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MONETARY TRANSMISSION IN ICELAND: EVIDENCE FROM A STRUCTURAL VAR MODEL

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Monetary transmission in Iceland: Evidence from a structural VAR model

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Abstract

This paper analyses the transmission mechanism of monetary policy in Iceland using three alternative identification schemes in a structural VAR setting. Consistent with the international literature, we find that an unexpected monetary policy tightening leads to a temporary but sizable contraction in output, a sustained appreciation of the nominal exchange rate, and a more sluggish and persistent decline in inflation. Three other structural shocks are also identified. All have a plausible economic interpretation and can explain the bulk of the variation in output and inflation over our sample period. By comparison, the contribution from monetary policy shocks is relatively modest, especially to output fluctuations. Historical decomposition shows, however, that monetary policy played an important role during the disinflation of the second half of the 2010s and in offsetting a large negative demand shock following the global pandemic at the start of this decade. However, the historical decomposition also suggests that the withdrawal of the post-Covid monetary easing was too slow, thus contributing to rising inflation by the end of the sample period.

JEL classification: C32, E52, F41.
Keywords: Monetary policy transmission, structural VAR, Iceland.

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1 Introduction

How does monetary policy affect economic activity and inflation? How large are these effects and how long are the transmission lags? How big a role does monetary policy have in explaining business cycle fluctuations and historical episodes of rising and falling inflation? These questions lie at the core of monetary economics and are of primary importance for the implementation of monetary policy in any country. We tackle these questions for the Icelandic economy using a structural vector autoregression (VAR), which has become a standard workhorse model for analysing the transmission mechanism of monetary policy since the seminal work of Sims (1980).

The VAR model includes output, inflation, the nominal exchange rate, and the monetary policy interest rate. The model is estimated for the period 2009-2022, thus avoiding the risk that our results becoming dominated by the financial crisis in 2008. To identify the structural shocks in the model a minimum number of identifying restrictions need to be imposed on the VAR. Three alternative identification schemes are used: two recursive schemes based on the standard Cholesky decomposition and one, more general, non-recursive scheme. The main results are found to be robust across these three identification schemes. All produce dynamic effects of monetary policy shocks that are both plausible and similar to what is typically found in the literature: an unanticipated tightening of monetary conditions (defined as an unexpected rise in the short-term nominal interest rate) leads to a transitory but sizable contraction in economic activity, a sustained appreciation of the nominal exchange rate, and a more sluggish and persistent decline in inflation.

The VAR model is also used to identify three other structural shocks that all have an economically plausible interpretation. The first is a positive demand shock that drives up output and inflation and leads to a rise in interest rates and an appreciation of the currency. The second is a negative supply shock that pushes up inflation at the same time as output contracts and the currency depreciates. This also triggers a monetary tightening but one that is more muted than in response to the demand shock. The third shock is interpreted as a positive shock to capital inflows which leads to an appreciation of the currency, raises output and inflation, and pushes up domestic interest rates.

Although the results suggest that the contribution of monetary policy shocks to output and, to a lesser extent, inflation fluctuations is relatively modest over the whole sample period, historical decomposition of the variation in the data suggests that the relatively tight monetary policy in the mid-2010s played a key role in the disinflation episode in the latter half of the decade and a relatively easy monetary stance played an important role in supporting economic activity when a negative demand shock pushed the economy into a deep contraction following the Covid-19 pandemic in early 2020.

However, the historical decomposition also suggests that the withdrawal of the post-Covid monetary easing was too slow, thus contributing to rising inflation by the end of the sample period.

We conclude the analysis by extending the VAR model to study the effect of an unexpected tightening of monetary policy in trading partner countries, which we find leads to a depreciation of the currency and pushes up domestic inflation, despite a rise in the domestic policy rate and a reduction of domestic output.

The remainder of the paper is structured as follows. In Section 2, we discuss the structural VAR approach and the restrictions that need to be imposed on the model to identify the structural shocks. Section 3 discusses the data and reports the empirical results. Section 4 concludes. An Appendix documents the robustness of our key results across the three alternative identification schemes that are utilised.

2 Identifying monetary policy shocks

Assume, as in Eichenbaum and Evans (1995) and Christiano et al. (1999), that monetary policy can be described as:

$$r_t = \theta(\Omega_t) + \epsilon_t^r \tag{1}$$

where r_t is the monetary policy rate (a short-term nominal interest rate), Ω_t is the monetary policy authority's information set, and θ is a linear function that maps this information into a time t policy rate decision. $\theta(\Omega_t)$ therefore captures the systematic component of monetary policy, i.e. the authority's reaction function. It can be interpreted literally as a monetary policy rule (e.g. a Taylor rule) or, more generally, as simply capturing all the time t information used by the monetary authority to generate their expectations on the future course of the economy. The serially uncorrelated random variable, ϵ_t^r, therefore captures shocks that are orthogonal to the elements of Ω_t and can therefore be interpreted as "monetary policy shocks" (i.e. unexpected deviations from the average monetary policy reaction). The standard approach in the literature is to focus on this non-systematic part of monetary policy (ϵ_t^r) rather than simply the actions of policy makers (i.e. the policy rate, r_t, itself) as the latter also contains the endogenous responses of monetary policy to all other structural shocks, making it difficult to interpret and make a meaningful inference about the causal effects of monetary policy on the economy without a complete structural model of the economy.[1]

[1] Thus, as Ramey (2016) points out, the identification of monetary policy shocks is in essence a search for instruments to identify the response of the economy to monetary policy.

Christiano et al. (1999) offer three alternative interpretations of these shocks. First, they can reflect exogenous shocks to the preferences of the monetary authority which causes a stochastic change in the relative weights of inflation and economic activity in their reaction functions (for example, because of changes in the composition of the monetary policy committee or changes in the relative power of individual committee members). Second, as discussed in Ball (1995) and Chari et al. (1998), exogenous variations in r_t, captured by ϵ_t^r, can arise from the monetary authority's strategic desire to avoid surprising private agents (i.e. if self-fulfilling shocks to private agents' expectations about monetary policy leads to exogenous variations in r_t). Finally, as discussed in Bernanke and Mihov (1998), the monetary policy shocks can reflect measurement errors in the preliminary data contained in Ω_t and available to the monetary authority at time t (in particular, the estimation of output and unemployment gaps, cf. Orphanides et al., 2000).

A standard approach to extracting these monetary policy shocks from the data and to analyse the dynamic responses of other economic variables to these shocks is the vector autoregression (VAR) approach pioneered in the seminal work of Sims (1980). This allows all the variables in the model to be treated as endogenous and requires only a minimum set of identification restrictions in order to allocate movements in these variables to different underlying structural shocks (i.e. shocks that can be given an economic interpretation), such as shifts in demand and supply and unforeseen changes in the monetary stance.

In particular, assume that the dynamic behaviour of the economy can be described by the following multivariate structural model (abstracting from deterministic variables to simplify the exposition):[2]

$$\boldsymbol{A}_0\boldsymbol{x}_t = \boldsymbol{A}(L)\boldsymbol{x}_t + \boldsymbol{B}(L)\boldsymbol{z}_t + \boldsymbol{\epsilon}_t \tag{2}$$

where $\boldsymbol{x}_t$ is a $n \times 1$ vector of endogenous macro variables of interest and $\boldsymbol{A}(L) = \boldsymbol{A}_1 L + \cdots + \boldsymbol{A}_k L^k$ is a $n \times n$ matrix polynomial of order k in the lag operator ($L^j x_t = x_{t-j}$). The VAR can also include a second set of $m \times 1$ variables, $\boldsymbol{z}_t$, that are exogenous and, in the context of a small open economy, are typically foreign variables that control for changes in the external environment (where $\boldsymbol{B}(L) = \boldsymbol{B}_1 + \cdots + \boldsymbol{B}_h L^h$ is a $n \times n$ lag polynomial of order h). These variables are allowed to contemporaneously impact the domestic economy.

The $n \times 1$ vector $\boldsymbol{\epsilon}_t$ reflects the set of n structural shocks (including monetary policy shocks) that drive the economy. These structural shocks are serially uncorrelated

[2] As shown by Blanchard and Kahn (1980), solutions to any linear rational expectations model can be represented by a structural VAR such as Eq. (1).

with a variance-covariance matrix given by the diagonal $n \times n$ matrix $\mathrm{E}(\boldsymbol{\epsilon}_t \boldsymbol{\epsilon}_t') = \boldsymbol{\Sigma}$ (thus restricting the structural shocks to be mutually uncorrelated). Finally, $\boldsymbol{A}_0$ is an $n \times n$ matrix that summarises the contemporaneous relationships between the variables of the VAR.

The structural shocks are unobservable but can be retrieved from the data if $\boldsymbol{A}_0$ is invertible, using the associated reduced form of the VAR:

$$\boldsymbol{x}_t = \boldsymbol{C}(L)\boldsymbol{x}_t + \boldsymbol{F}(L)\boldsymbol{z}_t + \boldsymbol{u}_t \tag{3}$$

where $\boldsymbol{C}(L) = \boldsymbol{A}_0^{-1}\boldsymbol{A}(L)$, $\boldsymbol{F}(L) = \boldsymbol{A}_0^{-1}\boldsymbol{B}(L)$, and $\boldsymbol{u}_t = \boldsymbol{A}_0^{-1}\boldsymbol{\epsilon}_t$ are the reduced form one-step ahead forecast errors of the VAR with a variance-covariance matrix $\mathrm{E}(\boldsymbol{u}_t \boldsymbol{u}_t') = \mathbf{V}$.

The structural shocks and their variance-covariance matrix can therefore be retrieved from the reduced form parameters as:[3]

$$\boldsymbol{\epsilon}_t = \boldsymbol{A}_0 \boldsymbol{u}_t; \ \boldsymbol{\Sigma} = \boldsymbol{A}_0 \mathbf{V} \boldsymbol{A}_0' \tag{4}$$

There are n^2 elements in $\boldsymbol{A}_0$ and n in $\boldsymbol{\Sigma}$. There are therefore $n(n+1)$ unknown structural parameters that need to be identified from the $n(n+1)/2$ distinct elements contained in $\mathbf{V}$. The diagonal of $\boldsymbol{A}_0$ can be normalised to unity without any loss of generality, reducing the number of additional restrictions that need to be imposed on the reduced form VAR to $n(n-1)/2$ to exactly identify the structural VAR. Three alternative set of restrictions to accomplish this are discussed in the following section.

3 Empirical results

3.1 The data

The VAR model includes the standard variables used to analyse the transmission mechanism of monetary policy in a small open economy, i.e. a monetary policy instrument (typically a short-term interest rate), the exchange rate, inflation, and real output. As a monetary policy instrument, the Central Bank of Iceland key interest rate is used (r_t, a 7-day nominal interest rate measured in percentages). Inflation is measured in year-on-year terms in percentages ($\pi_t = 100\log(P_t/P_{t-4})$), where P_t is the Consumer Price Index, CPI). The exchange rate is measured using the log of the nominal effective exchange rate ($e_t = 100\log(1/E_t)$), where E_t is the trade-weighted average exchange

[3] An alternative approach to identifying monetary policy shocks is to combine the contemporaneous (short-run) restrictions used here with the Blanchard and Quah (1989) long-run restrictions approach, as in Galí (1992) and Gerlach and Smets (1995). The relatively short sample period used here makes this approach impractical, however.

index, which measures the amount of local currency (króna) needed to buy one unit of foreign currency. As the inverse of E_t is used, a rise in e_t reflects an appreciation of the króna. Real output is measured as the seasonally adjusted (using X12) log of real GDP ($y_t = 100\log(Y_t)$), where Y_t is real GDP (the data are multiplied by 100 to ensure that deviations from the pre-shock baseline in the VAR have the same units for all the four variables).

Grilli and Roubini (1995) show that it is important to control for global monetary policy (which they proxy using US monetary policy) in VAR models of small open economies and Sims (1992) shows that this is best captured by a short-term interest rate rather than, for example, money aggregates. The VAR is therefore also conditioned on the contemporaneous value of a trade-weighted average foreign monetary policy rate (r_t^w) to capture external monetary conditions.[4]

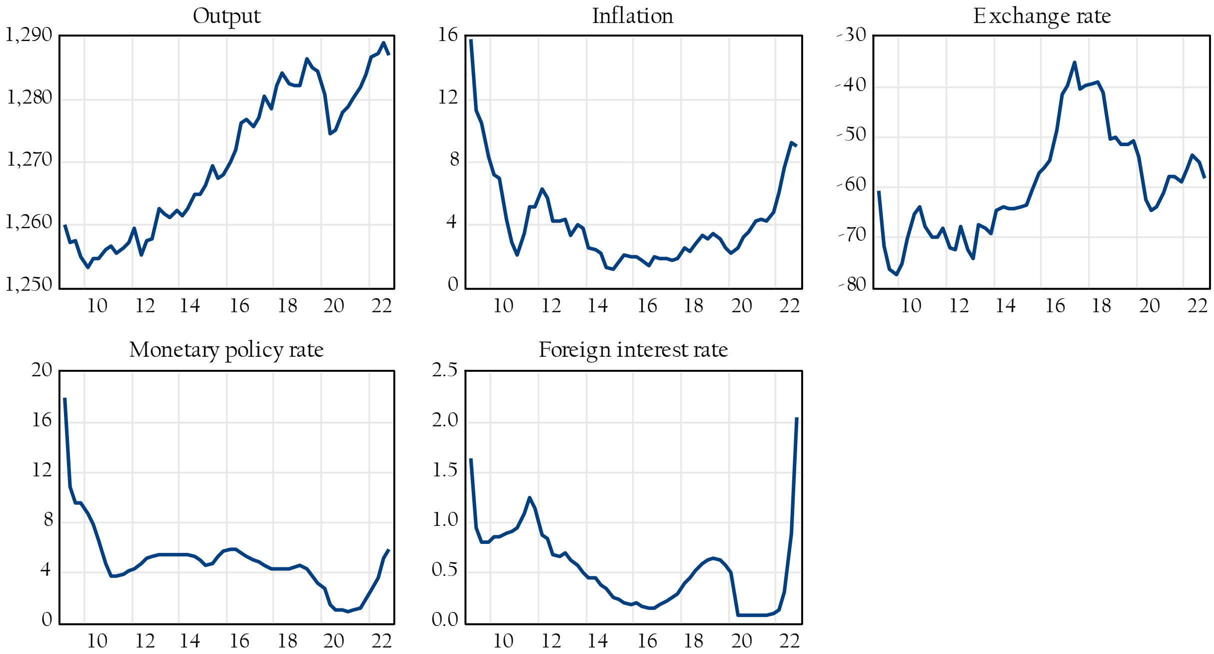

Figure 1 The data.

We use quarterly data from 2009Q1 to 2022Q4, shown in Figure 1 (the GDP and CPI data come from Statistics Iceland, while the exchange rate and interest rate data are from the Central Bank of Iceland). The analysis therefore starts after the financial crisis in 2008 which led to a collapse of the local banking system and the currency, together with a large contraction in output and a sharp rise in inflation (see, for example, Einarsson et al., 2015, for a discussion of the financial crisis) to avoid the risk of our

[4] Other studies often include a richer list of foreign variables, such as foreign output and inflation, and global oil and commodity prices. Here, the foreign conditional information set is limited to the average trading partners' monetary policy rate to conserve degrees of freedom given the relatively short sample period.

results being dominated by this extreme and unique event. The starting point of the analysis also coincides with major monetary policy reforms following the financial crisis, which included the introduction of a new five-member monetary policy committee (MPC), revisions to the policy toolkit, and publications of MPC minutes and other widespread reforms designed to increase monetary policy transparency (see Pétursson, 2019, for more details).

3.2 The dynamic effects of monetary policy shocks

For our four-dimensional VAR, the variable vector becomes $\boldsymbol{x}_t' = (y, \pi_t, e_t, r_t)$. The VAR is estimated with 1 lag as suggested by the Schwartz information criterion and includes the contemporaneous value of the foreign interest rate, $\boldsymbol{z}_t = r_t^w$ as an exogenous variable. The estimated model is therefore given as:

$$\begin{pmatrix} y_t \\ \pi_t \\ e_t \\ r_t \end{pmatrix} = \boldsymbol{C} \begin{pmatrix} y_{t-1} \\ \pi_{t-1} \\ e_{t-1} \\ r_{t-1} \end{pmatrix} + \boldsymbol{F} r_t^w + \begin{pmatrix} u_t^y \\ u_t^\pi \\ u_t^e \\ u_t^r \end{pmatrix} \tag{5}$$

where $\boldsymbol{C}$ and $\boldsymbol{F}$ are now a 4×4 matrix and 4×1 vector of coefficients, respectively.

The estimated VAR is found to be stable with all roots inside the unit circle. Furthermore, there is no evidence of any residual autocorrelation (a LM test for first order autocorrelation gives a p-value equal to 0.70).

3.2.1 A recursive identification scheme with monetary policy responding to the contemporaneous value of the exchange rate

With $n = 4$, we need to impose $n(n-1)/2 = 6$ restrictions on the $\boldsymbol{A}_0$ matrix to identify the four structural shocks in the model. The most common approach to identifying monetary policy shocks in a VAR model is to orthogonalize the reduced form residuals using a Cholesky decomposition (cf. Sims, 1980, and Christiano, et al., 1999) which imposes a recursive structure (or a Wold causal chain) on the shocks by assuming that the $\boldsymbol{A}_0$ is a lower triangular matrix:

$$\boldsymbol{A}_0 \boldsymbol{x}_t = \begin{pmatrix} 1 & 0 & 0 & 0 \\ -\beta_1 & 1 & 0 & 0 \\ -\gamma_1 & -\gamma_2 & 1 & 0 \\ -\lambda_1 & -\lambda_2 & -\lambda_3 & 1 \end{pmatrix} \begin{pmatrix} y_t \\ \pi_t \\ e_t \\ r_t \end{pmatrix} \tag{6}$$

The recursive ordering therefore assumes a monetary policy reaction function where the monetary authority observes and reacts to the contemporaneous values of all the three other macro variables. The exchange rate is allowed to respond contemporaneously to shocks in output and inflation but not to monetary policy shocks, while inflation only reacts to output shocks contemporaneously. Output is assumed to be the most exogenous variable in the system, reacting only to the other variables with a one quarter lag.

This recursive ordering therefore implies that monetary policy only affects the other three variables with a lag. The delayed responses of output and inflation is a standard assumption in the VAR literature – reflecting the inherent inertia (e.g. adjustment costs, planning delays, and staggered wage and price contracts) in real activity and price setting decisions found in many theoretical macro models (see, for example, Sims and Zha, 2006). Although other papers have also restricted the exchange rate from reacting contemporaneously to a monetary policy shock (e.g. Mojon and Peersman, 2003, Jääskelä and Jennings, 2011), this is a more contentious assumption, and we will return to this issue below.

From $\boldsymbol{\epsilon}_t = \boldsymbol{A}_0 \boldsymbol{u}_t$ in Eq. (4), we see that these identifying restrictions imply that the output shock is simply given as the reduced form output equation residual, while the other three shocks are a linear combination of two or more of the four VAR residuals:

$$\begin{pmatrix} \epsilon_t^y \\ \epsilon_t^\pi \\ \epsilon_t^e \\ \epsilon_t^r \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ -\beta_1 & 1 & 0 & 0 \\ -\gamma_1 & -\gamma_2 & 1 & 0 \\ -\lambda_1 & -\lambda_2 & -\lambda_3 & 1 \end{pmatrix} \begin{pmatrix} u_t^y \\ u_t^\pi \\ u_t^e \\ u_t^r \end{pmatrix} \tag{7}$$

Figure 2 shows the resulting impulse responses from a one standard deviation shock to the policy interest rate over a five-year period. Thus, the policy rate rises by 65 basis points on impact before gradually returning to its baseline level in roughly 2 years (reflecting the policy reaction to the disinflation caused by the initial policy tightening) based on the 68% confidence interval reported (calculated using the asymptotic distribution of the VAR coefficients and covariance matrix of the innovations).

The impulse responses of the other three variables display the typical hump-shapes found in the literature with a contractionary monetary policy shock leading to an appreciation of the currency and a reduction in output and inflation that are both sizable and statistically significant. The output effect peaks after 6 quarters when output is almost 0.6% below its pre-shock level but the effect is transitory and becomes statistically insignificant after 9 quarters. Inflation, as is typically found, is more sluggish than output, however: the effect on inflation reaches a peak after 10 quarters at 0.4 percentage points below its pre-shock level. The effect on inflation is also more persistent than on output, lasting for roughly 5 years based on the confidence interval.

While these responses of output and inflation to the monetary tightening are consistent with standard macro theory, the exchange rate reaction is not fully in accordance with the simple uncovered interest rate parity (UIP) theory which suggests that the exchange rate should appreciate immediately following a monetary tightening before gradually depreciating again to offset the widening interest rate differential vis-à-vis abroad. As Figure 2 shows, the currency does indeed appreciate, but inconsistent with the UIP prediction, what follows is a long and sustained period of appreciation – with the króna still 1% higher relative to its pre-shock level after about 2 years and remaining significantly above its pre-shock for about 4 years.

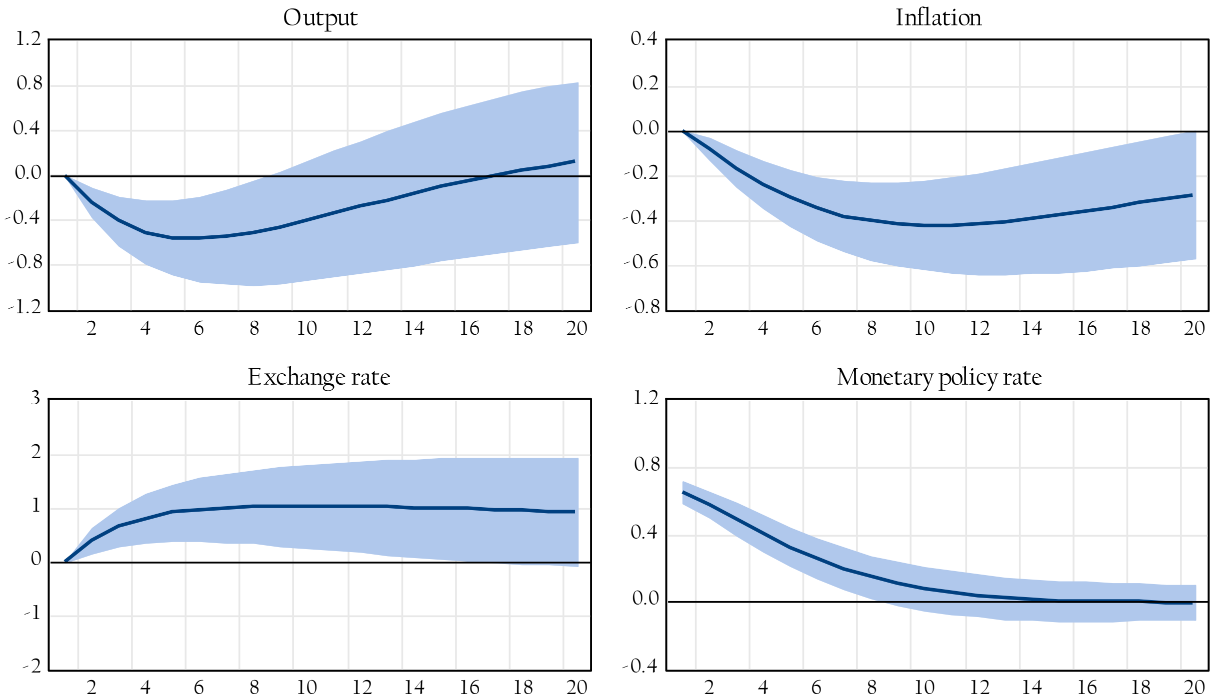

Figure 2 The effects of a 1 standard deviation monetary policy shock over a 20 quarters period using the identifying restrictions from Eq. (7). Shaded area shows the 68% confidence interval.

This persistent hump-shaped exchange rate appreciation implies that, following a monetary policy tightening, expected returns of investing in domestic short-term bonds rises relative to the returns from investing in similar assets abroad – and that these excess returns are persistent. Similar results have been found in many other VAR-based analyses of monetary policy shocks, such as Eichenbaum and Evans (1995), and is often referred to as the "forward discount bias puzzle" or the "delayed overshooting puzzle". It is consistent with a large literature on the failure of forward exchange rates to predict future spot rates (cf. Froot and Thaler, 1990) and is more in line with exchange rate models with learning (cf. Gourinchas and Tornell, 1996) in which agents are uncertain whether they should interpret monetary policy shocks as being temporary or more persistent (see Eichenbaum and Evans, 1995). As reported below, these persistent deviations from the UIP following a monetary shock turn out to be robust to alternative identification schemes (see also the discussions in Faust and Rogers, 2003).

3.2.2 A recursive identification scheme with monetary policy responding to the previous quarter's value of the exchange rate

The recursive structure above delivers plausible estimates of the dynamic effects of monetary policy shocks on output and inflation and while the exchange rate appreciates as expected, the lack of a contemporaneous exchange rate response can be questioned as discussed in more detail below. An alternative recursive ordering is therefore to assume that the exchange rate reacts immediately to a monetary policy shock while the policy rate reacts only to the exchange rate with a delay (as in Eichenhaum and Evans, 1995, and Peersman and Smets, 2003). This simply amounts to reversing the order of the exchange rate and policy rate which, in the context of the structure of our VAR model, implies the following mapping from the reduced form residuals to the structural shocks:

$$\begin{pmatrix} \epsilon_t^y \\ \epsilon_t^\pi \\ \epsilon_t^e \\ \epsilon_t^r \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ -\beta_1 & 1 & 0 & 0 \\ -\gamma_1 & -\gamma_2 & 1 & -\gamma_4 \\ -\lambda_1 & -\lambda_2 & 0 & 1 \end{pmatrix} \begin{pmatrix} u_t^y \\ u_t^\pi \\ u_t^e \\ u_t^r \end{pmatrix} \tag{8}$$

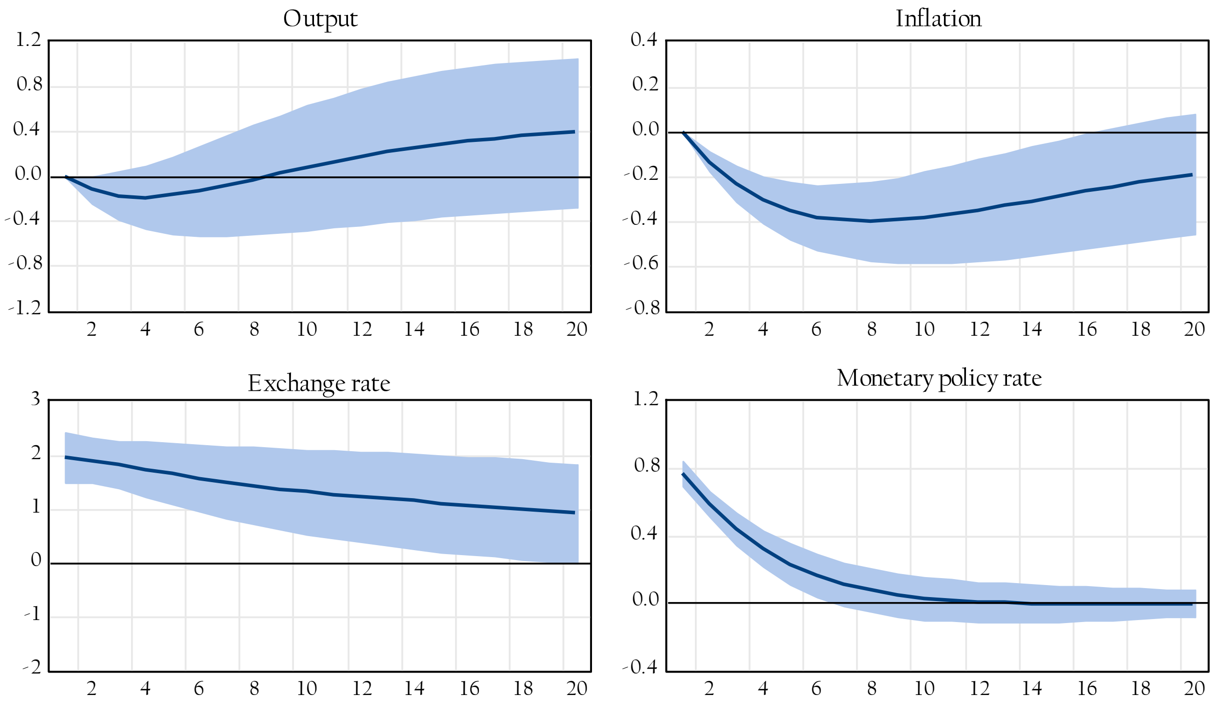

Figure 3 The effects of a 1 standard deviation monetary policy shock over a 20 quarters period using the identifying restrictions from Eq. (8). Shaded area shows the 68% confidence interval.

As shown in Figure 3, the impulse responses for output and inflation are qualitatively very similar to those reported in Figure 2. Output declines with a peak effect of 0.2% 4 quarters after the initial shock. The output effect is therefore smaller than previously found and is only significant in the first quarter after the initial shock. The dynamic effects on inflation are, however, almost identical to what was previously reported although the peak impact occurs slightly earlier and dies out somewhat faster based on the confidence bands. The short- to medium-term reaction of the exchange rate has, however, significantly changed from what is reported in Figure 2. Now, the currency appreciates on impact by almost 2% before gradually returning to baseline with a long-run adjustment that is very similar to what was found with the previous identification scheme. The re-ordering of the recursive structure of the model does therefore not alter the finding of sustained deviations from the UIP previously reported.

3.2.3 A non-recursive identification scheme

The two previous recursive identifying schemes are simple to implement and yield plausible results for the dynamic responses to a monetary policy shock. But both involve identifying assumptions that are perhaps not fully satisfying in terms of a small open economy such as Iceland. We therefore pursue an alternative non-recursive identification scheme that allows for contemporaneous feedback effects, following the more generalised structural VAR approach suggested by Blanchard and Watson (1986), Bernanke (1986), and Sims (1986).

First, we address the assumption of our first recursive scheme in Eq. (7) that restricted the exchange rate from responding contemporaneously to a monetary policy shock. This seems to be too restrictive given that the exchange rate is a forward-looking asset price that should be able to respond to all shocks immediately (cf. Sims and Zha, 2006, and Kim and Roubini, 2000). At the same time, the assumption that monetary policy does not react to the contemporaneous value of the exchange rate in the second recursive scheme in Eq. (8) is not fully satisfying either. For such a small economy it seems plausible to assume that the monetary authority would be concerned about the effects of an exchange rate depreciation on inflation and would want to react contemporaneously with a monetary tightening, even within an inflation targeting framework.

Second, for such a small open economy, with a large component of the consumption basket imported from abroad, it appears plausible to allow inflation to react contemporaneously to exchange rate shocks (see, for example, Gerlach and Smets, 1995, and Cushman and Zha, 1997) – which is excluded in both the recursive structures analysed above. This is of particular importance given the history of relatively high and rapid pass-through of exchange rate fluctuations to inflation in Iceland (cf. Pétursson, 2008). Finally, following the timing structure typically used in specifications of the

Phillips curve in Iceland (cf. Pétursson, 2018, and Daníelsson et al., 2019), we also assume that inflation adjusts to fluctuations in real economic activity with a one quarter lag.[5]

If we continue to assume that monetary policy only affects output and inflation with a lag, and that output responds to the two other shocks with a delay, we are left with 5 restrictions on $\boldsymbol{A}_0$ – thus, one restriction short of what is needed. For our final identification restriction, we follow a common practice in the literature and assume that monetary policy does not react to the contemporaneous value of output. This restriction can be motivated on the grounds of an information delay, i.e. the fact that the monetary authority does not observe y_t immediately but only with a delay as quarterly GDP data is released with a one quarter lag (see, for example, Leeper et al., 1996, and Sims and Zha, 2006). Note that this does not imply that monetary policy does not respond to output variations. To see that, note that the interest rate equation in the structural VAR in Eq. (2) (with 1 lag) can be written as $r_t = \lambda_1 y_t + \lambda_2 \pi_t + \lambda_3 e_t + a_y y_{t-1} + a_\pi \pi_{t-1} + a_e e_{t-1} + a_r r_{t-1} + b r_t^w + \epsilon_t^r$, with the part excluding ϵ_t^r specifying the monetary policy reaction function (or the systematic part of monetary policy, $\theta(\Omega_t)$, in Eq. (1)). Thus, even if $\lambda_1 = 0$ as in the identification scheme in Eq. (9), monetary policy reacts to output variations but just to its previous quarter's value due to the informational lag inherent in GDP data.

The non-recursive identification scheme thus gives the following restrictions on $\boldsymbol{A}_0$:

$$\begin{pmatrix} \epsilon_t^y \\ \epsilon_t^\pi \\ \epsilon_t^e \\ \epsilon_t^r \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & -\beta_3 & 0 \\ -\gamma_1 & -\gamma_2 & 1 & -\gamma_4 \\ 0 & -\lambda_2 & -\lambda_3 & 1 \end{pmatrix} \begin{pmatrix} u_t^y \\ u_t^\pi \\ u_t^e \\ u_t^r \end{pmatrix} \tag{9}$$

As Figure 4 shows, the dynamic responses of output and inflation are qualitatively almost identical to those previously reported: output declines temporarily with a peak effect of 0.5% after 5 quarters. The responses are found to be significant but to have died out after 7 quarters based on the estimated confidence interval. The output effect is therefore similar in size to the one in Figure 2 but peaks a quarter earlier.

As noted above, inflation is allowed to react contemporaneously to exchange rate fluctuations in this identification scheme, which opens the possibility of a

[5] We also tried restricting the contemporaneous impact of the exchange rate on inflation to be zero but allowing a contemporaneous effect of output on inflation (as in the two recursive identification schemes). This obviously forces the contemporaneous effect of a monetary policy shock on inflation to be zero while otherwise the results are almost identical to those reported here (although the effect on output becomes less precisely estimated, with a statistically significant impact only observed in the first quarter after the shock as in the specification in Eq. (8)).

contemporaneous reaction of inflation to monetary policy shocks through the exchange rate (i.e. through β_3). As the figure shows, the monetary policy shock does indeed affect inflation contemporaneously, but the impact is found to be positive even though the exchange rate does appreciate at impact and the point estimate of $\beta_3 = 0.16$ is correctly signed. The impact effect is however statistically insignificant from zero (and a LR over-identification test for zero contemporaneous impact gives a p-value equal to 0.28) and from the second quarter, inflation starts to decline significantly in a similar manner to that found using the previous identification schemes: the effect is more delayed and persistent than that on output – it peaks at 0.4 percentage points below its pre-shock level after 10 quarters but has died out after almost 5 years.[6]

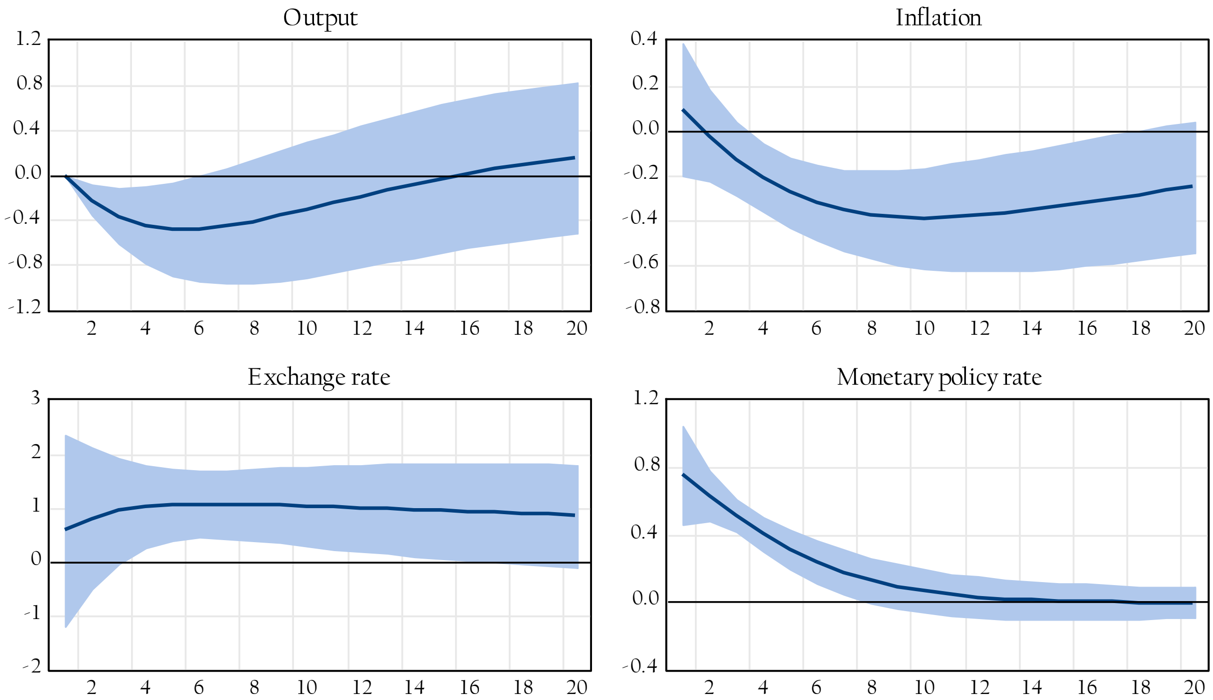

Figure 4 The effects of a 1 standard deviation monetary policy shock over a 20 quarters period using the identifying restrictions from Eq. (9). Shaded area shows the 68% confidence interval.

As in the second recursive identification scheme in Eq. (8), the exchange rate appreciates on impact and remains persistently above its pre-shock level for roughly 4 years based on the estimated confidence interval. The shape of the impulse response is,

[6] A positive contemporaneous or short-run effect of monetary tightening on prices (or inflation) before a steady decline is sometimes reported in the literature and is commonly referred to as the "price puzzle", typically thought to arise because some measure of expected future inflation pressures (typically proxied using oil or commodity prices) is missing from the estimated monetary reaction function (cf. Sims, 1992). Note that in an open economy context, the exchange rate basically assumes the role of this information variable (cf. Sims and Zha, 2006). The price puzzle is also sometimes explained as reflecting temporary supply-side cost effects through the impact of monetary policy on the cost of working capital (see, for example, Barth and Ramey, 2002, and Christiano et al., 2005).

however, slightly different from that reported in Figure 3: there the peak effect is at impact which is followed by a monotonic decline but here (as in Eichenbaum and Evans, 1995), the króna appreciates by 0.6% on impact with a peak effect of 1% in roughly a year. Furthermore, here the exchange rate response only becomes statistically significant after 3 quarters.

We will focus on the VAR identification scheme in Eq. (9) in what follows but, just as for the monetary policy shocks reported above, our other key findings are found to be robust across the three identification schemes as documented in Appendix 1.

3.2.4 Comparison with impulse responses from a typical macro model

The literature on the monetary policy transmission mechanism in Iceland is rather scarce. Pétursson (2001a) gives an overview and general description of the key transmission channels, with preliminary estimates of the dynamic effects of monetary policy shocks using a simple VAR model, while Pétursson (2001b) and Central Bank of Iceland (2018, 2023) focus only on segments of the transmission mechanism. Analysis of the key macro effects of monetary policy for comparison with our results is therefore difficult to come by. Our estimates of the dynamic effects of monetary policy can, however, be compared to impulse responses from the Central Bank of Iceland's main macro model, QMM (a medium-sized forward-looking macro-econometric model; see, Daníelsson et al., 2019).

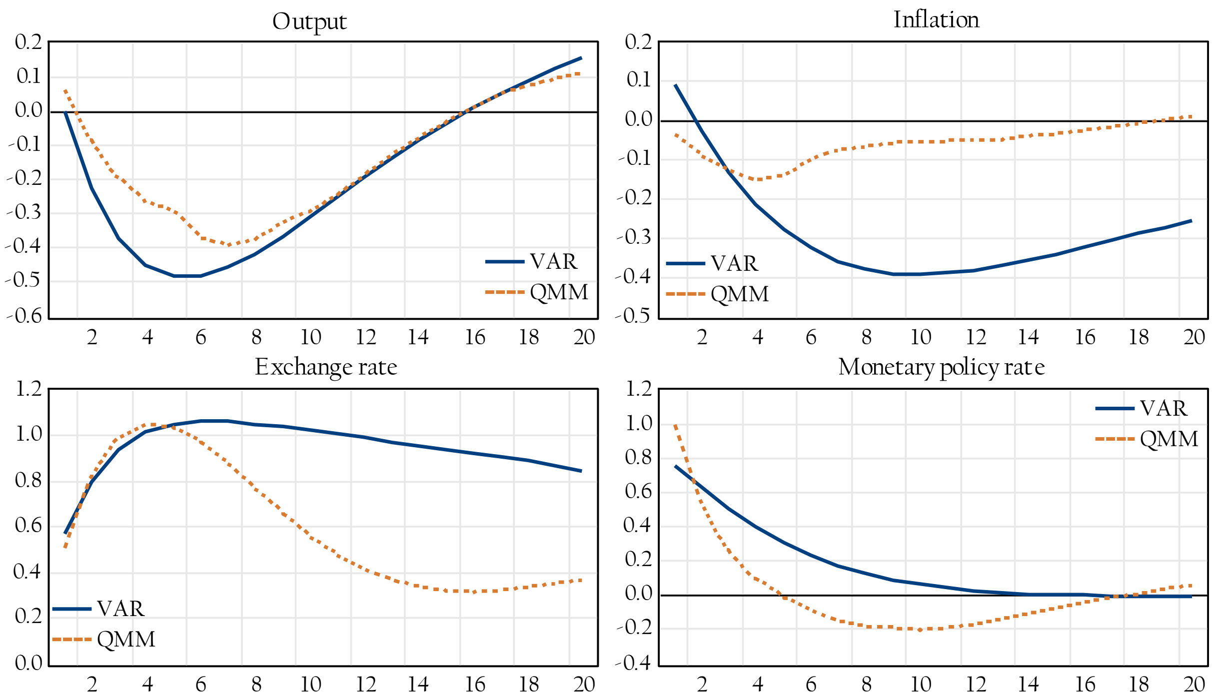

Figure 5 Comparing impulse responses from the non-recursive VAR in Eq. (9) and the Central Bank of Iceland QMM macro model.

As Figure 5 shows, the output responses are almost identical in the two models. The short-run effect on inflation is also similar but the medium-term effects in the VAR model are both larger and more persistent (with the peak effect roughly twice as large in the VAR model). Although the impulse responses for the exchange rate are almost identical for the first year after the shock, the VAR produces a more persistent appreciation – which explains the more persistent inflationary effect.

The impulse responses for output also appear broadly similar to what is typically found in VAR analyses for other countries, both in terms of size and transmission lags (see, for example, Gerlach and Smets, 1995, Kim, 1999, Peersman and Smets, 2003, and Ramey, 2016). The inflationary effects appear somewhat larger, however, although the transmission lags are similar to what is typically found in other advanced economies (see Havranek and Rusnak, 2013, and International Monetary Fund, 2023).

3.3 The dynamic effects of the three other structural shocks

Monetary policy shocks are of course not the only structural shocks in our VAR model, and it is of interest to analyse whether a meaningful economic interpretation can also be attached to the other three shocks – i.e. the shocks to output, inflation, and the exchange rate. It turns out that the other shocks do in fact have a meaningful behavioural interpretation.

First, we look at the output shock (ϵ_t^y) reported in the first column of Figure 6. As the figure shows, the shock leads to a rise in output and inflation, triggering a monetary tightening and an appreciation of the exchange rate. This looks very much like a positive demand shock (e.g. an autonomous spending shock triggered, for example, by fiscal policy or external demand). The shock has a persistent effect on output (with output still above its pre-shock level 5 years after the shock), but the effects on the other three variables have died out in 2-3 years based on the estimated confidence intervals.

The inflationary shock (ϵ_t^π) is reported in the second column of Figure 6. Unlike in the previous case, this shock leads to a rise in inflation but a fall in output – lending itself to an obvious interpretation of a supply shock were real activity and inflation move in the opposite direction (e.g. an exogenous change to commodity prices or the terms of trade, or a productivity shock). Despite a larger increase in inflation, the response of monetary policy is more muted than in the previous case as the monetary authority now faces the difficult trade-off of rising inflation and falling output. The ensuing decline in real interest rates (reflecting the declining return to capital caused by the negative supply shock) leads to a persistent depreciation of the exchange rate, which adds to the inflationary pressures but, at the same time, supports real activity through a boost to net exports. Just as for the demand shock, the supply shock has a persistent effect on output, but inflation returns faster to its pre-shock level as the downward pressures on output offset the positive inflationary pressures arising from the supply shock and the exchange rate depreciation.

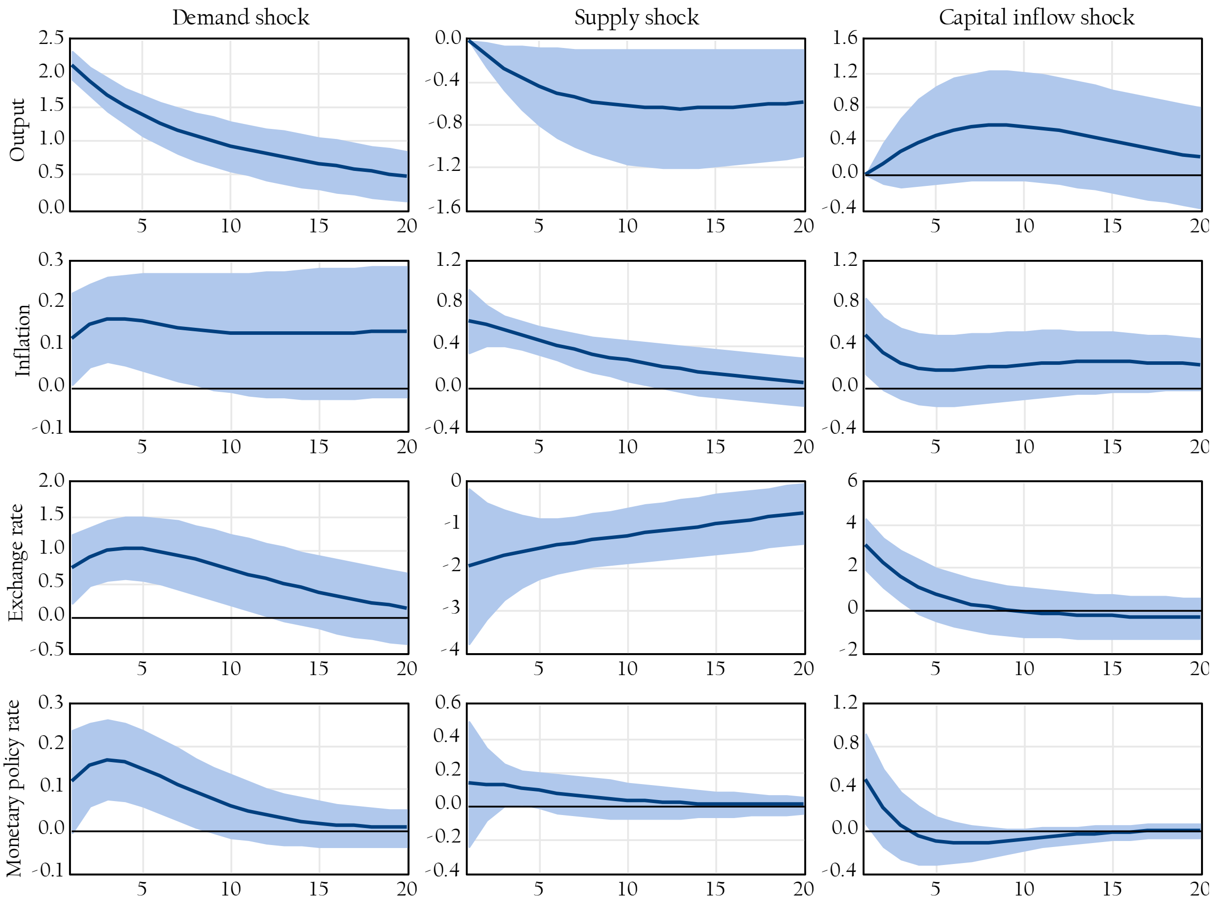

Figure 6 The effects of a 1 standard deviation shocks to output (demand shock), inflation (supply shock), and the exchange rate (capital inflow shock) over a 20 quarters period using the identifying restrictions from Eq. (9). Shaded area shows the 68% confidence interval.

The last column of Figure 6 shows the dynamic responses to a positive shock to the nominal exchange rate (ϵ_t^e). This shock leads to an appreciation of the exchange rate that lasts for a year, with output and inflation also increasing, and monetary policy tightening. One way to interpret this shock is as a capital inflow shock where an inflow of foreign capital into the economy appreciates the local currency and increases domestic economic activity. This increase in economic activity pushes up inflation, despite the currency appreciation lowering import prices, and triggers a rise in the monetary policy interest rate to avoid a fall in real interest rates and to ensure that inflation eventually returns to target. Unlike in the case of the two previous shocks, the impact of the capital inflow shock is relatively short-lived and, in the case of output, statistically insignificant, presumably reflecting the offsetting forces pushing output and inflation in opposite directions (with the boost in domestic spending pushing against the negative net export effect on output and the boost in activity pushing against the deflationary impact of the exchange rate appreciation on inflation). The difference in the dynamic responses to the capital inflow shock and the monetary policy shock reported earlier are also worth highlighting. Both lead to an appreciation of the currency and a rise in the monetary policy rate, but the impact on output and inflation are drastically different. In the case of the monetary policy shock, tighter monetary conditions lead to a decline in activity and inflation, while the capital inflow shock pushes up activity and inflation.

An alternative interpretation of this shock is to think of it as a negative exchange rate risk premium shock (a decline in the risk premium that appreciates the domestic currency). However, this interpretation appears less convincing in our case as the literature would typically predict an exchange rate appreciation being followed by a decline in inflation and domestic interest rates (cf. Adrian et al., 2020) – a finding that appears consistent with the experience of many emerging market economies (cf. Kilinic and Tunc, 2014).

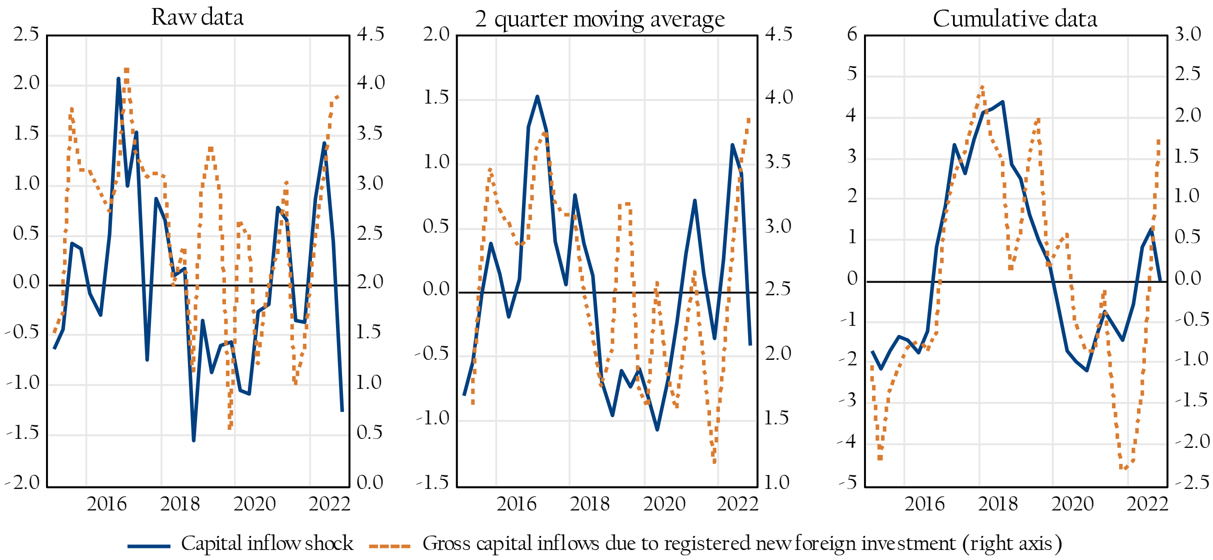

Figure 7 Capital inflow shock (ϵ_t^e) using the identifying restrictions from Eq. (9) and data on gross capital inflows due to registered new foreign investment (log of billions of króna). The cumulative gross data are detrended using Hodrick-Prescott filter.

A shock to capital inflows therefore seems a more plausible interpretation. This also appears to be supported by the data as reported in Figure 7, which compares the estimated capital inflow shock (ϵ_t^e) to data on gross capital inflows into Iceland that is due to registered new foreign investment (in billions of króna; data available from 2015 from the Central Bank of Iceland). As the figure shows, the identified capital inflow shock coincides quite well with the gross inflow data at the quarterly frequency (correlation coefficient equal to 0.37) and the two-quarter moving average of the data (correlation coefficient equal to 0.50). The cumulative capital flow shock also closely matches the (Hodrick-Prescott detrended) cumulative gross inflows closely (correlation coefficient equal to 0.76). Thus, data on actual capital inflows appears to support the interpretation of the structural shock identified from the structural VAR as a capital inflow shock, even though no such data is used in the VAR to identify the shock.

3.4 The main sources of macroeconomic fluctuations

3.4.1 Variance decomposition

The impulse responses in the previous section suggest that monetary policy shocks have a significant, if only temporary, effect on economic activity but an analysis of its relative contribution to output fluctuations over the whole sample period suggests a relatively modest role – with monetary policy shocks explaining less than 10% of the variation in output over the whole sample period (Table 1). This is to be expected given that the monetary policy shocks reflect unexpected deviations from average policy behaviour over the sample period. This does therefore not contradict the standard notion that systematic monetary policy ($\theta(\Omega_t)$ in Eq. (1)) plays an important part in dampening business cycle fluctuations, nor does it necessarily preclude that monetary policy shocks played an important role in particular historical episodes of business cycle developments, as discussed below.

The variance decomposition does however suggest a larger contribution of monetary policy shocks to fluctuations in the monetary policy rate – indicating significant and frequent deviations of monetary policy from its average behaviour. The results in Table 1 also suggest a larger contribution of monetary policy shocks to the variation of inflation and the exchange rate, with monetary policy shocks explaining about a quarter of the long-term variation in the nominal exchange rate and roughly a third of the long-term variation in inflation.

Finally, Table 1 also reports the contribution of the three other structural shocks to fluctuations in our four variables. Output is found to be dominated by demand shocks – especially over short-to-medium-term horizons – with a rising role of supply shocks over longer horizons. Supply shocks, however, dominate fluctuations in inflation over shorter horizons but there is also a sizable role of capital inflow shocks (and monetary policy shocks as discussed earlier). The same applies to the nominal exchange rate.[7]

[7] The relatively large role of supply shocks and capital inflow shocks for explaining fluctuations in inflation is consistent with the findings in Thórarinsson (2022), who reports that supply shocks and exchange rate shocks dominate fluctuations in inflation. The relatively large share of demand and supply shocks in explaining fluctuations in the exchange rate is also in line with findings in Central Bank of Iceland (2017) and highlights an important shock absorbing role of the currency (see also Faust and Rogers, 2003).

Table 1 Forecast error variance decomposition

Variable	Quarters ahead	Monetary policy shock	Demand shock	Supply shock	Capital inflow shock
Output	4	2.8	93.9	1.6	1.7
	8	5.3	82.9	5.7	6.1
	20	4.5	69.2	16.4	10.0
	40	7.3	61.8	21.9	9.0
Inflation	4	3.7	4.6	68.5	23.1
	8	16.6	5.5	60.1	17.7
	20	33.4	6.6	39.1	20.9
	40	33.6	9.2	33.8	23.4
Exchange rate	4	7.7	9.2	35.0	48.1
	8	13.4	12.9	39.5	34.3
	20	22.1	11.9	41.9	24.1
	40	26.6	10.5	39.1	23.8
Monetary policy rate	4	75.8	5.1	3.1	16.1
	8	73.4	7.0	3.5	16.1
	20	72.1	7.5	3.5	17.0
	40	72.1	7.5	3.5	17.0

The table shows the percentage of k-step-ahead forecast error variance of output, inflation, the exchange rate, and the monetary policy rate due to the four structural shocks identified using the identifying restrictions in Eq. (9).

These results are broadly in line with findings from other countries (see, for example, Gerlach and Smets, 1995, Kim, 1999, Kim and Roubini, 2000, Peersman and Smets, 2003, and Ramey, 2016), although the contribution of monetary policy shocks to fluctuations in the policy rate is in the higher range of international findings. The contribution of monetary policy shocks to fluctuations in inflation is also somewhat larger than typically found in the literature. The important role of demand shocks to output fluctuations is also typical, as is the increasing role of supply shocks over longer horizons.

3.4.2 Historical decomposition

The variance decomposition in the previous section suggests that the overall importance of monetary policy shocks to fluctuations in output and (to a lesser extent) inflation is relatively modest. This does, however, not preclude the possibility that these shocks have an important role in explaining different historical episodes. To analyse this possibility, the historical values of the data are decomposed into a baseline projection and the accumulated effects of current and past structural shocks. This decomposition of the data allows us to attribute the unanticipated movements of each of the four variables to each structural disturbance at every date. In this way, we can calculate the proportion of the forecast errors in each series explained by each of the four structural shocks discussed above. This therefore goes beyond the analysis of impulse responses in the previous sections, as the historical decomposition allows us to focus on the role of the structural shocks in any given historical episode (see, for example, Kim, 1999).

Figure 8 reports the historical decomposition for the four data series starting in 2010. First, the historical decomposition of the monetary policy rate (the last column of the figure) shows that monetary policy shocks explain most of the forecast errors in the monetary policy rate. The figure also suggests that there are two periods of relatively loose monetary policy (periods of negative monetary policy shocks) in our sample period – i.e. periods were monetary policy is loose compared to the average monetary policy response to economic disturbances: from 2010 to mid-2012 and from mid-2019 to mid-2022; and two periods of relatively tight monetary policy: from mid-2012 to mid-2019 and the most recent period from late 2022.

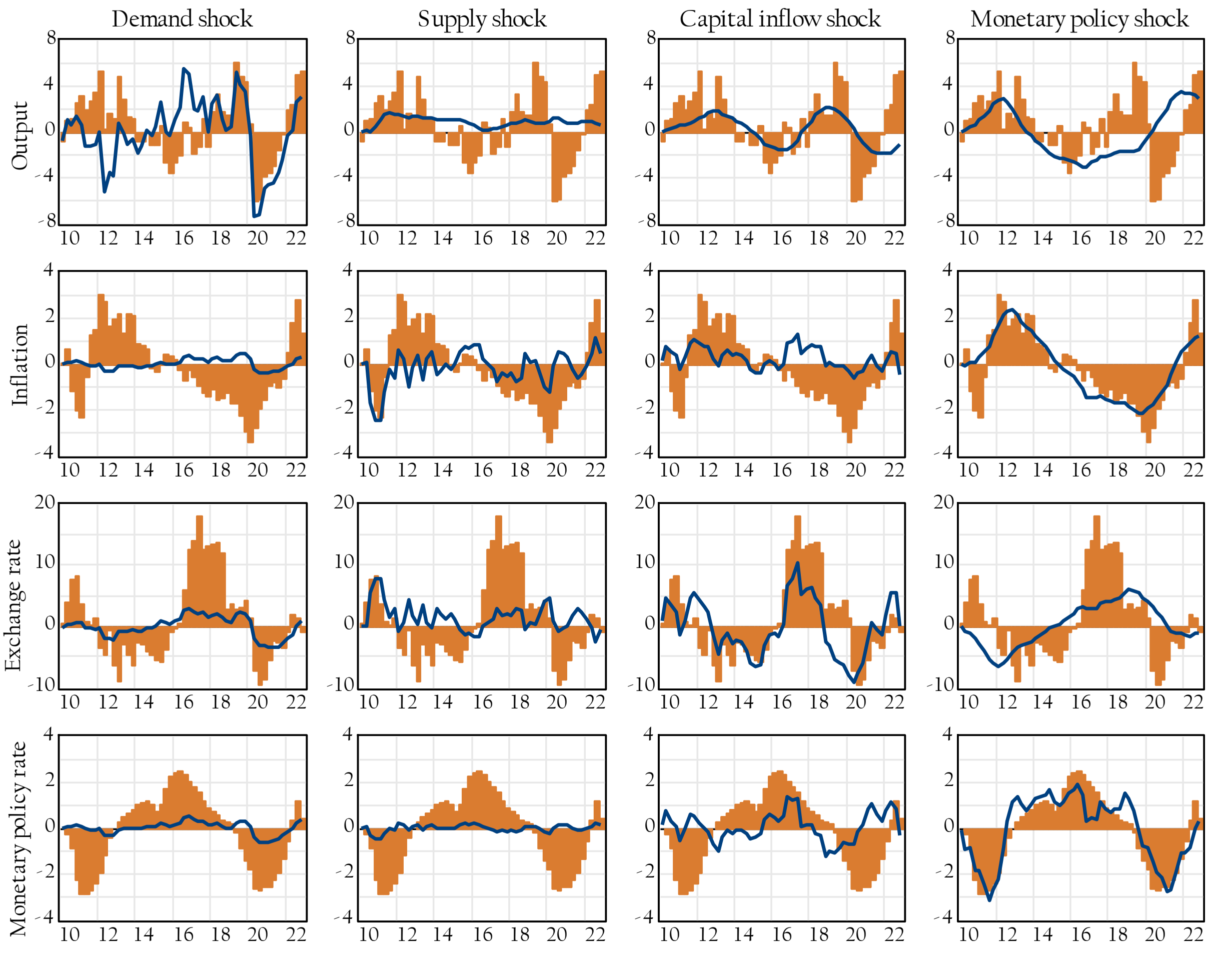

Figure 8 Historical decomposition and the contribution of structural shocks using the identifying restrictions from Eq. (9). The bars show the forecast error of each series and the solid line the contribution of each structural shock.

The last column of the figure also shows how this monetary policy cycle has affected the three other variables. First, the 2012-2019 tightening cycle appears to have slowed down output, appreciated the currency and pushed down inflation from 2015, with a peak effect on inflation in mid-2019.[8] Second, the figure clearly shows how the monetary easing by the end of the decade significantly weighed against the deep output contraction following the Covid-19 pandemic in 2020: without the offsetting monetary easing, the contraction would have been both deeper and more prolonged. The historical decomposition also suggests, however, that the withdrawal of the post-Covid monetary easing was too slow, thus contributing to rising inflation by the end of the sample period.

Figure 8 also shows the impact of the three other structural shocks over the sample period. For example, the output contraction during the pandemic appears to have been mainly driven by a negative demand shock. At the same time, positive demand shocks played an important role in the cyclical expansions in the latter half of the last decade and in the last two years. Supply shocks clearly create short-term fluctuations in inflation and the exchange rate (as reflected in the variance decomposition analysis above) and it appears that some of the increase in inflation in the last two years can be attributed to negative supply shocks.

Finally, the third column of the figure shows the role of capital inflow shocks during this period. They contributed to the cyclical upswing in the mid-2010s (also putting an upward pressure on inflation) and the contraction during the pandemic (and, generally, display a clear pro-cyclical pattern). Positive capital inflow shocks also appreciated the currency in the mid-2010s, before reversing during the pandemic.

3.5 A monetary tightening in trading partner countries

Finally, we want to analyse the effects of a monetary policy shock in Iceland's trading partner countries on the domestic economy. To do this, the basic VAR model needs to be altered slightly. In the previous analysis, the VAR was conditioned on trading partners' monetary policy through the inclusion of the contemporaneous value of the trade-weighted average foreign monetary policy rate as an exogenous variable. To analyse the impact of an unforeseen shock to this rate on the domestic economy, r_t^w needs to be elevated to the vector of endogenous variables of the VAR, but, as in Cushman and Zha (1997), the lag matrix polynomial of the VAR is forced to be block exogenous to preserve the exogeneity of the global economy to fluctuations in the Icelandic economy:

$$\begin{pmatrix} r_t^w \\ \boldsymbol{x}_t \end{pmatrix} = \begin{pmatrix} \phi_{11} & \boldsymbol{0} \\ \boldsymbol{F}_{21} & \boldsymbol{C} \end{pmatrix} \begin{pmatrix} r_{t-1}^w \\ \boldsymbol{x}_{t-1} \end{pmatrix} + \begin{pmatrix} u_t^w \\ \boldsymbol{u}_t \end{pmatrix} \tag{10}$$

[8] The important role of monetary policy in bringing down inflation in the second half of the 2010s is consistent with the findings from Pétursson (2018, 2022) using alternative time-varying parameter specifications of the Phillips curve.

where ϕ_{11} is a scalar, $\mathbf{0}$ is a 1×4 vector of zeros, $\boldsymbol{F}_{21}$ is 4×1 coefficient vector, and $\boldsymbol{C}$ is 4×4 matrix as before. Ordering r_t^w before the other variables, also ensures that the domestic structural shocks are not able to contemporaneously affect the global economy, while preserving the non-recursive identification structure from Eq. (9) for the domestic economy. The $\boldsymbol{A}_0$ matrix is therefore defined as:

$$\begin{pmatrix} \epsilon_t^w \\ \epsilon_t^y \\ \epsilon_t^\pi \\ \epsilon_t^e \\ \epsilon_t^r \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ -\alpha_0 & 1 & 0 & 0 & 0 \\ -\beta_0 & 0 & 1 & -\beta_3 & 0 \\ -\gamma_0 & -\gamma_1 & -\gamma_2 & 1 & -\gamma_4 \\ -\lambda_0 & 0 & -\lambda_2 & -\lambda_3 & 1 \end{pmatrix} \begin{pmatrix} u_t^w \\ u_t^y \\ u_t^\pi \\ u_t^e \\ u_t^r \end{pmatrix} \tag{11}$$

Figure 9 shows the impact of a one standard deviation shock (a rise of 25 basis points) to r_t^w on the domestic economy.[9] The domestic policy rate rises immediately but slightly less than the foreign rate (18 basis points), but it continues to rise and peaks 40 basis points above its pre-shock level after 3 quarters before gradually easing back to its baseline level.

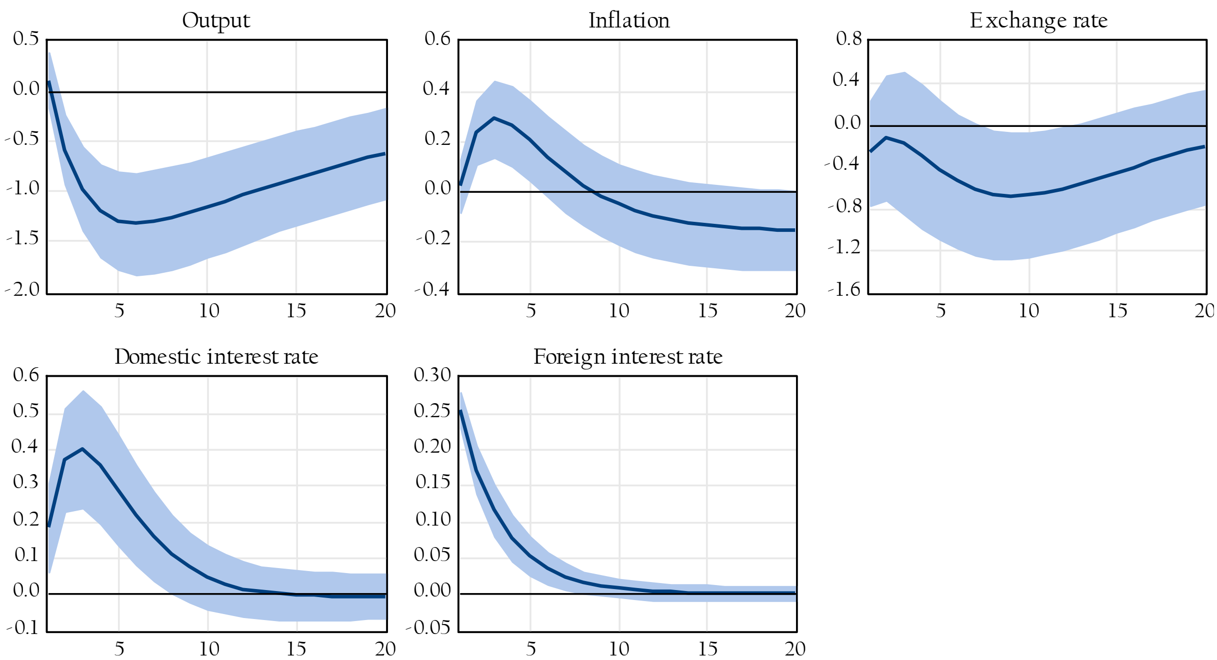

Figure 9 The effects of a 1 standard deviation foreign monetary policy shock over a 20 quarters period using the identifying restrictions from Eq. (11). Shaded area denotes the 68% confidence interval.

[9] Note that in addition to foreign monetary shocks, the ϵ_t^w shocks may also reflect other foreign structural shocks that trigger a global monetary tightening since r_t^w is contemporaneously exogenous to all the other variables (see Kim and Roubini, 2000). The effects of the domestic structural shocks (including monetary policy shocks) are almost identical to those previously reported.

The domestic tightening response to the trading partners' monetary policy shock can reflect three effects. First, the global monetary tightening could reflect a rise in international inflationary pressures which triggers a domestic monetary tightening as imported inflation picks up. Second, the domestic tightening may reflect the desire of the domestic monetary authority to dampen the inflationary effects of the local currency depreciation following the rise in the trading partners' monetary policy rate. Finally, the increase in domestic interest rates could reflect financial spill-over effects of higher foreign interest rates.

The currency response again shows evidence of the overshooting behaviour reported before. The sustained depreciation leads to an increase in inflation, which peaks at 0.3 percentage points above its pre-shock level after 3 quarters. The inflationary effect gradually fades, however, and has died out after 5 quarters – reflecting the impact of higher interest rates and weakening of domestic activity, with output declining significantly and persistently over the next 5 years.

These dynamic responses to a foreign interest rate shock are consistent with predictions from standard macro models and are very similar to those reported in Kim and Roubini (2000) for the G-7 countries, although they sometimes find evidence of output increasing rather than falling as reported here. This reflects the two opposite forces affecting output. One the one hand, there is a contractionary effect from a higher domestic interest rate on domestic demand, but output is also boosted at the same time by the increase in net exports from the effect of the exchange rate depreciation.

4 Concluding remarks

We analyse the transmission mechanism of monetary policy in Iceland using three alternative identification schemes in a structural VAR setting to extract monetary policy shocks from the data. Our results indicate that an unexpected monetary policy tightening, measured as a one standard deviation of monetary policy from its average reaction function (equivalent to roughly 75 basis points), leads to a temporary but sizable contraction in output with a peak effect of about 0.2-0.6% 1 to 1.5 years after the initial shock, depending on the identification scheme applied. The monetary policy shock also leads to a sustained nominal appreciation of the domestic currency, and a more sluggish and persistent decline in inflation with peak effect of roughly 0.4 percentage points 2 to 2.5 years after the initial shock.

The VAR model is used to identify three other structural shocks. The first two are the standard aggregate demand and supply shocks, while the third shock is interpreted as a shock to capital inflows. These three shocks are found to explain most of the variation in output and inflation over our sample period, while the contribution of monetary policy shocks is relatively modest, especially to fluctuations in output. But a historical decomposition of the variation in the data suggests an important role of monetary policy during the disinflation of the second half of the 2010s and in offsetting a large negative demand shock following the global pandemic at the start of this decade. However, the historical decomposition also suggests that the withdrawal of the post-Covid monetary easing was too slow, thus contributing to rising inflation by the end of the sample period. We conclude the analysis by extending the VAR to analyse the effect of an unexpected tightening of monetary policy in trading partner countries, which typically depreciates the local currency and pushes up domestic inflation, despite a rise in the domestic policy rate and a slowdown of output.

Overall, our analysis of monetary policy shocks in Iceland generates plausible results that are robust to alternative identification schemes. The impulse responses generated by the model are consistent with predictions of standard theory and are broadly in line with the international literature. The three other structural shocks identified also have plausible interpretations and, together, the four structural shocks provide a plausible account of different historical episodes in our sample period.

Appendix 1

The Appendix compares our key findings across the three VAR identification schemes used in the paper. First, as discussed in the main text, the identification of the monetary policy shocks appears robust across the three identification schemes. This is seen even more clearly from the high contemporaneous correlation coefficients reported in Table A1 and the comparison of the cumulated monetary policy shocks shown in Figure A1.

Table A1 Contemporaneous correlation of monetary policy shocks across different VAR identification schemes

	Monetary policy shocks		
Identification scheme	Eq. (7)	Eq. (8)	Eq. (9)
Eq. (7)	1.00	0.85	0.98
Eq. (8)	0.85	1.00	0.91
Eq. (9)	0.98	0.90	1.00
	Cumulated monetary policy shocks		
Identification scheme	Eq. (7)	Eq. (8)	Eq. (9)
Eq. (7)	1.00	0.94	0.99
Eq. (8)	0.94	1.00	0.97
Eq. (9)	0.99	0.97	1.00

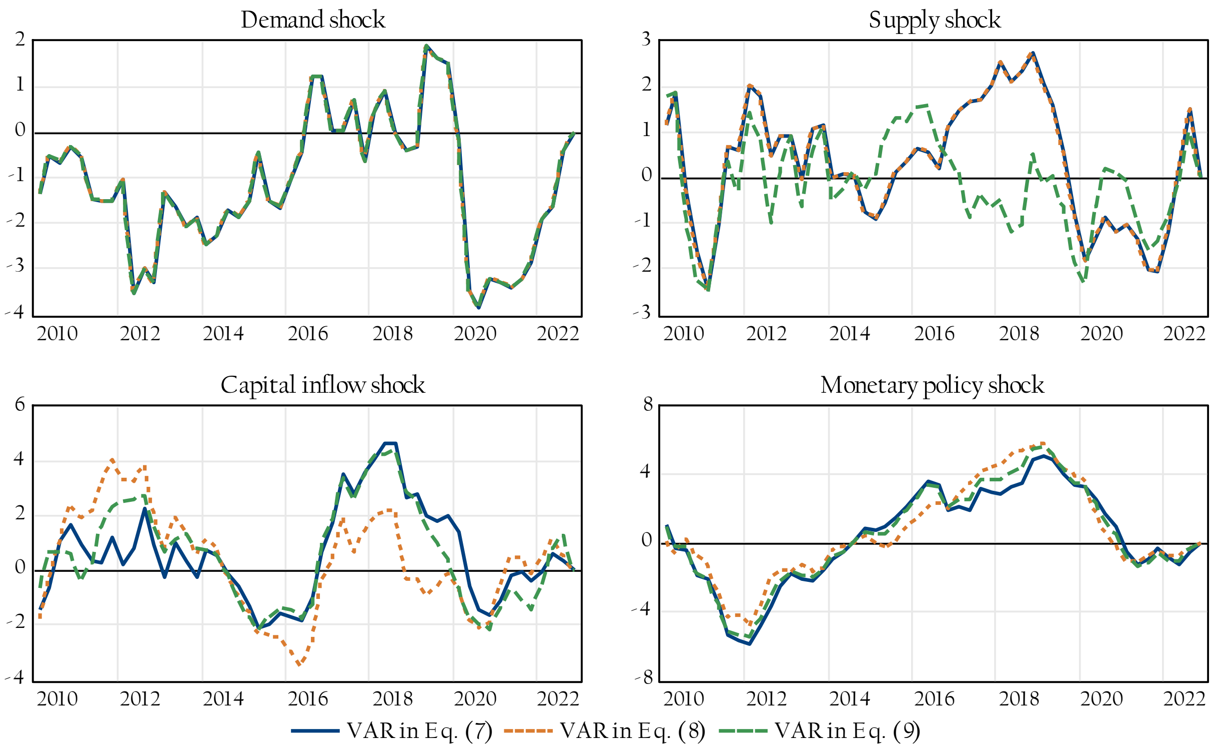

Figure A1 Cumulative structural shocks from the three VAR identification schemes.

Figure A1 also compares the cumulative series of the other three structural shocks identified in our VAR. Note first that the demand shocks are identical across the three identification schemes by construction and the same applies for supply shocks in identification schemes in Eq. (7) and Eq. (8). But beyond that, the schemes in Eq. (7) and Eq. (8) suggest more persistent positive supply shocks in the latter half of the 2010s compared to the identification scheme in Eq. (9), and the scheme in Eq. (8) a more muted capital inflow shock over the same period compared to the schemes in Eq. (7) and Eq. (9). Other than that, the estimated structural shocks look very similar across all three identification schemes.

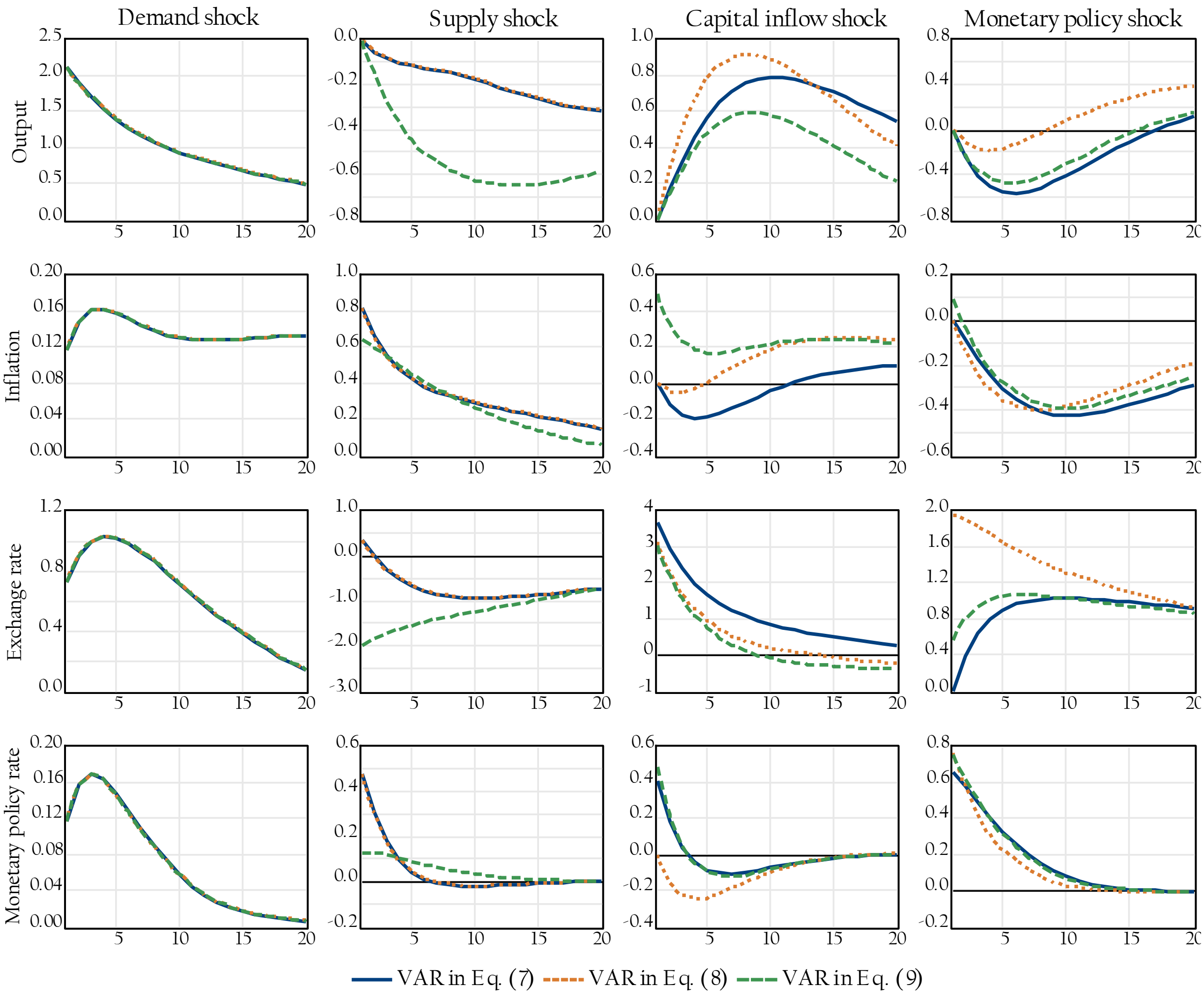

Figure A2 Impulse response functions for the three VAR identification schemes.

Figure A2 shows the impulse response functions for the four structural shocks. As already reported in the main text, the impulse responses for the monetary policy shock are found to be robust across the three identification schemes. The same applies for the three other shocks (again, with the impact of demand shocks identical by construction). The impact of supply shocks on inflation are found to be very similar, while the impact on output is more muted in the identification schemes in Eq. (7) and Eq. (8) compared to Eq. (9). The short-run impact of supply shocks on the exchange rate is also smaller for the identification schemes in Eq. (7) and Eq. (8) although they become almost identical to that in Eq. (9) after about 2 years. They also suggest a stronger reaction of monetary policy to supply shocks than according to Eq. (9). The biggest difference across these three identification schemes concerns the impact of capital inflow shocks. All three give a similar impact on output but the inflationary impact of the shock is different. Inflation initially falls according to the identification scheme in Eq. (8) before rising after a year with very similar medium-term effects to that found in the scheme in Eq. (9) reported in the main text. For the scheme in Eq. (7) the fall in inflation is more persistent, however. The monetary policy response to a capital inflow shock is also different, with the identification scheme in Eq. (7) almost identical to the non-recursive one in Eq. (9) while the scheme in Eq. (8) suggests a policy rate reduction following the capital inflow shock.

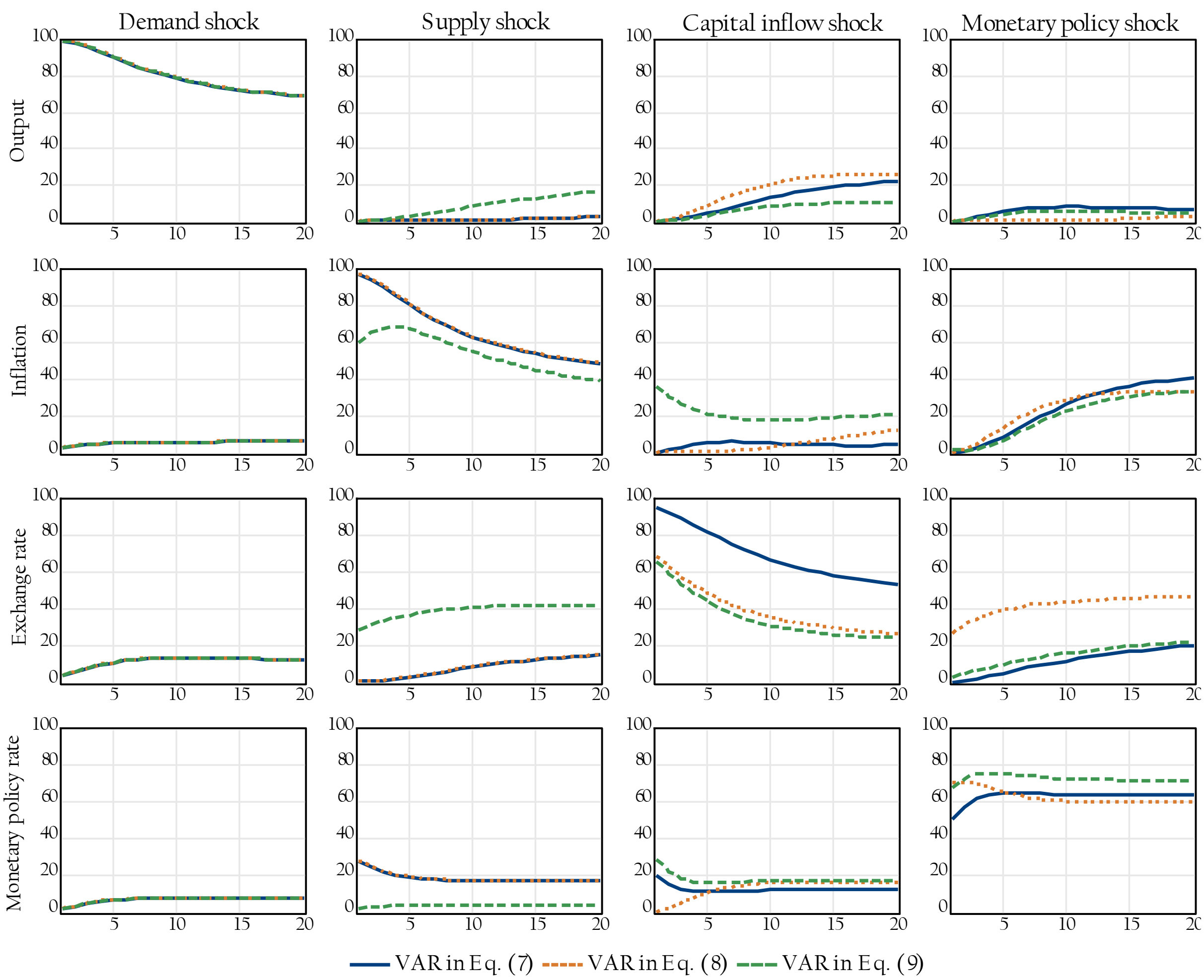

Figure A3 Forecast error variance decomposition for the three VAR identification schemes.

Finally, Figure A3 shows that the decomposition of forecast error variances is also broadly similar across the three identification schemes – in particular, the limited contribution of monetary policy shocks to output fluctuations and its roughly 30% share in medium- and long-term inflation fluctuations. There are some differences, however. For example, the identification schemes in Eq. (7) and Eq. (8) assign a larger role to supply shocks in explaining short-run fluctuations in inflation compared to the scheme in Eq. (9) but they are very similar over the medium- to long-run. Instead, the scheme in Eq. (9) assigns a larger role to capital inflow shocks in explaining short-run fluctuations in inflation. At the same time, the scheme in Eq. (9) contributes a greater share of exchange rate fluctuations to supply shocks compared to the other two, which in turn contribute a larger share to capital inflow shocks (Eq. (7)) and monetary policy shocks (Eq. (8)).

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