Online Appendix for: Monetary policy transmission in Denmark

Rasmus B. Larsen* Christoffer J. Weissert†

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*Danmarks Nationalbank. Email: rbl@nationalbanken.dk.
†Danmarks Nationalbank. Email: cjw@nationalbanken.dk.

Appendix A Identification procedure

ECB policy surprises are constructed from yield changes by estimating the following factor model using principal components:

$$X = F\Lambda + \varepsilon. \tag{A.1}$$

X is an $M \times 7$ matrix containing changes in the 1, 3, and 6 month, and 1, 2, 5, and 10-year overnight index swap (OIS) yields around the M ECB monetary policy decision releases in the sample period of January 2002 until June 2023 from the EA-MPD database.[1] F is an $M \times k$ matrix containing $k \leq 7$ orthogonal common factors – ECB policy surprises – that drive yield changes around press releases, while Λ is a $k \times 7$ matrix containing the factor loadings.

As explained in Section 3, we extract $k = 2$ factors and rotate F into a target factor and a path factor using the rotation matrix $\tilde{C}$:

$$Z = F\tilde{C}. \tag{A.2}$$

$Z = (Z^{Target}, Z^{Path})$ is an $M \times 2$ matrix containing the target and path factors, while $\tilde{C}$ is the 2×2 rotation matrix. Borrowing from the rotation by Gürkaynak, Sack and Swanson (2005), we impose that the path factor does not affect the one-month OIS yield, while insuring that the factors are orthogonal and have unit variance. This amounts to the following four restrictions on $\tilde{C}$ that uniquely pin down the rotation:

- Unit variance of factors implies that the squared entries of each column sum to one (this imposes two restrictions on $\tilde{C}$).
- Orthogonal factors means that the dot product of columns of $\tilde{C}$ equals zero imposing one additional restriction.
- The path factor does not load on the one-month OIS yield.

A.1 Inspecting the monetary policy shocks

Appendix A.1 plots the estimated monetary policy shocks and information shocks from the poor man's sign restrictions, while we list the most sizeable movements in the monetary policy shock series in Table A.1

If we consider the largest easing of monetary policy rates, it occurred on 3 November 2011, which was Mario Draghi's first meeting as ECB President and at which ECB cut monetary policy rates by 25 basis points. Altavilla *et al.* (2019) also estimates this shock as the largest negative realization of the target factor. The second-largest easing occurred on 4 May 2023 when the ECB cut monetary policy rates by 25 basis points after raising rates by 50 basis points at each of the three preceding meetings.

[1] OIS yields of a maturity longer than 2 years are only available from August 2011. Prior to that, we use German sovereign yields.

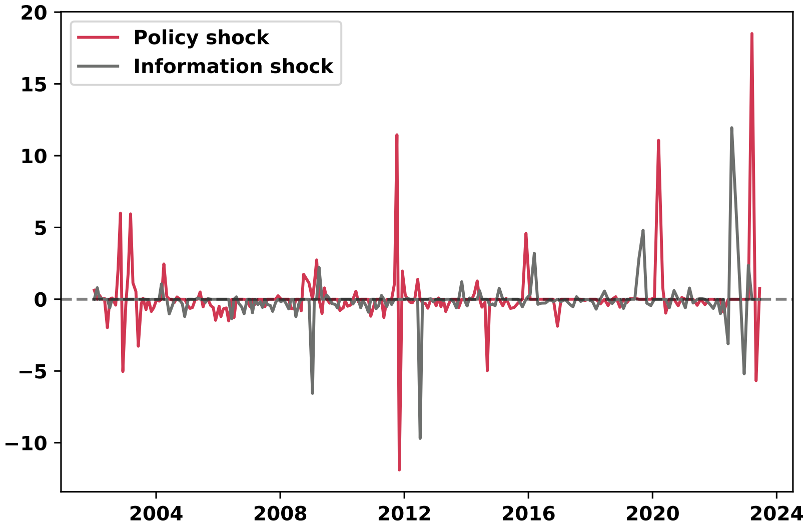


FIGURE A.1. Informationally robust target factor

Notes. The figure shows the estimated monetary policy and information shocks based on the poor man's sign restriction approach outlined in Section 3.2.

The largest monetary policy tightening happened at the 16 March 2023 meeting, where the ECB raises monetary policy rates by 50 basis points. A few days prior to the meeting, Silicon Valley Bank failed after a bank run, while Credit Suisse experienced turmoil at the same time resulting in an acquisition by UBS on 19 March 2023. Other sizeable tightenings include the 6 October 2011 and the 12 March 2020 meetings at which monetary policy rates were kept unchanged.

A.2 Rotational sign restrictions

As an alternative to the poor man's sign restricitons, information effects can be purged from the target factor by decomposing it into pure monetary policy shocks and information shocks.

$$Z^{Target} = Z^{Target,MP} + Z^{Target,Info}. \tag{A.3}$$

Storing Z^{Target} in the first column of an $M \times 2$ matrix, D, together with stock price changes in the second column, we rotate D into a matrix $U = (Z^{Target,MP}, Z^{Target,Info})$ holding the monetary policy and information shocks:

$$D = UC, \qquad \text{where } U'U \text{ is diagonal and } C = \begin{bmatrix} 1 & c_{MP} < 0 \\ 1 & c_{Info} > 0 \end{bmatrix}, \tag{A.4}$$

where c_{MP} and c_{Info} are scalars imposing the sign restrictions.

Diagonality of $U'U$ implies that $Z^{Target,MP}$ and $Z^{Target,Info}$ are orthogonal. The ones in the first column of the rotation matrix, C, ensure that the decomposition in Equation (A.3) holds, while the sign restriction $c_{MP} < 0$ in its second column imposes that the monetary policy shock

TABLE A.1. Largest monetary policy shocks within sample period

Meeting	**Monetary policy shock size (basis points)**
3 November 2011	-11.89
4 May 2023	-5.67
5 December 2002	-5.04
4 September 2014	-4.98
5 June 2003	-3.27
6 March 2003	5.94
7 November 2002	6.00
12 March 2020	11.07
6 October 2011	11.45
16 March 2023	18.51

Notes. The table presents the estimated values of the monetary policy shocks for the five largest policy easings and the five largest policy tightenings over the sample period January 2002 to July 2023.

is positively correlated with the target factor and negatively with stock price changes. $c_{Info} > 0$ imposes that the information shock is positively correlated with both the target factor and stock price changes. The rotation matrix C is not unique so we follow the methodology by Jarociński (2022) and use the rotation angle, which implies that the variance share of monetary policy shocks, $Var(Z^{Target,MP})/Var(Z^{Target})$ equals the variance share of monetary policy shocks in the poor man's sign restriction approach.[2]

[2] The variance share equals 69.5%, which is close to the number obtained by Jarociński (2022).

Appendix B Data

B.1 Financial market time series

Table B.1 lists the financial time series that we use in Section 4.

Table B.1. Financial time series

Variables	**Description**	**Source**
1M, 3M, 6M and 12M money market rates	CIBOR (2002-February 2013) spliced with CITA (February 2013 and onwards)	Refinitiv Eikon
2Y and 10Y government bond rates	Zero-coupon Danish government bond rate at market closing	Refinitiv Eikon
Short mortgage bond rate	Average rate on non-callable mortgage bonds with a duration of less than two years (weekly interpolated to daily)	Finans Danmark
Long mortgage bond rate	Average rate on 30-year callable mortgage bonds (weekly interpolated to daily)	Finans Danmark
Exchange rates	Buying rates at noon New York time	Federal Reserve Board H.10 release
Stock price	C20 index at market closing	Nasdaq
Oil price	Europe Brent Spot Price	The U.S. Energy Information Administration

Market closing days are not the same across countries, but our primary markets of interest are the Danish financial markets. Because of this, we interpolate foreign time series on foreign closing days when Danish markets are open. Six ECB policy announcements fall on Danish market closing days during our sample period. We keep these events in our sample and interpolate the Danish data on these days.

Money market rates are measured using the CITA, which is the interest swap offered rate quoted for the day-to-day rate (Tomorrow/Next). Because CITA was first introduced in 2013, we splice the rate with CIBOR rates. The data underlying CITA and CIBOR are collected between 10:30am and 10:45am, which is before ECB policy decisions are announced. Hence, we lead all money market rates by one business day in the dataset (for example, money market rates on ECB policy announcement days refer to the CITA/CIBOR quote the following morning).

Government bond rates are measured using zero-coupon rates from Refinitiv Eikon's benchmark series at market closing.

The daily series of mortgage rates are constructed by interpolating Finans Danmark's weekly series of mortgage rates. Long mortgage rates refer to an average of the yield on 30-year callable mortgage bonds, while short mortgage rates refer to the yield on non-callable mortgage bonds with a maturity of less than two years.

Exchange rates are obtained from the Federal Reserve Board's statistics of daily exchange rates (H.10 releases). These data are noon buying rates in New York, i.e. late afternoon exchange rates in the euro area.[3]

Danish stock prices are measured using the OMXC20 index at market closing. This index is a market value weighted index of the 20 most-traded stocks on Nasdaq Copenhagen.

Oil prices are measured using the Europe Brent spot price FOB in US dollars at market closing from the U.S. Energy Information Administration.

B.2 Description of the data used for real macroeconomic impulse response estimates

Table B.2 lists the macroeconomic time series variables that we use in Section 5.

Table B.2. Macroeconomic time series variables.

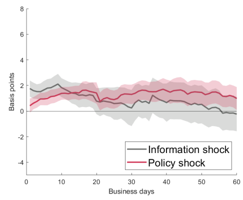
	Variable	Source	Note
Main model	Three-month money market rate	Refinitiv Eikon	CIBOR (2002-February 2013) spliced with CITA (February 2013 and onwards)
	Industrial production	Statistics Denmark	IPOP2015, seasonally adjusted, C (manufacturing)
	Unemployment rate	Statistics Denmark	AUP02X (before 2007) spliced with AUP02 (after 2007), seasonally adjusted
	Consumer prices	Statistics Denmark	PRIS117, All-items HICP, seasonally adjusted
	Commodity prices	Danmarks Nationalbank	NPR_ENERTOT, seasonally adjusted
	Corporate spread	FRED	Moody's Seasoned Baa Corporate Bond Yield Relative to Yield on 10-Year Treasury Constant Maturity, Not Seasonally Adjusted
The role of imports	Exchange rates	Danmarks Nationalbank	DNVALM, end-month rates
	Price indices	Statistics Denmark	PRIS118, constant taxes indices
	Import shares	Eurostat and Statistics Denmark	Constructed from FIGARO and Statistics Denmark input-output tables
Robustness checks	GDP	Statistics Denmark	NKN1, 2020-prices chained values, seasonally adjusted
	Retail sales	Statistics Denmark	DETA212, quantity indices, seasonally adjusted
	Industrial production excl. pharma	Statistics Denmark	IPOP2015, seasonally adjusted, C31 (manufacturing excl. pharmaceuticals)
	One-year money market rate	Refinitiv Eikon	CIBOR (2002-February 2013) spliced with CITA (February 2013 and onwards)

[3] We do not use exchange rate statistics from the ECB since these data are recorded in the Monetary Event Window at 2:15 pm.

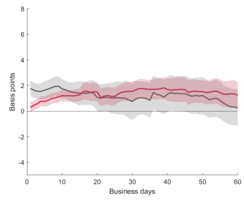
Appendix C Robustness checks

C.1 Results from pre-pandemic sample period

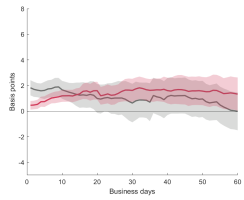
FIGURE C.1. Impulse-response functions of financial variables to ECB monetary policy (2002-2019 period)



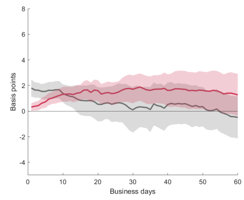
(A) 1M money market rate



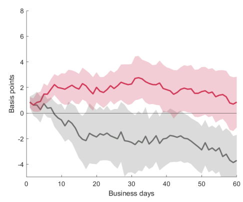
(B) 3M money market rate



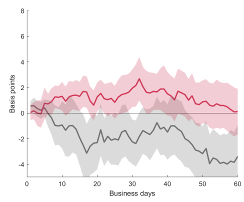
(C) 6M money market rate



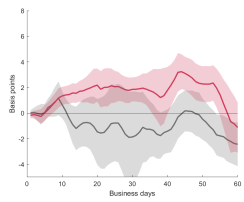
(D) 1Y money market rate



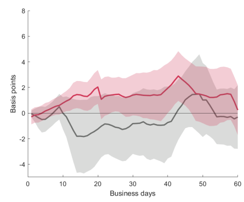
(E) 2Y government bond yield



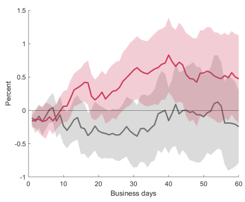
(F) 10Y government bond yield



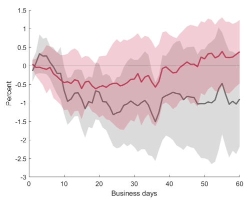
(G) Short mortgage bond yield



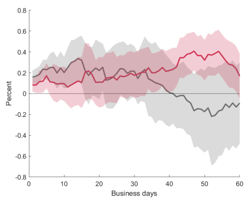
(H) Long mortgage bond yield



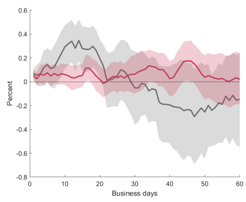
(I) Stock prices



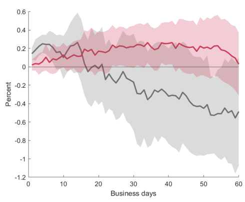
(J) Oil prices



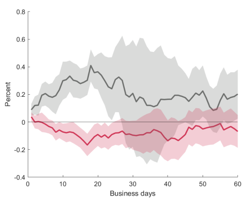
(K) USD



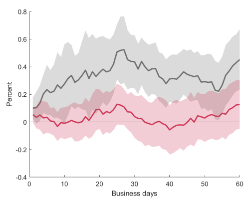
(L) GBP



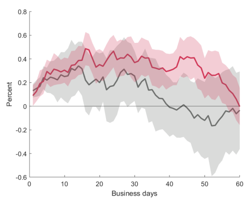
(M) JPY



(N) SEK



(O) NOK



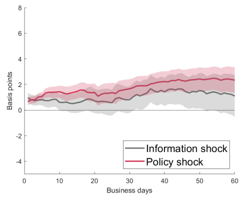
(P) CNY

Notes. The figure shows the estimated impulse-response function at a daily horizon to a monetary policy shock (red) and an information shock (grey) on the period 2002-2019. Estimates are obtained from local projections with 30 lags. Bands indicate 10% confidence intervals constructed using heteroskedasticity-robust standard errors.

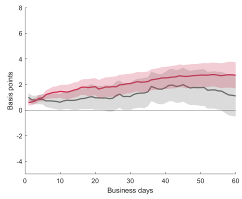
C.2 Rotational sign restriction

We have estimated a version of the daily local projections using the rotational sign restrictions of Jarociński (2022) as detailed in Appendix A.2. The results are reported in Figure C.2.

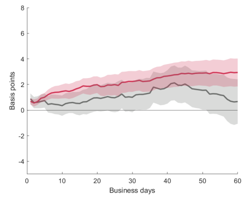
Figure C.2. Impulse-response functions of financial variables to ECB monetary policy (rotational sign restrictions)



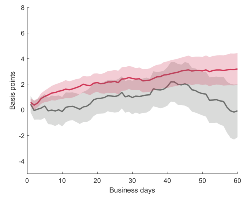
(a) 1M money market rate



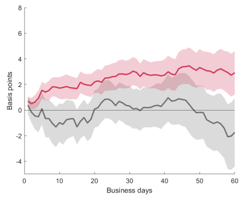
(b) 3M money market rate



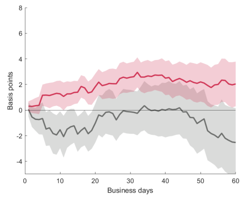
(c) 6M money market rate



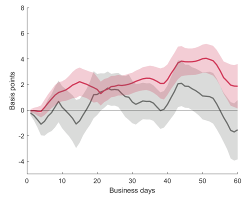
(d) 1Y money market rate



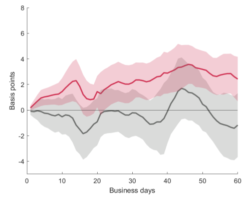
(e) 2Y government bond yield



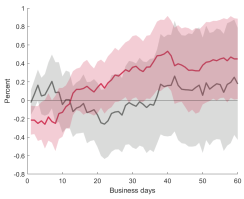
(f) 10Y government bond yield



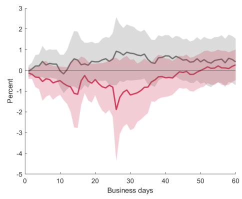
(g) Short mortgage bond yield



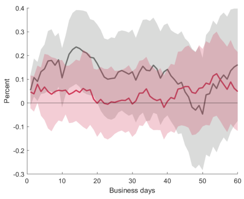
(h) Long mortgage bond yield



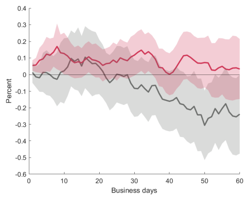
(i) Stock prices



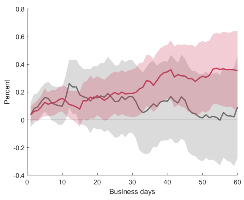
(j) Oil prices



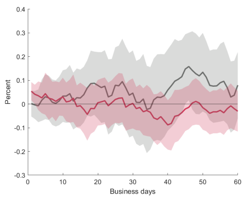
(k) USD



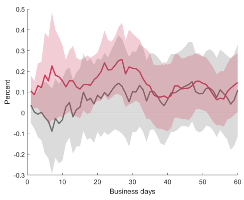
(l) GBP



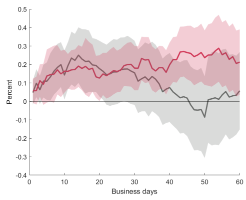
(m) JPY



(n) SEK



(o) NOK



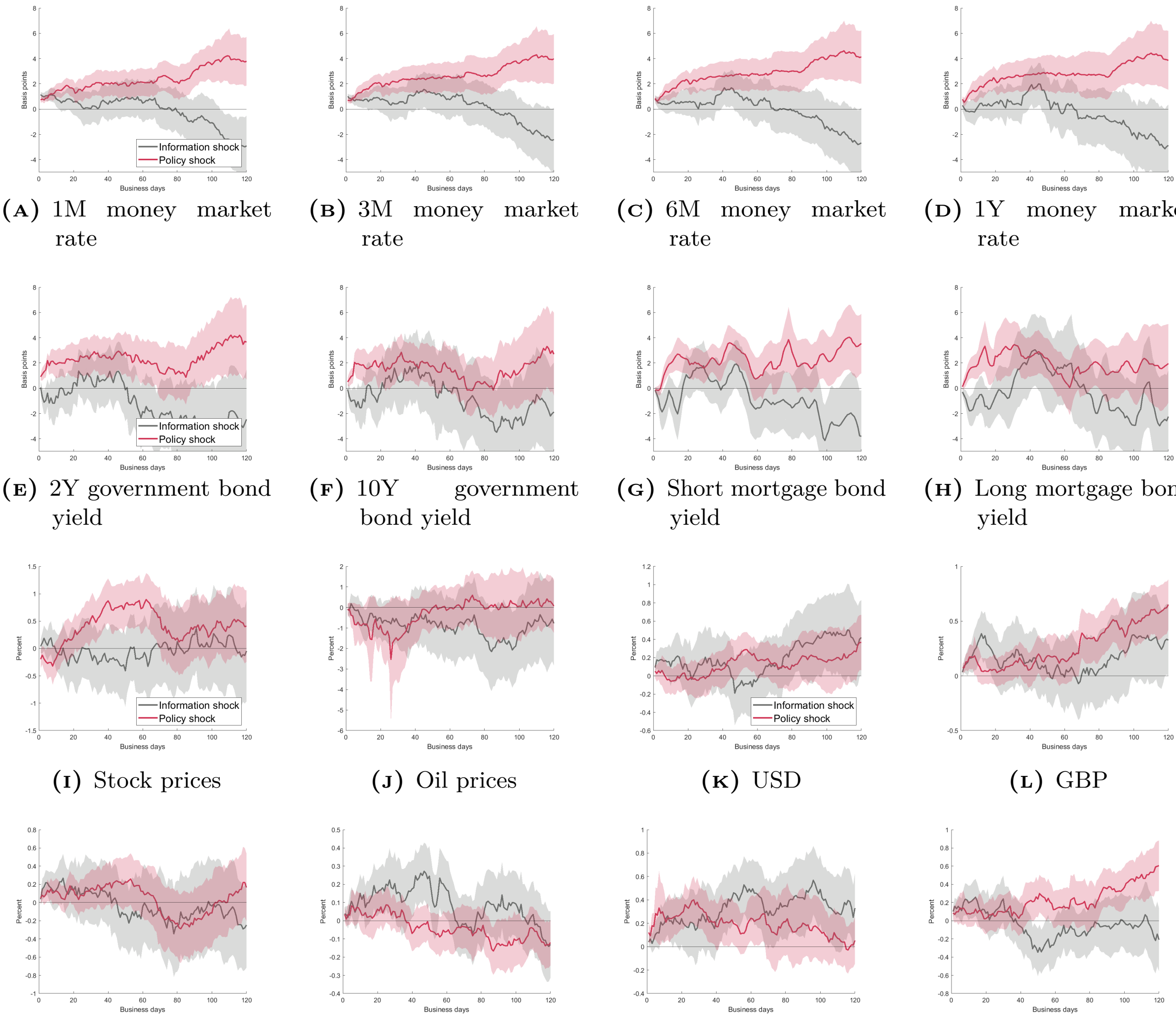
(p) CNY

Notes. The figure shows the estimated impulse-response function at a daily horizon to a monetary policy shock (red) and an information shock (grey) using rotational sign restrictions detailed in Appendix A.2. Estimates are obtained from local projections with 30 lags. Bands indicate 10% confidence intervals constructed using heteroskedasticity-robust standard errors.

C.3 Results with longer lag length

Figure C.3 shows the estimated financial market responses from the daily local projections when using a lag length of 120 days.

Figure C.3. Impulse-response functions of financial variables to ECB monetary policy (120 day lag length)



(a) 1M money market rate

(b) 3M money market rate

(c) 6M money market rate

(d) 1Y money market rate

(e) 2Y government bond yield

(f) 10Y government bond yield

(g) Short mortgage bond yield

(h) Long mortgage bond yield

(i) Stock prices

(j) Oil prices

(k) USD

(l) GBP

(m) JPY

(n) SEK

(o) NOK

(p) CNY

Notes. The figure shows the estimated impulse-response function at a daily horizon to a monetary policy shock (red) and an information shock (grey) when using a lag length of 120 days. Bands indicate 10% confidence intervals constructed using heteroskedasticity-robust standard errors.

Appendix D Robustness checks of the macroeconomic responses

D.1 Responses to an information shock

We illustrate the importance of controlling for information effects by instrumenting the money market rate with the information shock obtained from the poor man's sign restriction outlined in Section 3.2 instead of the pure monetary policy shock. The resulting impulse-response estimates are shown in Figure D.1 and exhibit a clear price puzzle with prices increasing when monetary policy is tightened. Moreover, the effects on industrial production are muted compared to those reported in Section 5.

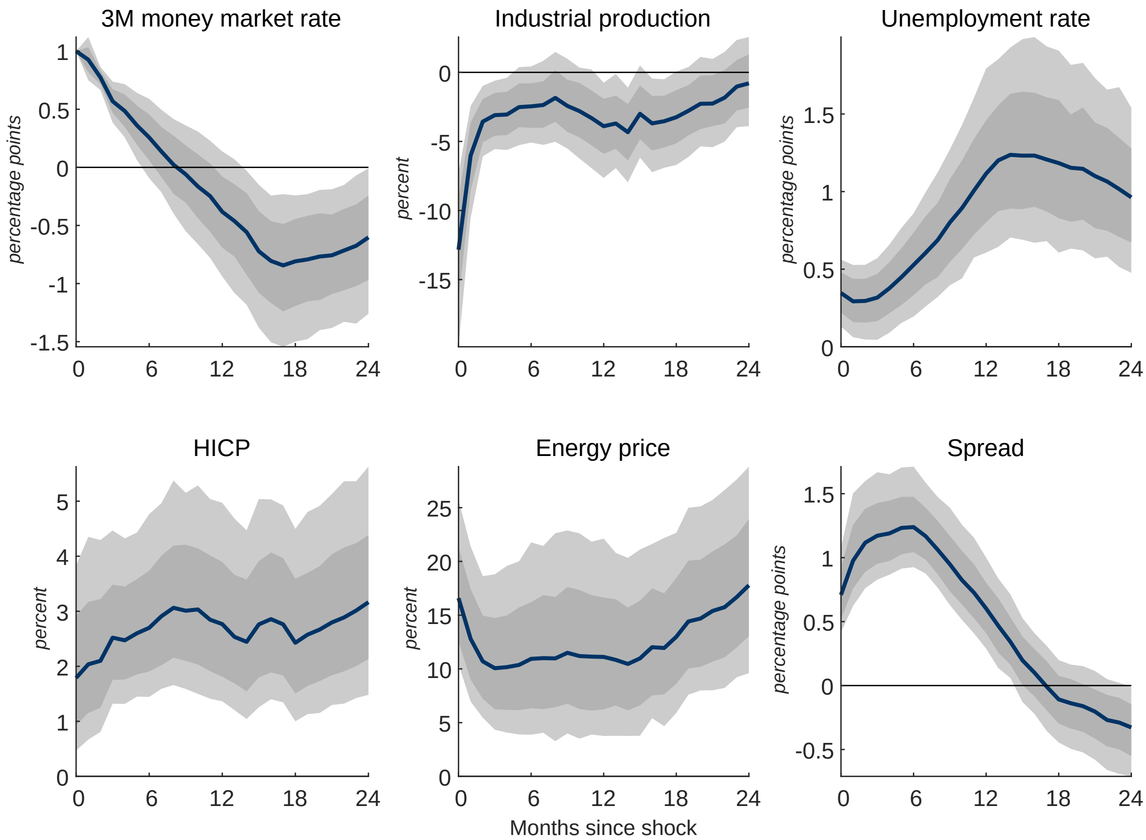


FIGURE D.1. Impulse-responses to an information shock

Notes. The solid blue lines show the median impulse responses. Shaded areas are 90 percent posterior coverage bands. The BLP model is identical to the main model from Section 5 with the only exception that we use the information shock instead of the monetary policy shock to instrument three-month money market rate.

D.2 Responses of (interpolated) GDP and retail sales

We assess the sensitivity of our results to using other measures of economic activity than industrial production. Specifically, we re-estimate the model using the retail sales index or interpolated GDP instead of industrial production. GDP is linearly interpolated from quarterly to monthly frequency. The results are shown in Figure D.2

FIGURE D.2. Impulse-responses when retail sales or GDP is used instead of industrial production

Notes. The solid blue lines show the median impulse responses. Shaded areas are 90 percent posterior coverage bands. The BLP model is identical to the main model from Section 5 with the only exception that retail sales (middle) or GDP (right) is used instead of the overall index for industrial production (left). GDP is interpolated from quarterly to monthly frequency.

D.3 Excluding pharmaceutical production

Figure D.3 shows how our main results regarding the Danish macroeconomy's response to monetary policy shocks from Section 5 change when we use an index for industrial production excluding pharmaceutical production.

D.4 Including inflation rates instead of price levels

Figure D.4 shows impulse response estimates from a model that includes the month-on-month inflation rates of the HICP and commodity price indices instead of their log levels.

D.5 Excluding Covid-19

To assess the sensitivity of our main results to the handling of the Covid-19 period, we conduct a sensitivity analysis by excluding observations from 2020 onwards and subsequently rerunning the main model. The resulting impulse-response patterns are illustrated in Figure D.5

D.6 Changing the measure of the money market rate

Figure D.6 shows how our main results regarding the Danish macroeconomy's response to monetary policy shocks from Section 5 change when we use a the one-year money market rate as policy variable.

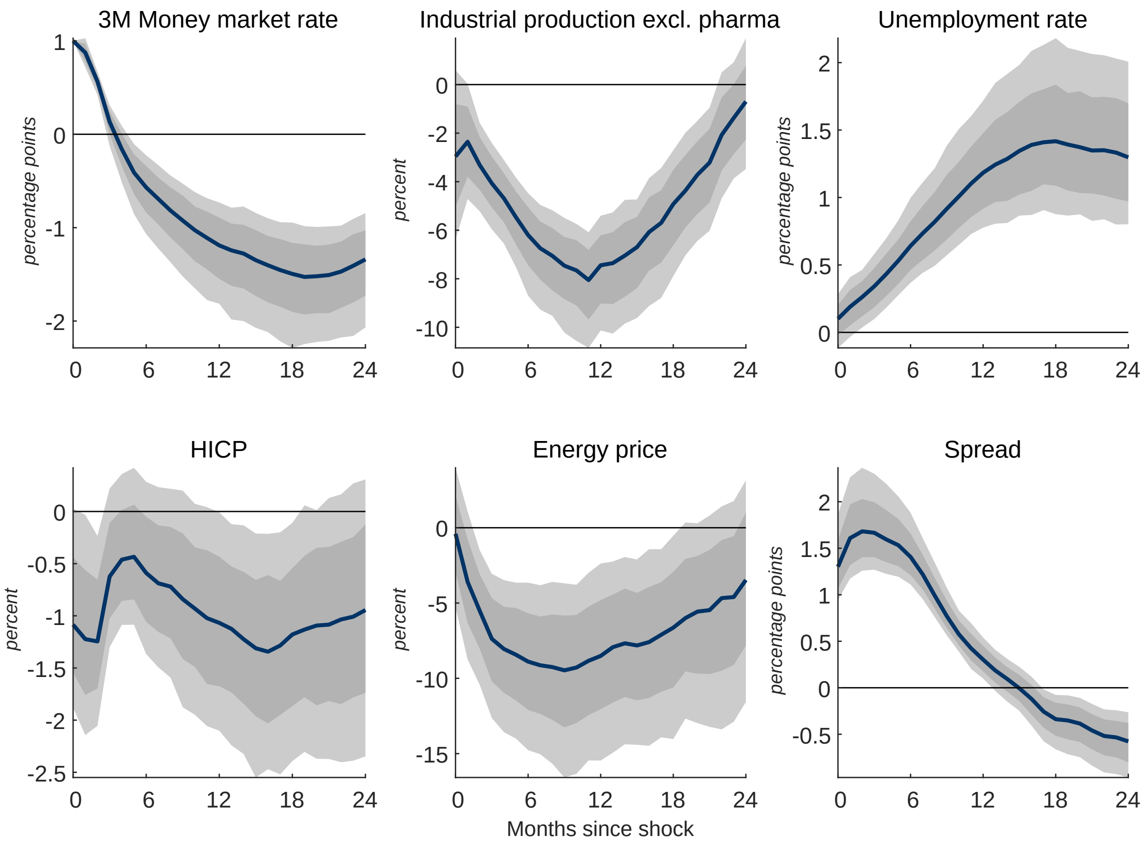


Figure D.3. Impulse-responses when pharmaceutical production is excluded from the overall index for industrial production.

Notes. The solid blue lines show the median impulse responses. Dark gray shaded areas are 68 percent posterior coverage bands. Light gray shaded areas are 90 percent posterior coverage bands. The BLP model is identical to the main model from Section 5 with the only exception that the overall index for industrial production excludes pharmaceutical production.

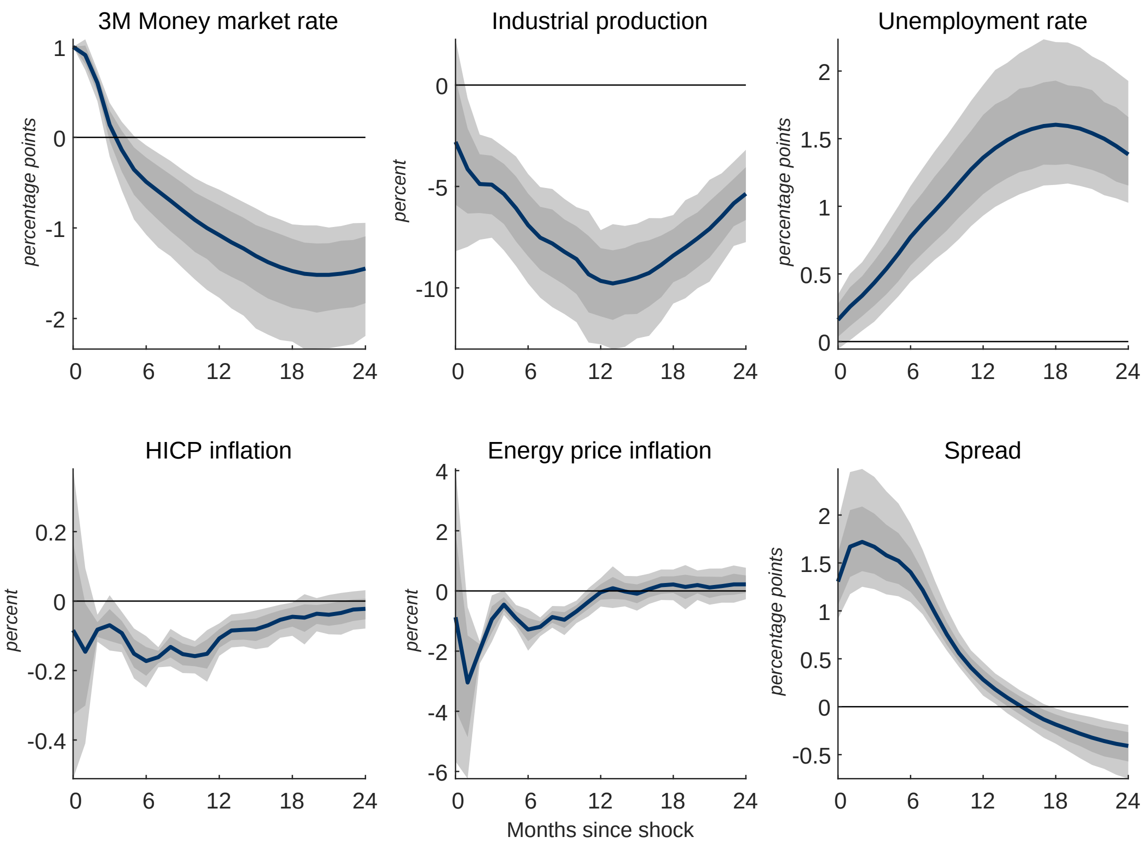


Figure D.4. Impulse-responses when including inflation rates instead of price levels

Notes. The solid blue lines show the median impulse responses. Shaded areas are 90 percent posterior coverage bands.

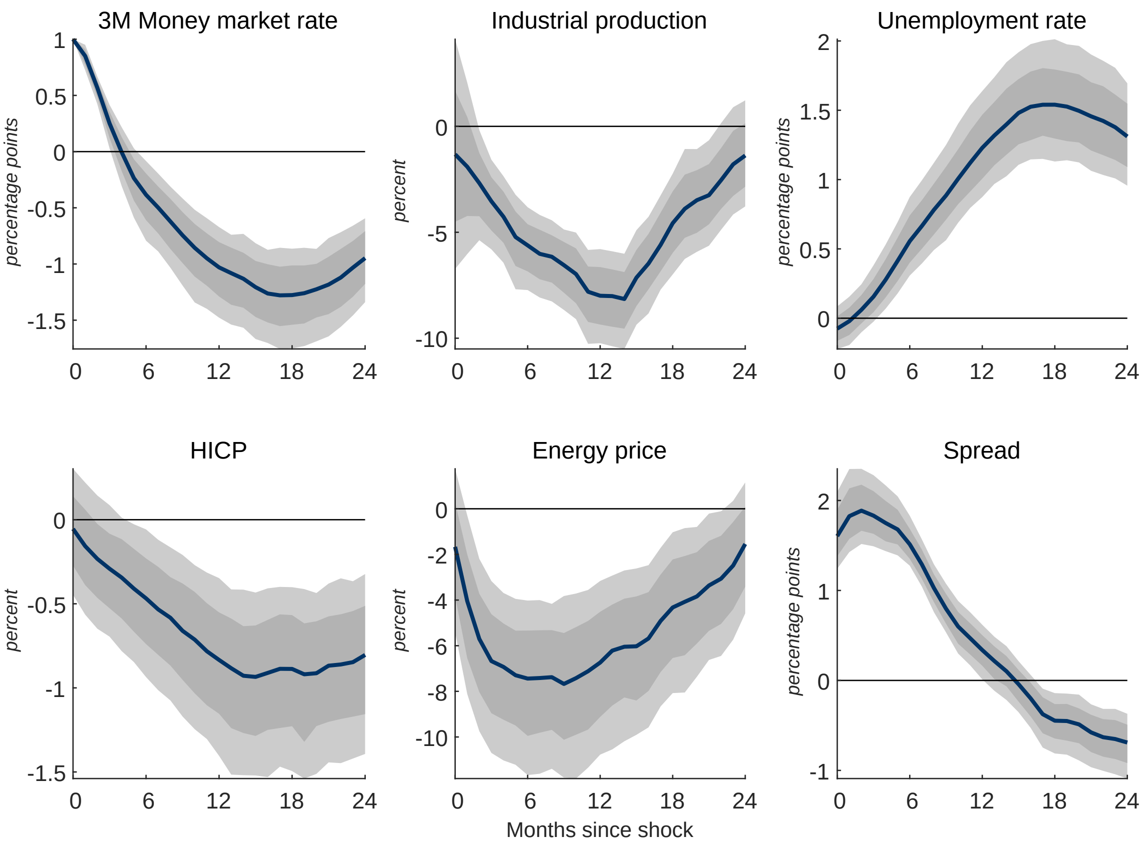


Figure D.5. Impulse-responses when the Covid-19 period is excluded from the sample

Notes. The solid blue lines show the median impulse responses. Dark gray shaded areas are 68 percent posterior coverage bands. Light gray shaded areas are 90 percent posterior coverage bands. The BLP model is identical to the main model from Section 5 with the only exception that our sample ends (and includes) December 2019.

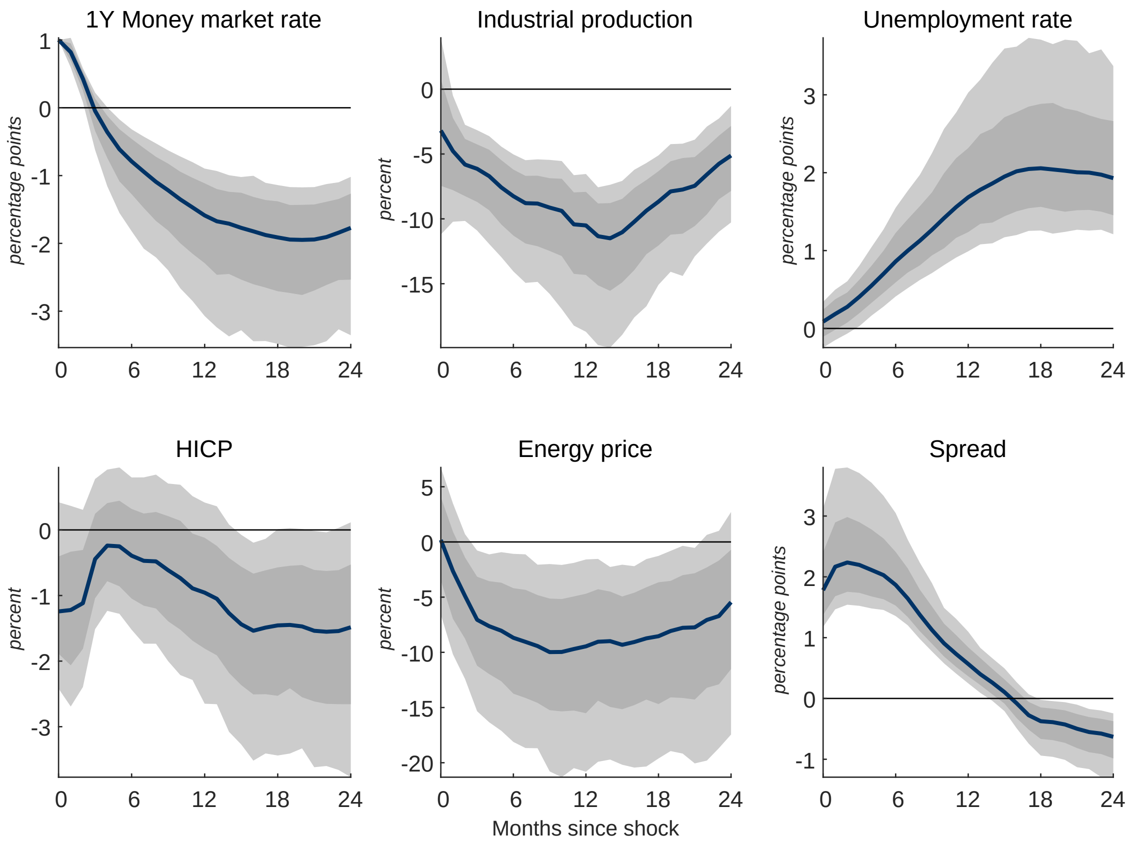


FIGURE D.6. Impulse-responses when 1-year money market rate is used as policy variable

References

Altavilla, C., Brugnolini, L., Gürkaynak, R. S., Motto, R., and Ragusa, G. (2019). "Measuring euro area monetary policy." *Journal of Monetary Economics*, vol. 108, pp. 162–179 (cited on page 1).

Gürkaynak, R. S., Sack, B., and Swanson, E. T. (2005). "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements." *International Journal of Central Banking*, vol. 1(1), pp. 55–92 (cited on page 1).

Jarociński, M. (2022). "Central bank information effects and transatlantic spillovers." *Journal of International Economics*, vol. 139, pp. 103683 (cited on pages 3, 6).