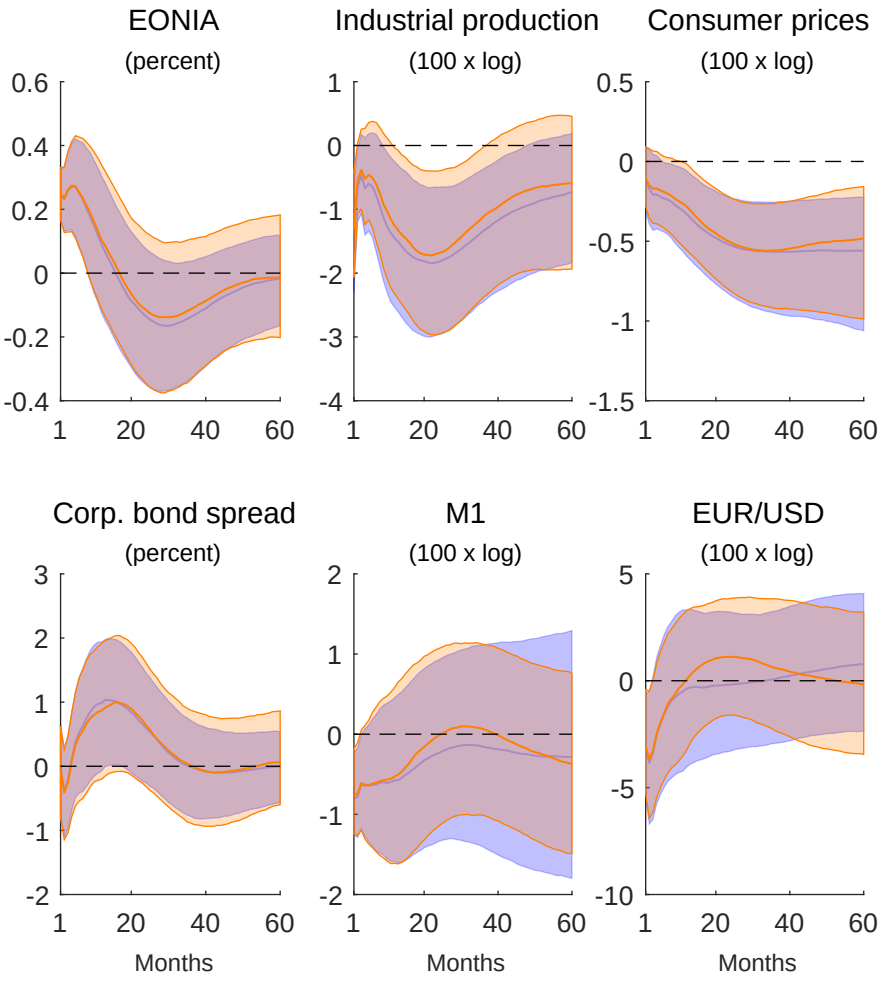

FIGURE D.1. IMPULSE RESPONSES, SHORT SAMPLE

Note: Impulse responses based on the short sample in orange, impulse responses from the baseline model based on the full sample in blue. Solid lines are median estimates, shaded areas correspond to 68% credible sets. The monetary policy shock has been normalized to have an impact of 25 basis points on *EONIA*.

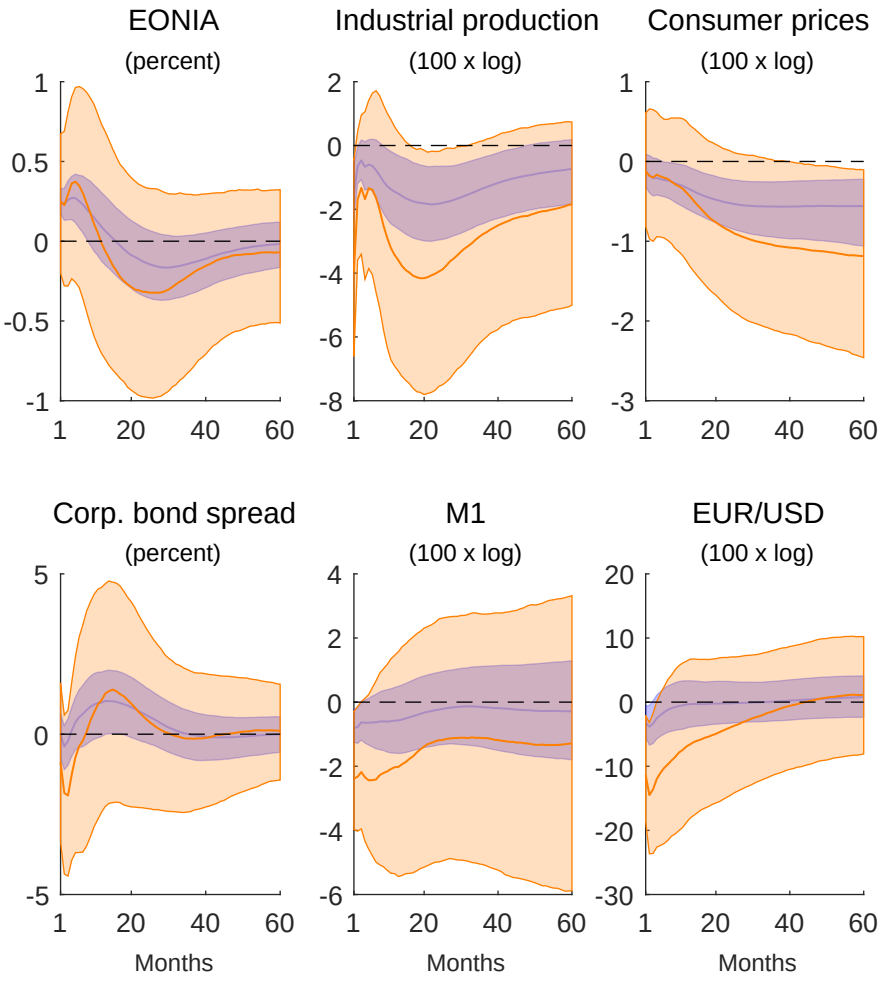

FIGURE D.2.1. IMPULSE RESPONSES, RESTRICTIONS SR1−SR4

Note: Impulse responses based on restrictions SR1−SR4 only (without magnitude restriction for November 2011) in orange. Impulse responses from the baseline model (including the magnitude restriction) in blue. Solid lines are median estimates, shaded areas correspond to 68% credible sets. The monetary policy shock has been normalized to have an impact of 25 basis points on *EONIA*.

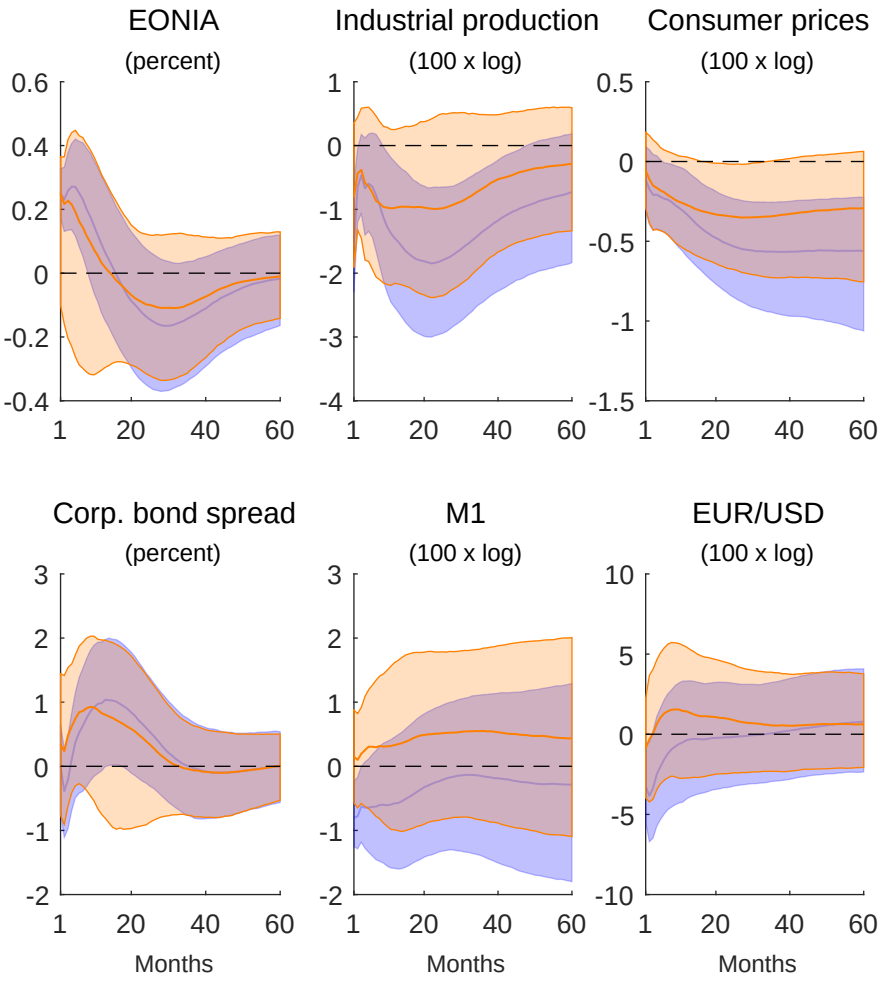

FIGURE D.2.2. IMPULSE RESPONSES, RESTRICTIONS SR4 AND MR

Note: Impulse responses based on restrictions SR4 and MR, i.e., the sign and magnitude restriction for November 2011, in orange. Impulse responses from the baseline model (including the three other sign restrictions SR1−SR3) in blue. Solid lines are median estimates, shaded areas correspond to 68% credible sets. The monetary policy shock has been normalized to have an impact of 25 basis points on *EONIA*.

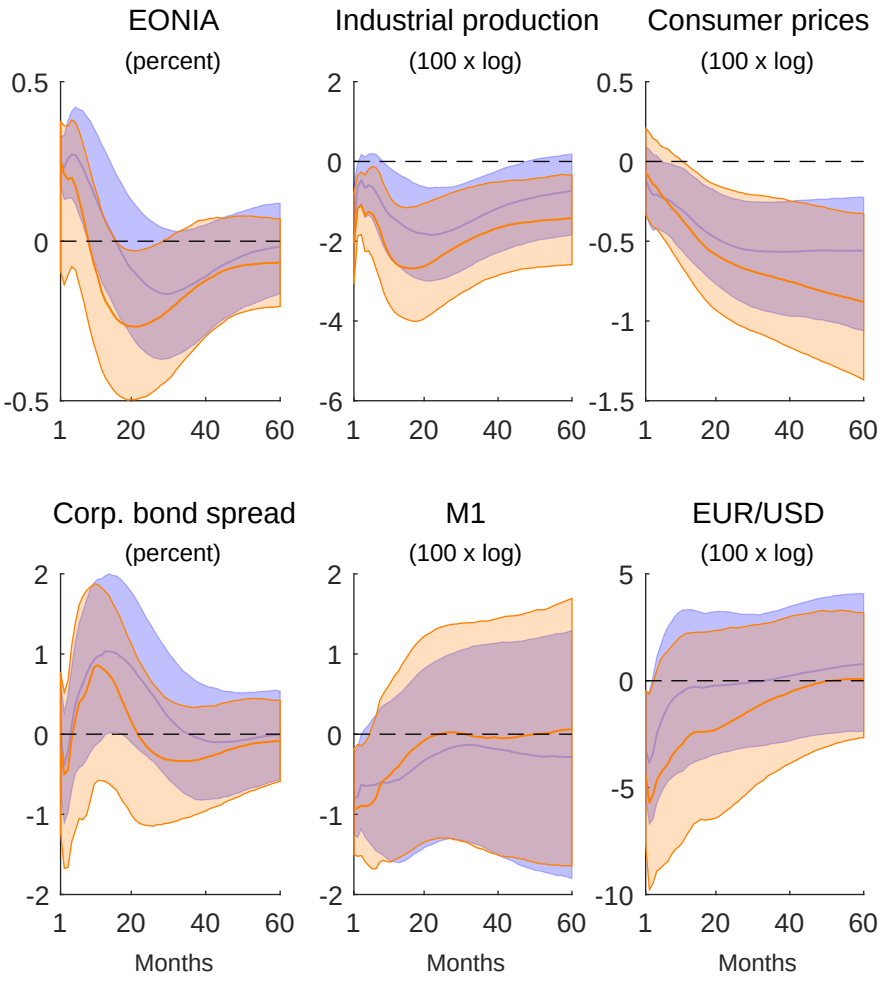

FIGURE D.3. IMPULSE RESPONSES, CONJUGATE PRIOR

Note: Impulse responses based on a model with a conjugate Minnesota prior in orange, impulse responses from the baseline model with an independent Minnesota prior in blue. Solid lines are median estimates, shaded areas correspond to 68% credible sets. The monetary policy shock has been normalized to have an impact of 25 basis points on *EONIA*.

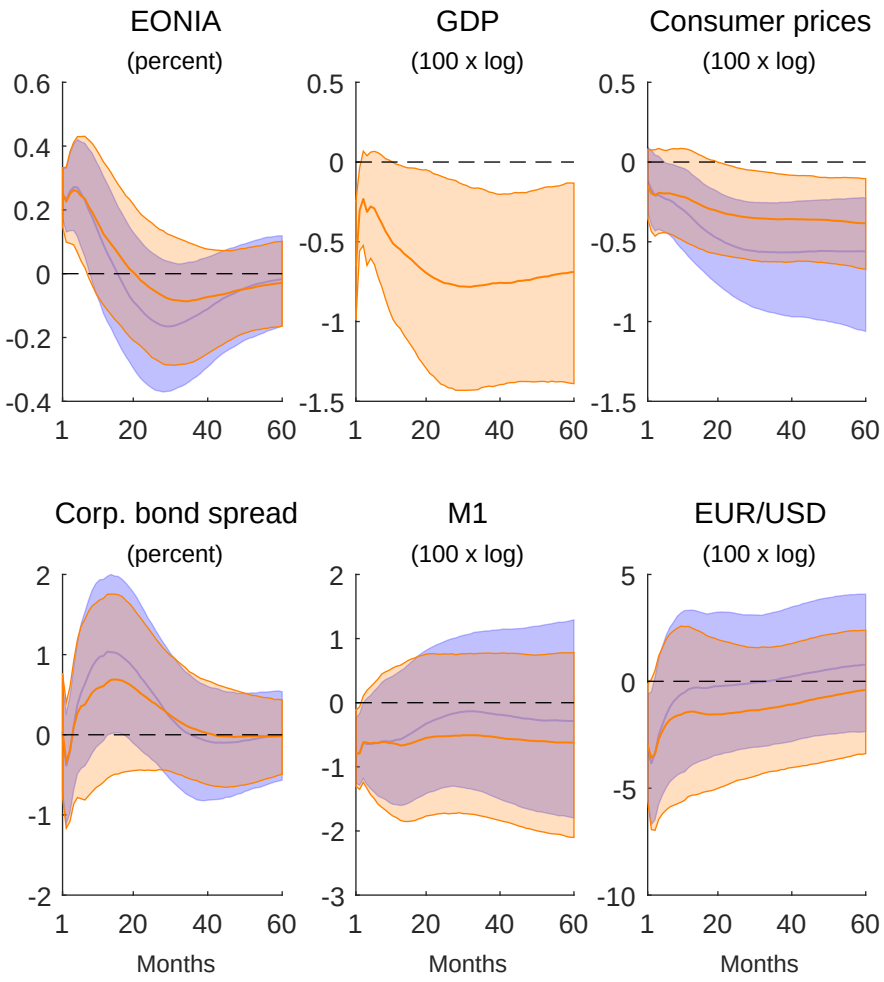

FIGURE D.4. IMPULSE RESPONSES, GDP MODEL

Note: Impulse responses based on a model with *IP* replaced by *GDP* in orange, impulse responses from the baseline model in blue. Solid lines are median estimates, shaded areas correspond to 68% credible sets. The monetary policy shock has been normalized to have an impact of 25 basis points on *EONIA*.

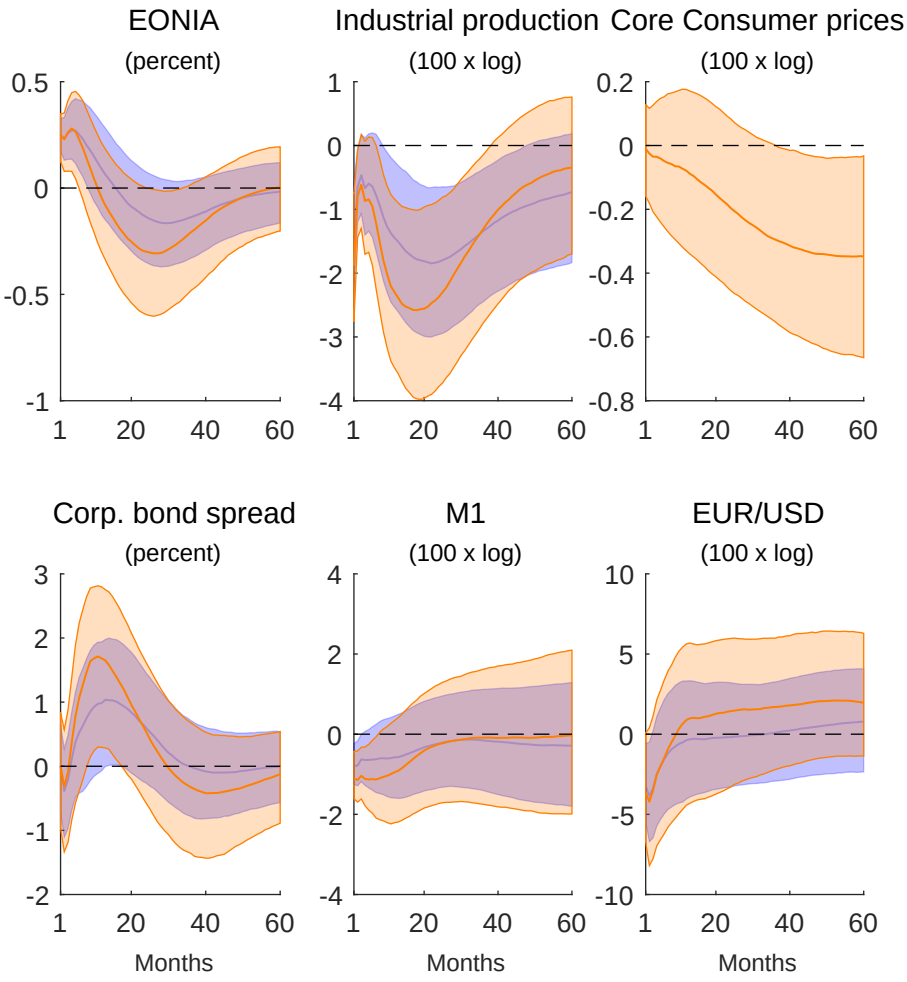

FIGURE D.5. IMPULSE RESPONSES, CORE INFLATION MODEL

Note: Impulse responses based on a model with *HCPI* replaced by core *HCPI* in orange, impulse responses from the baseline model in blue. Solid lines are median estimates, shaded areas correspond to 68% credible sets. The monetary policy shock has been normalized to have an impact of 25 basis points on *EONIA*.

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