Australian National University

Crawford School of Public Policy

CAMA

Centre for Applied Macroeconomic Analysis

Monetary policy shocks and exchange rate dynamics in small open economies

CAMA Working Paper 15/2022
February 2022

Firmin Doko Tchatoka
University of Adelaide

Qazi Haque
University of Adelaide
Centre for Applied Macroeconomic Analysis, ANU

Madison Terrell
Reserve Bank of Australia

Abstract

In this paper we provide new insights on the dynamics between monetary policy shocks and real exchange rates in small open economies using a time-varying structural vector autoregression model with stochastic volatility. Identification is achieved using a combination of short-run and long-run restrictions while preserving the contemporaneous interaction between monetary policy and the exchange rate. For several small open economies, we find no evidence of the 'exchange rate puzzle' or the 'delayed overshooting puzzle,' in line with recent studies on this topic (see e.g. Bjørnland, 2009). However, there is evidence of the 'forward discount puzzle' in some countries, suggesting that the uncovered interest parity (UIP) is violated. In addition, a substantial decrease in the volatility of monetary policy shocks is evident in most countries, accompanied by a decline in the importance of policy shocks in explaining the volatility of exchange rates and other macroeconomic variables since the 1990s.

Keywords

Monetary policy shocks, Exchange rate, TVP-VARs, UIP

JEL Classification

C32, E52, F31, F41

Address for correspondence:

(E) cama.admin@anu.edu.au

ISSN 2206-0332

Monetary policy shocks and exchange rate dynamics in small open economies*

Firmin Doko Tchatoka
University of Adelaide†

Qazi Haque
University of Adelaide and CAMA‡

Madison Terrell
Reserve Bank of Australia§

January 27, 2022

Abstract

In this paper we provide new insights on the dynamics between monetary policy shocks and real exchange rates in small open economies using a time-varying structural vector autoregression model with stochastic volatility. Identification is achieved using a combination of short-run and long-run restrictions while preserving the contemporaneous interaction between monetary policy and the exchange rate. For several small open economies, we find no evidence of the 'exchange rate puzzle' or the 'delayed overshooting puzzle,' in line with recent studies on this topic (see e.g. Bjørnland, 2009). However, there is evidence of the 'forward discount puzzle' in some countries, suggesting that the uncovered interest parity (UIP) is violated. In addition, a substantial decrease in the volatility of monetary policy shocks is evident in most countries, accompanied by a decline in the importance of policy shocks in explaining the volatility of exchange rates and other macroeconomic variables since the 1990s.

JEL Classifications: C32, E52, F31, F41.
Keywords: Monetary policy shocks; Exchange rate; TVP-VARs; UIP.

---

*Funding: Doko Tchatoka acknowledges financial support from the Australian Research Council via the Discovery Grant DP200101498. The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Reserve Bank of Australia.

†School of Economics and Public Policy, The University of Adelaide, 10 Pulteney St, Adelaide SA 5005, Australia. Email: firmin.dokotchatoka@adelaide.edu.au. Phone: +61883131174 (corresponding author).

‡School of Economics and Public Policy, The University of Adelaide, 10 Pulteney St, Adelaide SA 5005, Australia and Centre for Applied Macroeconomic Analysis, Australian National University. Email: qazi.haque@adelaide.edu.au. Phone: +61883134927.

§Reserve Bank of Australia, 65 Martin Place, Sydney NSW 2000. Email: terrellm@rba.gov.au.

1 Introduction

Since the early 1990s, several countries including Australia, Canada, New Zealand, and the United Kingdom have shifted to an inflation-targeting regime. This has led to a high degree of transparency and accountability, with central banks from these countries regularly issuing monetary policy statements to explain and motivate their policy to the general public. Most of these inflation-targeting countries are relatively small open economies with free capital mobility, where the exchange rate plays a prominent role in the transmission mechanism of monetary policy. For example, a depreciation (or an appreciation) in the exchange rate can affect the demand for domestic and foreign goods, which subsequently influences prices and therefore inflation. As such, the exchange rate allows additional channels for the transmission of domestic monetary policy as well as provides a medium for foreign shocks to be transmitted to the domestic economy. Being an asset price that reflects the expected returns on assets, the exchange rate is expected to respond instantaneously to changes in monetary policy. This creates a nexus between monetary policy and the exchange rate, where both variables influence and react to one another (Svensson, 2000).

Despite its important role, the effect of monetary policy shocks on the exchange rate is far from settled as existing empirical studies employing vector autoregressions (VARs) have found puzzling results (see, e.g. Eichenbaum and Evans, 1995; Kim and Roubini, 2000). However, most studies in the VAR literature aimed at identifying and estimating the relationship between monetary policy and exchange rate fluctuations have used time-invariant approaches, i.e., the VAR parameters and shock volatilities are kept fixed over the sample period. Nonetheless, the effects of monetary policy shocks on the exchange rate can be misleadingly estimated when different monetary policy regimes are pooled – see, e.g. Kim et al. (2017), who show that the uncovered interest parity (UIP) fails during the Volcker era but tends to hold in the post-Volcker era in the U.S. They also show that monetary policy shocks have substantial impacts on exchange rate fluctuations but misleadingly appear to have small impacts when monetary policy regimes are pooled. Kim and Lim (2018) discuss similar issues related to shifts to inflation-targeting regimes in small open economies, and suggest that in order to overcome the puzzling results, it is important to estimate the VAR over stable monetary policy regimes. In light of these findings, we re-examine the effects of monetary policy shocks on exchange rates in several small open economies within the time-varying parameter VAR with stochastic volatility (TVP-VAR-SV) framework of Cogley and Sargent (2005) and Primiceri (2005).

We estimate the TVP-VAR-SV model for six small open economies: Australia, Canada, Norway, New Zealand, Sweden and the United Kingdom, using a standard Bayesian Markov Chain Monte Carlo (MCMC) method over the post-1980s period. Identification is achieved using a combination of zero short-run and long-run restrictions following Bjørnland (2009). We impose a recursive structure between macroeconomic variables and the domestic interest rate, so that variables such as output and inflation do not react contemporaneously to monetary policy shocks, while there is a simultaneous feedback from macroeconomic variables to domestic monetary policy setting. Similar recursive restrictions are imposed on the relationship between the exchange rate and macroeconomic variables. The exchange rate can react immediately to all shocks but there is slow exchange rate passthrough to macroeconomic variables. However, Bjørnland (2009) documents the importance of allowing for simultaneity between monetary policy and the exchange rate. Hence, we leave the impact response of these two variables unrestricted in our TVP-VAR-SV model, while identification is achieved by assuming that monetary policy shocks do not have long-run effects on real exchange rates (similar to Bjørnland, 2009).

First, we find a dramatic decrease in the volatility of monetary policy shocks over time in all countries, demonstrating the importance of modeling stochastic volatility in the estimated VAR. Second, following an 'averaged-sized' monetary policy shock, we find that the exchange rate appreciates instantaneously in almost all countries across time. This implies that there is no evidence of the exchange rate puzzle in the countries studied, a result that contrasts with previous findings by Grilli and Roubini (1995) (for G-7 countries excluding the U.S.). Second, the maximum impact of the policy shock on the exchange rate occurs instantaneously in most countries across time, except for the United Kingdom where it is delayed by one quarter, suggesting that there is no evidence of delayed overshooting in most countries. Thereafter, the exchange rate depreciates back to its long-run level in line with Dornbusch's (1976) exchange rate overshooting hypothesis, which states than an increase in the interest rate should lead to an instantaneous appreciation of the exchange rate followed by a gradual depreciation.

Nevertheless, we find evidence of the forward discount puzzle with the violation of UIP in four out of the six countries. Specifically, with the exception of Australia and New Zealand where the responses are consistent with UIP, a contractionary monetary policy shock leads to a fall in the expected returns from investing in foreign short-term bonds relative to the returns from investing in domestic bonds. More generally, our results highlight evidence of the forward discount puzzle even without delayed overshooting, which is in line with Scholl and Uhlig (2008).

Next, to ascertain the importance of time variation we also estimate a constant-parameter VAR with stochastic volatility. We find that this model captures the dynamic effects of monetary policy shocks relatively well for most countries, suggesting that time variation in the dynamic effects of monetary policy shocks plays a minor role. Despite this evidence, the estimated stochastic volatility shows similar patterns as in our TVP-VAR-SV model, with a drastic decline in the volatility of policy shocks over time. As a result, similar to the TVP-VAR-SV model, a substantial decrease in the contribution of monetary policy shocks in driving exchange rate volatility is observed with the constant-parameter VAR-SV model, particularly since the 1990s. This coincides with the adoption of inflation-targeting and central bank independence in most of the countries. Overall, our results suggest that monetary policy shocks have not been an important driver of exchange rate fluctuations in these countries since the 2000s, and we find that the contribution of policy shocks in explaining inflation and output volatility have also fallen over the same time frame. These findings underline the importance of modeling stochastic volatility in the estimated VARs.

The paper is organized as follows. Section 2 provides a brief overview of some related papers in the literature to give further background and motivation to our work and compares our findings to some closely related studies. Section 3 presents the TVP-VAR model with stochastic volatility, describes the data used in the estimation and outlines the identification strategy. Section 4 documents the main results of the paper. Additional robustness checks are performed in Section 5. Finally, Section 6 concludes. Further empirical results are provided in the Appendix.

2 Related literature

The literature on the effects of monetary policy shocks on exchange rates dates back to the well-known Dornbusch's (1976) overshooting hypothesis, which suggests that an increase in domestic interest rates relative to foreign interest rates leads to an instantaneous appreciation of the exchange rate followed by a persistent depreciation in line with UIP. However, the empirical assessment of the overshooting hypothesis using VAR approaches have led to conflicting evidence, some of which are often counter-intuitive. For example, Grilli and Roubini (1995) find that a contractionary monetary policy shock causes the exchange rate to depreciate instantaneously in most G-7 countries other than the U.S. This has been termed as the 'exchange rate puzzle'. Eichenbaum and Evans (1995) – one of the first studies to apply the VAR model – investigate the effects of monetary policy shocks on exchange rates using U.S. data. Employing a recursive identification scheme whereby monetary policy affects all variables with a lag but the exchange rate, they find that a contractionary monetary policy shock leads to persistent and significant appreciation of the U.S. dollar, a finding also inconsistent with the overshooting hypothesis and often referred to as 'delayed overshooting' or the 'forward discount puzzle' (see e.g. Cushman and Zha, 1997).

Many subsequent studies have since investigated the issues further and have found mixed evidence. For instance, Peersman and Smets (2001) and Marcellino and Favero (2004) (for the aggregate Euro area), Mojon and Peersman (2001) (for individual Euro area countries) and Lindé (2003) (for Sweden) find little support for the overshooting hypothesis. Instead, they find that following a contractionary monetary policy shock, the exchange rate either depreciates, or when it appreciates, it does so gradually and for a prolonged time period. Faust and Rogers (2003) find no robust evidence regarding the timing of the peak response of the exchange rate, but observe a robust evidence in favor of large deviations from UIP due to monetary policy shocks. On the other hand, Kim and Roubini (2000) (for G-7 countries), Kim (2003) (for the U.S.), and Kim and Lim (2018) (for several small open economies) find that delays in overshooting are relatively short and deviations from UIP are relatively small, while Cushman and Zha (1997) (for Canada) find no evidence of the exchange rate puzzle. More recently, Bjørnland (2009) and Bjørnland and Halvorsen (2014) find that the puzzles disappear and the effect of policy shocks on exchange rates falls in line with Dornbusch's hypothesis once an alternative and more plausible identification method is used.

Closely related studies to our paper are Bjørnland (2009), Bjørnland and Halvorsen (2014) and Kim and Lim (2018). Bjørnland (2009) is the first study to combine zero short-run and long-run restrictions to study the effect of monetary policy shocks on exchange rate fluctuations in small open economies. Using a time-invariant VAR framework, she finds no evidence of the exchange rate puzzle or delayed overshooting, and shows that the response of the exchange rate is consistent with UIP in most cases. Bjørnland and Halvorsen (2014) combine sign restrictions with zero contemporaneous restrictions to analyze the monetary policy and exchange rate nexus in several small open economies. In line with Bjørnland (2009), they find that the exchange rate appreciates on impact (as imposed) following a contractionary policy shock and then gradually depreciates in all countries, consistent with Dornbusch's hypothesis. In contrast, Scholl and Uhlig (2008) employ an identification strategy based on sign restrictions to show sizeable evidence of both delayed overshooting and the forward discount puzzle for the U.S. economy. On the other hand, Kim and Lim (2018) also use sign restrictions to study the effects of monetary policy shocks on exchange rates in small open economies and confirm the findings of Bjørnland (2009) and Bjørnland and Halvorsen (2014). Kim and Lim (2018) argue that their results rely on estimating the model over the inflation-targeting period with stable monetary policy operating procedures.

In contrast to these studies, we use a time-varying parameter VAR model with stochastic volatility. Our findings are in line with Bjørnland (2009), Bjørnland and Halvorsen (2014), and Kim and Lim (2018) in the sense that the exchange rate appreciates instantaneously followed by a gradual depreciation. However, our results also suggest that Dornbusch's overshooting hypothesis holds not just on average over the entire sample (as in these other studies based on time-invariant VARs), but also across time for most countries in our sample, including both pre and post inflation-targeting periods.[1] Nevertheless, in contrast to Bjørnland (2009) and Kim and Lim (2018), we find sizeable deviations from UIP in most countries, despite the exchange rate behavior being consistent with Dornbusch's overshooting hypothesis. In that regard, our findings align with Scholl and Uhlig (2008) who show evidence of the forward

[1] The only exceptions in our sample are Australia and Norway, where we find that monetary policy shocks do not have significant effects on exchange rates in some cases.

discount puzzle for the U.S. economy even without delayed overshooting. Additionally, we find a dramatic decrease in the importance of policy shocks in explaining exchange rate and macroeconomic fluctuations in the post inflation-targeting period. This result stands in sharp contrast to Bjørnland (2009), who suggest that policy shocks explain a large fraction of the exchange rate volatility in small open economies. This difference is driven by the large dispersion in the estimated forecast error variance decompositions across the sample period, as evident from our results. Failure to take into account the decline in the volatility of policy shocks over time leads to averaging out the time-varying contributions and misleadingly overestimating the impact of policy shocks on exchange rate fluctuations, as in Bjørnland (2009). From that perspective, our findings also depart from Kim and Lim (2018) who find different patterns for different countries, while the same pattern is observed in our estimations, i.e., a persistent decline in the contribution of monetary policy shocks for all countries in our sample.

A growing number of studies have used the TVP-VAR setting to establish empirical evidence of the dynamic structure of the economy – see e.g., Canova and Gambetti (2009); Benati and Lubik (2014a,b); Haque and Magnusson (2021); Haque et al. (2021). However, few have focused on the relationship between monetary policy and the exchange rate. Yang and Zhang (2021) employ a TVP-VAR model to study the effect of monetary policy on the exchange rate in the U.S. economy. They identify the VAR by using high frequency surprises in financial markets on central bank announcement days, and therefore incorporate monetary policy into the TVP-VAR model as an exogenous variable. They find that monetary policy shocks have time-varying effects on the U.S. dollar, with contractionary monetary policy leading to a larger exchange rate appreciation during unconventional monetary policy periods. Mumtaz and Sunder-Plassmann (2013) investigate the evolving dynamics of the real exchange rate for Canada, the euro area and the United Kingdom using a TVP-VAR model. They employ a sign restriction-based identification strategy and find that demand and nominal shocks have substantially larger effects on the real exchange rate after the mid-1980s. However, they do not specifically identify a monetary policy shock, nor address the open-economy puzzles discussed earlier.

To the best of our knowledge, we are the first to investigate the dynamic effects of monetary policy shocks in multiple small open economies using the TVP-VAR with stochastic volatility framework. Most importantly, in doing so, our study sheds new light on the various puzzles discussed above.

3 Econometric framework

3.1 Time-varying parameter VAR with stochastic volatility

We specify a time-varying parameter vector autoregression (TVP-VAR) with stochastic volatility based on the framework of Cogley and Sargent (2005) and Primiceri (2005):

$$\boldsymbol{Y}_t = c_t + B_{1,t}\boldsymbol{Y}_{t-1} + \ldots + B_{p,t}\boldsymbol{Y}_{t-p} + u_t, \quad t = p+1, \ldots, T, \tag{3.1}$$

where $\boldsymbol{Y}_t$ is a $n \times 1$ vector of observed endogenous variables, c_t is an $n \times 1$ vector of time-varying intercept coefficients, $B_{i,t}, i = 1, \ldots, p$, are $n \times n$ matrices of time-varying coefficients; u_t are heteroscedastic unobservable shocks with variance covariance matrix Ω_t. The VAR's reduced-form innovations in equation (3.1) are assumed to have zero-mean and be normally distributed. As the time-varying covariance matrix Ω_t is positive definite for all t, there exist a lower triangular matrix A_t and a positive definite diagonal matrix Σ_t such that $\Omega_t = A_t^{-1}\Sigma_t\Sigma_t' A_t^{-1'}$, where Σ_t and A_t are explicitly defined as

$$\Sigma_t = \begin{pmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{n_t} \end{pmatrix}, \quad A = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ a_{21,t} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \\ a_{n1,t} & \cdots & a_{nn-1,t} & 1 \end{pmatrix}.$$

Therefore, we can decompose u_t as $u_t = A_t^{-1}\Sigma_t\varepsilon_t$ with $\varepsilon_t \sim N(0, I_n)$, such that (3.1) can be expressed as:

$$\boldsymbol{Y}_t = c_t + B_{1,t}\boldsymbol{Y}_{t-1} + ... + B_{p,t}\boldsymbol{Y}_{t-p} + A_t^{-1}\Sigma_t\varepsilon_t. \tag{3.2}$$

Defining $X_t = I_k \otimes (1, \boldsymbol{Y}'_{t-1}, \ldots, \boldsymbol{Y}'_{t-p})$, where $\otimes$ denotes the Kronecker product, we can write equation (3.2) as

$$\boldsymbol{Y}_t = X_t \boldsymbol{\beta}_t + A_t^{-1} \Sigma_t \, \varepsilon_t, \quad t = p+1, \ldots, T, \tag{3.3}$$

where $\boldsymbol{\beta}_t = [(\text{vec}(c_t))', \, (\text{vec}(B_{1,t}))', \ldots, (\text{vec}(B_{p,t}))']'$ is a $(n^2 p + n) \times 1$ vector with $\text{vec}(\cdot)$ denoting the vectorization operator, and where $\boldsymbol{\beta}_t, A_t$ and Σ_t are all time-varying.

Following Primiceri (2005), we denote $\boldsymbol{a}_t$ as stacked vector of the lower-triangular elements in A_t such that $\boldsymbol{a}_t = (a_{21,t}, a_{31,t}, a_{32,t}, a_{41,t}, \ldots, a_{nn-1,t})'$, and define $\boldsymbol{h}_t$ from the vector of the diagonal elements of the matrix Σ_t as $\boldsymbol{h}_t = (\log(\sigma_{1t}^2), \ldots, \log(\sigma_{nt}^2))'$. We assume that these time-varying parameters have the following dynamics:

$$\boldsymbol{\beta}_{t+1} \;=\; \boldsymbol{\beta}_t + u_{\beta_t}, \; \boldsymbol{a}_{t+1} = \boldsymbol{a}_t + u_{a_t}, \; \boldsymbol{h}_{t+1} = \boldsymbol{h}_t + u_{h_t}, \tag{3.4}$$

$$\begin{pmatrix} \varepsilon_t \\ u_{\beta_t} \\ u_{a_t} \\ u_{h_t} \end{pmatrix} \sim N \left(0, \begin{pmatrix} I_n & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix} \right)$$

for $t = p+1, \ldots, n$, where $\boldsymbol{\beta}_{p+1} \sim N(\mu_{\beta_0}, \Sigma_{\beta_0})$, $\boldsymbol{a}_{p+1} \sim N(\mu_{a_0}, \Sigma_{a_0})$ and $\boldsymbol{h}_{p+1} \sim N(\mu_{h_0}, \Sigma_{h_0})$ for some initial vectors and matrices of parameters μ_{β_0}, Σ_{β_0}, μ_{a_0}, Σ_{a_0}, μ_{h_0}, and Σ_{h_0}. The variance and covariance structure for the innovations of the time-varying parameters are controlled by the parameters Σ_β, Σ_a and Σ_h. Following Primiceri (2005), we assume that Σ_a is a diagonal matrix, meaning that the contemporaneous relationships between the variables are assumed to evolve independently across equations but are correlated within equations. We also assume that Σ_β and Σ_h are diagonal matrices to simplify the estimation of the parameters. As seen, (3.4) postulates a random walk behavior for all $\boldsymbol{a}_t$, $\boldsymbol{\beta}_t$ and $\boldsymbol{h}_t$. The random walk assumption allows us to focus on gradual and permanent shifts in the coefficients and reduces the number of parameters to estimate in the TVP-VAR model (see Primiceri, 2005).[2]

[2] Primiceri (2005) provide further discussion on how this model can be extended to more general autoregressive processes.

The TVP-VAR setting provides a flexible framework through which the interaction between monetary policy and exchange rates can be analyzed over time while allowing for the possibility of time-varying parameters and heteroscedastic shocks. This seems appropriate for the economies in our study, which have undergone structural changes over the past decades. For example, Nelson (2003) shows that the Bank of England has been more aggressive in responding to inflation during the 1990s than in the preceding decades. For the economies under consideration, structural changes may have also occurred along other dimensions. Likewise, TVP-VARs allow for flexible changes in the shock volatilities that are independent from the changes in the time-varying parameters.

We estimate the model using standard Bayesian MCMC methods. In particular, we use the MCMC routine developed by Nakajima (2011), and to shorten the presentation we refer the readers to his paper for a detailed description of the sampling algorithms. We use Nakajima's (2011) routine as it allows for more efficient joint sampling of the parameters.[3] For the initial states of the parameters, we place relatively uninformative priors. Specifically, we set $\mu_{\beta_0} = \mu_{a_0} = \mu_{h_0} = 0$ and $\Sigma_{\beta_0} = \Sigma_{a_0} = \Sigma_{h_0} = 10 \times I_n$. The corresponding hyper-parameters' priors for each draw i are respectively $(\Sigma_\beta)_i^{-2} \sim Gamma(80, 0.0005)$, $(\Sigma_a)_i^{-2} \sim Gamma(6, 0.005)$, $(\Sigma_h)_i^{-2} \sim Gamma(6, 0.005)$. The relatively tighter hyper-parameter priors for the VAR coefficients, i.e. $(\Sigma_\beta)_i^{-2}$, are chosen such that we can impose a stability constraint on the VAR coefficients. Looser priors for $(\Sigma_\beta)_i^{-2}$ allow for more drifts in the VAR coefficients but can also make the VAR unstable.[4] To compute the posterior estimates, we collect 5000 *restricted* posterior samples after discarding the initial 2000 as burn-in. Following Cogley and Sargent (2005), our posterior draws are restricted to be comprised of only those that produce stable VAR dynamics at each point in time.[5]

3.2 Data

The model is estimated for six small open economies including Australia, Canada, Norway, New Zealand, Sweden and the United Kingdom. We focus on small open economies as the

[3] The Matlab code is available at https://sites.google.com/site/jnakajimaweb/program.

[4] Another reason for choosing tighter priors for the VAR coefficients than those set for the variance and covariance states is because otherwise time variation in the variances of the model may be absorbed by the VAR coefficients, exaggerating the drifts in the systematic relationship between the variables. See Sims's (2001) comment on Cogley and Sargent (2001).

[5] See Appendix B of Cogley and Sargent (2005) for more details on this step.

exchange rate is potentially an important transmission channel for monetary policy. Quarterly data from 1983Q1 to 2019Q4 are used to estimate the model. The variables in the model are chosen following Bjørnland (2009) and reflect the theoretical setup of a New Keynesian small open economy model.[6] In particular, our empirical analysis is based on the vector of observables $\boldsymbol{Y_t} = [R_t^*, \pi_t, y_t, R_t, \Delta re_t]'$, where R_t^* is the trade-weighted foreign interest rate, π_t is the annual change in the log of consumer prices, i.e. inflation, y_t is the log of real gross domestic product, R_t is the domestic interest rate, and Δre_t is the first difference of the log of the trade-weighted real exchange rate.[7] We quadratically detrend the data before the estimations.[8]

3.3 Identification strategy

Our identification strategy follows Bjørnland (2009) and is based on a combination of short-run and long-run restrictions. First, a standard recursive structure is imposed between macroeconomic variables and the domestic interest rate, so that variables such as output and inflation do not react contemporaneously to monetary policy shocks, whereas there may be a simultaneous feedback from macroeconomic variables to domestic monetary policy setting. Similar recursive restrictions are imposed on the relationship between the exchange rate and macroeconomic variables. The exchange rate can react immediately to all shocks but there is slow exchange rate pass through to macroeconomic variables, for instance, due to nominal rigidities. Regarding the ordering of the remaining three variables, the foreign interest rate is placed on top of the ordering followed by inflation and output, assuming that domestic macroeconomic variables will be affected by exogenous foreign monetary policy contemporaneously (a plausible small open economy assumption). However, as discussed in Bjørnland (2009), responses to a monetary policy shock or an exchange rate shock (which are the last two variables in the ordering) will be invariant to the ordering of the first three variables.

[6] See Clarida et al. (2001) and Svensson (2000).

[7] See the Appendix for a description of the data sources.

[8] Bjørnland (2009) estimates a constant-parameter VAR together with a linear time trend. We choose to quadratically detrend the data instead of linear detrending as we extend the sample. Doing so makes the data comparable to Bjørnland (2009) for the overlapping period (comparison available upon request).

Turning to the interaction between monetary policy and the exchange rate, the above identification assumptions are not enough to separately identify monetary policy and exchange rate shocks. A standard identification scheme, as often adopted in the literature, is to use Cholesky decomposition that either (i) restricts monetary policy from reacting contemporaneously to an exchange rate shock (Eichenbaum and Evans, 1995, e.g.), or (ii) restricts the exchange rate from reacting immediately to a monetary policy shock (Marcellino and Favero, 2004; Mojon and Peersman, 2001, e.g.). However, as discussed in Bjørnland (2009), both restrictions are inconsistent with established theory as well as central bank practice. For instance, (i) is equivalent to assuming that the monetary authority ignores any surprise changes in exchange rates during the time monetary policy decisions are made. Identification scheme (ii) is also dubious since exchange rates, being asset prices, are known to react instantaneously to monetary policy. Bjørnland (2009) documents that it is important to allow for full simultaneity between monetary policy and exchange rate response as otherwise the identified structural shocks will be biased. Hence, we do not impose a recursive structure between the domestic interest rate and the real exchange rate. Instead, identification is achieved following Bjørnland (2009) by assuming that monetary policy shocks do not have long-run effects on real exchange rates,[9] which is a standard neutrality assumption that holds for a large class of monetary models in the literature.[10] The long-run neutrality assumption is also consistent with Dornbusch's overshooting model. The monetary policy shock is now uniquely identified and the identification restrictions allow for contemporaneous interaction between monetary policy and the exchange rate.[11]

4 Empirical results

The model is estimated with three lags for Australia, Canada, New Zealand, Norway, Sweden and the United Kingdom. The lag length is set in accordance with Bjørnland (2009).[12] The

[9] That is why the exchange rate enters as a first difference so that when long-run restrictions are applied to the first-differenced real exchange rate, the effect on the level of the exchange rate will eventually be zero.

[10] The exchange rate may still be permanently affected by other types of shocks, thus allowing for long-run deviations from purchasing power parity (PPP), which is a well established empirical fact.

[11] We follow Binning (2013)'s implementation of Rubio-Ramirez et al. (2010)'s algorithm for imposing combined short-run and long-run restrictions.

[12] Our results remain essentially unchanged when using two lags instead as in Cogley and Sargent (2005); Primiceri (2005).

results from the baseline specification are presented in this section while the next section contains some robustness checks.

Figure 1 plots the median (solid lines) and the 68% credible intervals (gray shaded areas) of the posterior distributions of the standard deviations of the estimated monetary policy shocks for each of the six countries. The figure shows that there has been a dramatic decline in the volatility of policy shocks in all countries over time with policy shocks being virtually negligible since the 2000s. Together with the adoption of inflation-targeting, this provides evidence of better monetary policy in the sense that policy has become less idiosyncratic over time. This result shows the importance of allowing for stochastic volatility in the estimated VAR. As discussed later, a direct implication of this finding is that the contribution of monetary policy shocks in explaining exchange rate and macroeconomic volatility have dramatically declined over time.

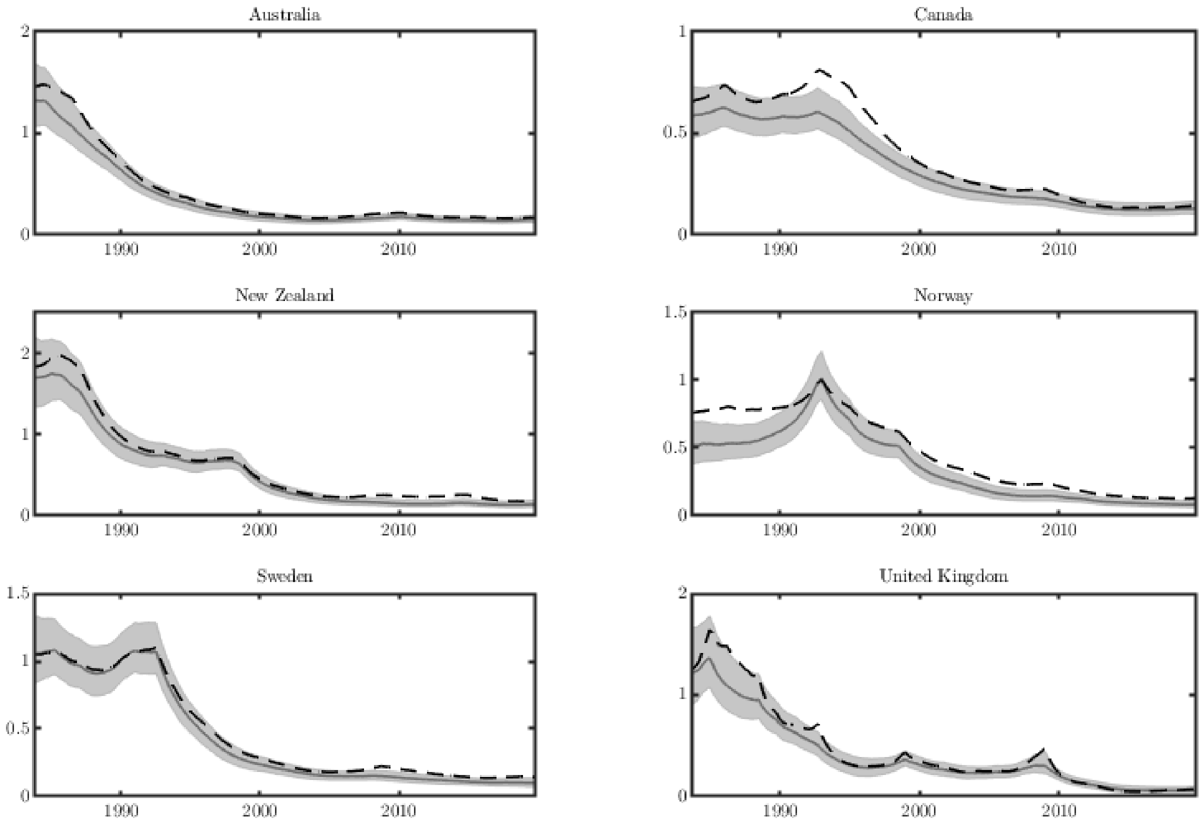

Figure 1: Standard deviation of monetary policy shocks. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

4.1 The Dornbusch overshooting hypothesis

Considering the dynamics of policy shocks, Figures 2-7 show the median (solid lines) and 68% credible intervals (gray shaded area) of the impulse responses of inflation, output, domestic interest rate and the first difference of the real exchange rate to a contractionary monetary policy shock for the six countries, respectively. To allow for comparability over time, we follow Nakajima (2011) and compute the impulse responses by fixing an initial shock size equal to the time series average of stochastic volatility over the sample period.[13]

As seen in the figures, the shock leads to significant and persistent increase in the interest rates in all countries. Similar to Bjørnland (2009), the shock is gradually offset with the interest rate returning to its steady-state value after about 3 years in most countries. In some countries the interest rate falls below steady-state before returning to its pre-shock level.

Looking at the response of the real exchange rate following the monetary shock, we see that it appreciates instantaneously in almost all countries. Hence, there is no evidence of an exchange rate puzzle in any of the countries studied, a result that contrasts with the findings of Grilli and Roubini (1995). However, in Australia and Norway, the exchange rate responses are not statistically significantly different from zero in the post-2000s. The maximum impact of the policy shock on the exchange rate occurs instantaneously in most countries across time, except for the United Kingdom where it is delayed by one quarter. Following the initial appreciation, the exchange rate thereafter depreciates back to its long-run level.[14] This result is consistent with economic theory – Dornbusch's (1976) exchange rate overshooting hypothesis states that an increase in the interest rate should cause the exchange rate to appreciate instantaneously, and then gradually depreciate. Our results are in line with Bjørnland (2009), who also confirms Dornbusch's theory. However, Bjørnland (2009) estimates a standard time-invariant VAR over the post-1980s (1983-2004 for most countries in her sample), meaning that her results depict the average effect over this time period. Notwithstanding this evidence, Kim et al. (2017) suggest, in the context of the U.S. economy, that the effects of monetary policy shocks on the exchange rate can be misleadingly estimated

[13] The impact response of the domestic interest rate nonetheless shows time variation due to the imposition of the long-run restriction, which, in turn, relies on accumulated responses over time.

[14] In the long-run, the policy shock has no effect on the level of the real exchange rate by construction, thanks to the long-run restriction imposed on the VAR.

when different monetary policy regimes are pooled. Kim and Lim (2018) discuss a similar issue related to shifts to inflation-targeting regime in small open economies in the 1990s. Nevertheless, our results suggest that Dornbusch's overshooting hypothesis not just holds on average but also across time for most countries in our sample, including both the pre and post inflation-targeting periods.[15]

Turning to the effect on output, we see that, consistent with economic theory, output falls in most countries across time following the policy shock. There is some evidence of time variation in the response of output in Australia, which becomes less negative over time and is insignificant from the 2000s. In contrast, the response of output becomes more negative in Canada during the 1990s. For New Zealand, the response of output is statistically insignificant over different horizons and across time. For the remaining countries, the responses remain fairly stable over time. For Australia, New Zealand and Norway, there is evidence of an initial prize puzzle, whereby inflation rises following a contractionary monetary policy shock. Following the price puzzle, the effect on inflation is eventually negative. This finding is in line with Bjørnland (2009) who also finds initial prize puzzles for Australia and New Zealand.[16] As discussed by Bjørnland (2009), price puzzles can be explained by a cost channel of the interest rate – higher interest rate increases borrowing costs and therefore marginal costs for firms which are then passed on to consumers as higher prices (see Ravenna and Walsh, 2006; Chowdhury et al., 2006).

Next, to ascertain the implications for time variation, we also estimate a constant-parameter VAR but with stochastic volatility. In this case, equation (3.1) becomes

$$\boldsymbol{Y}_t = c + B_1\boldsymbol{Y}_{t-1} + \ldots + B_p\boldsymbol{Y}_{t-p} + u_t, \quad t = p+1, \ldots, T, \tag{4.1}$$

where $\text{var}(u_t) = \Omega_t = A^{-1}\Sigma_t\Sigma_t'A^{-1\prime}$. Note that since B_j, where $(j = 1, \ldots, p)$, and A are both constants, i.e. time-invariant, Σ_t is the only time-varying component capturing stochastic volatility as before. We estimate this model using the same number of lags, dataset, sample period and prior for the initial states as above.

[15] The only exceptions are Australia and Norway where monetary policy shocks do not have any significant effects on exchange rates in the post-2000s period.

[16] Bjørnland (2009) does not have Norway in her dataset.

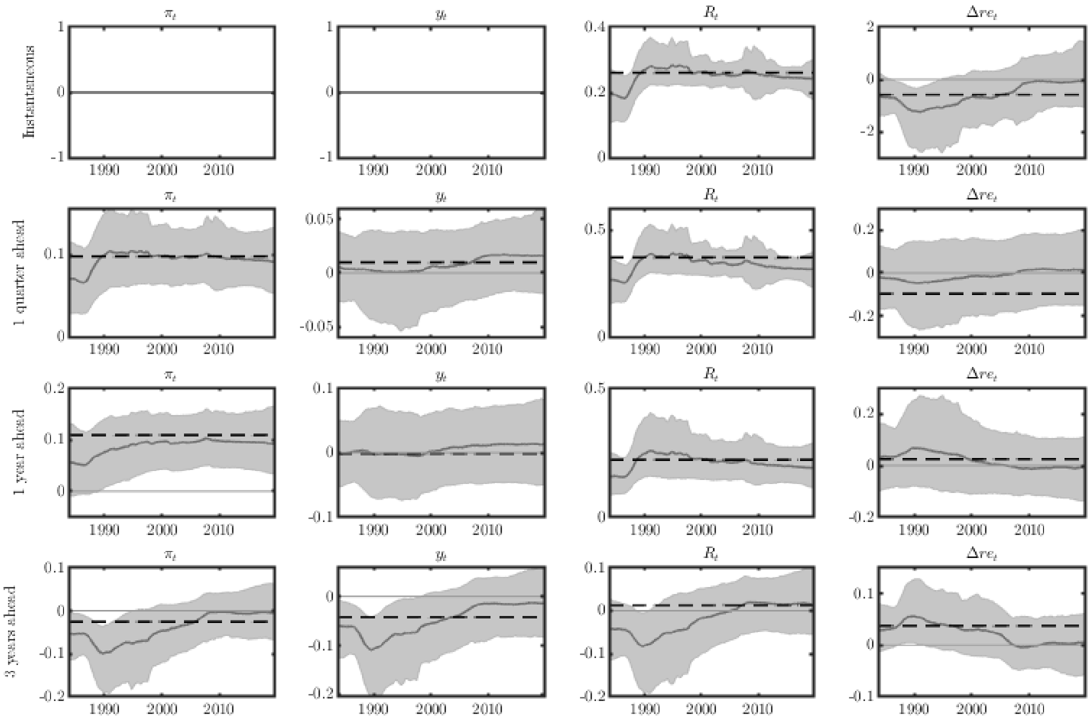

Figure 2: Australia – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

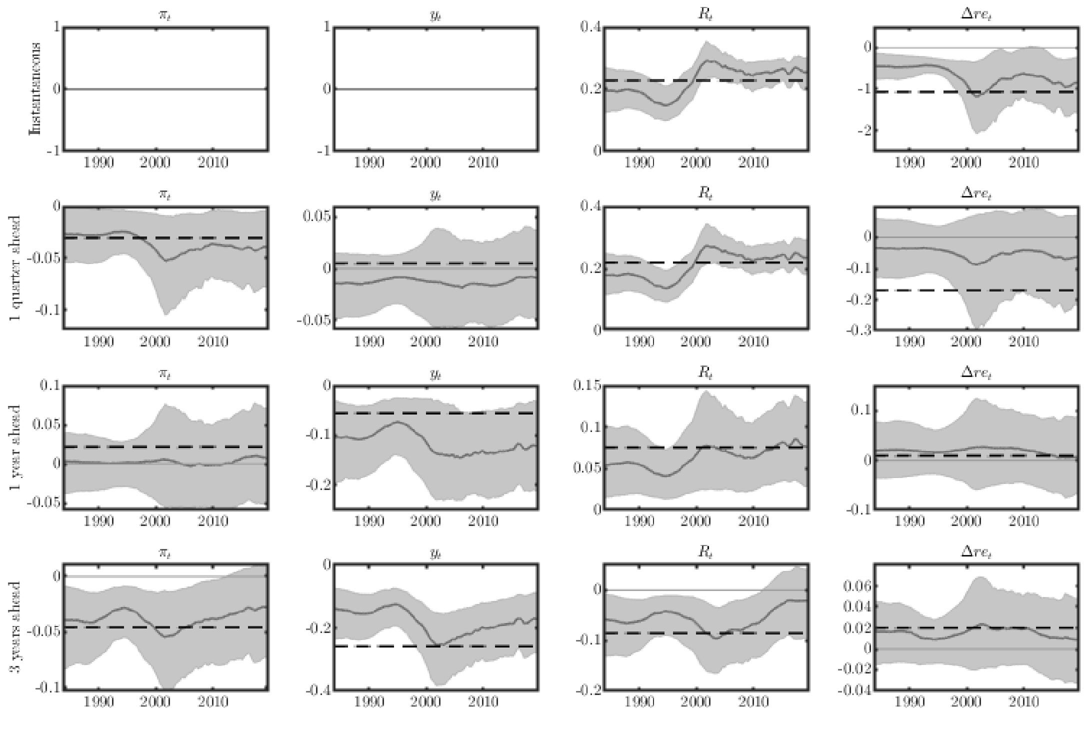

Figure 3: Canada – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

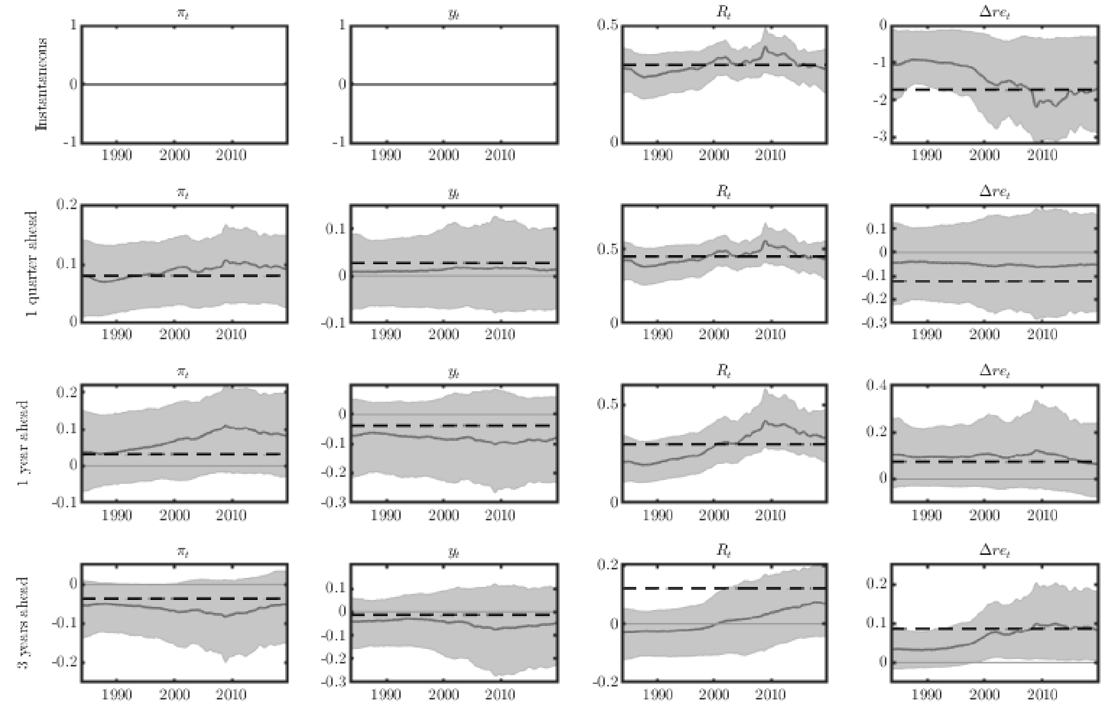

Figure 4: New Zealand – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

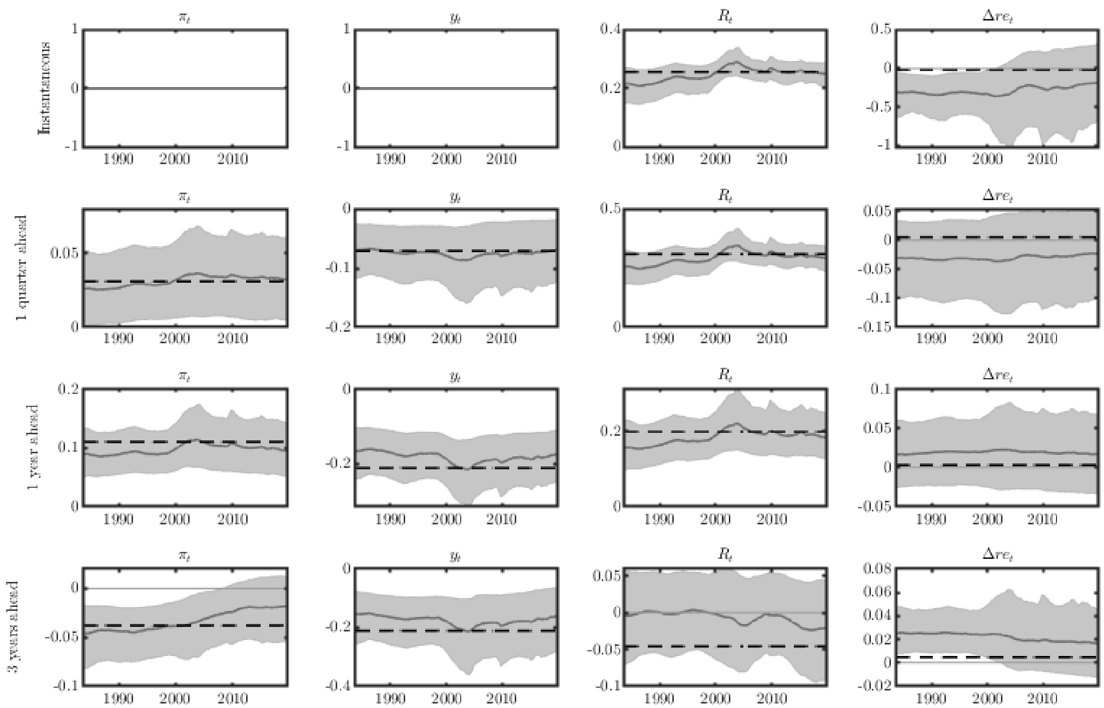

Figure 5: Norway – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

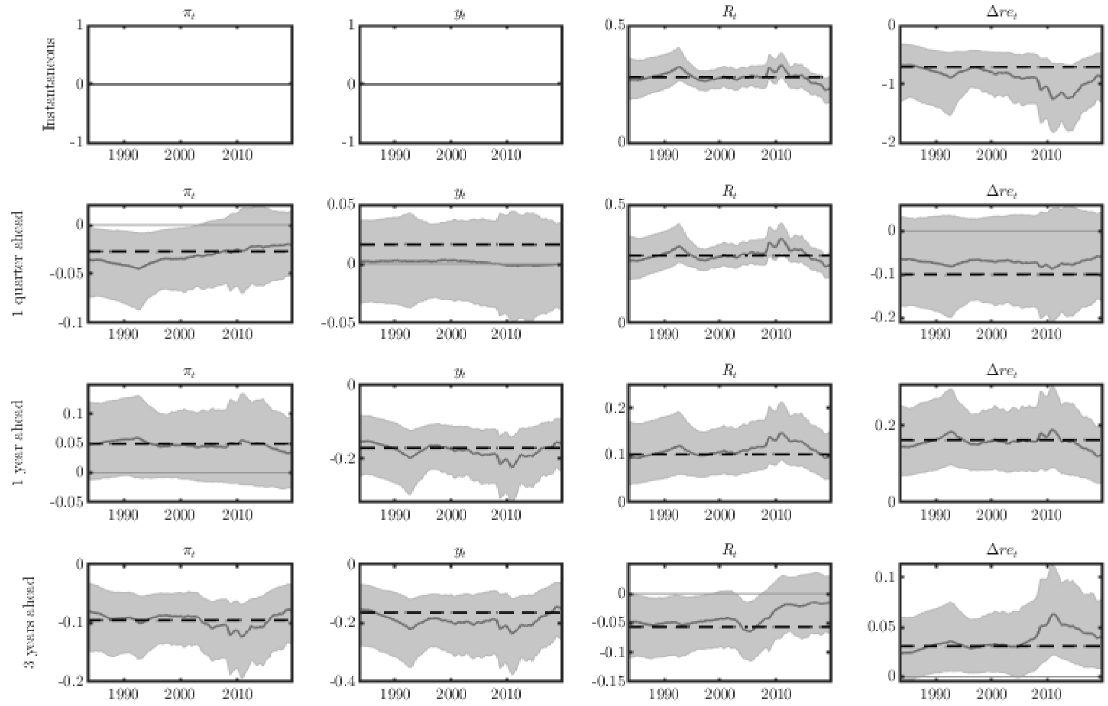

Figure 6: Sweden – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

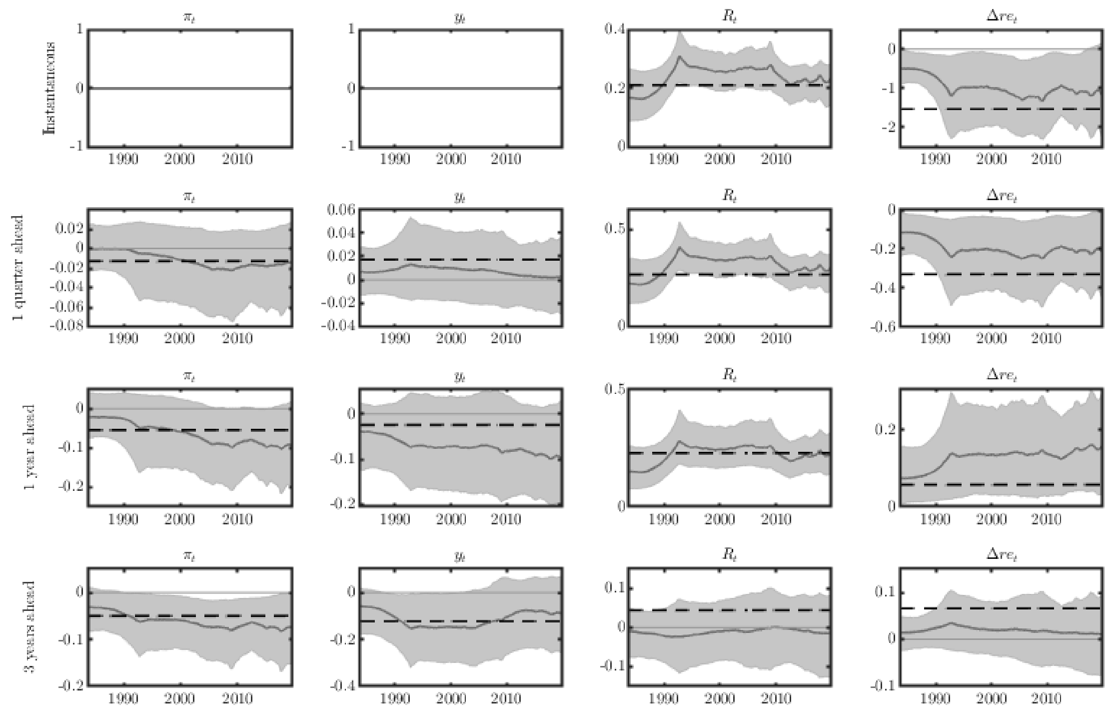

Figure 7: United Kingdom – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

First, we confirm that the pattern of the estimated stochastic volatility of the policy shocks remain quite similar, as seen from the dotted lines in Figure 1 which depict the posterior median estimates, with the volatility of monetary policy shocks declining over time. In Canada and Norway, the estimated volatility coming from the VAR-SV model (dotted line) is slightly higher in some periods than that from the TVP-VAR-SV model (solid line). Next, we look at the estimated impulse responses to monetary policy shocks, with the posterior median estimates reported as dotted lines in Figures 2-7. To ensure comparability between the impulse responses, we compute the impulse responses for the same sized initial shock as in the TVP-VAR-SV model. As seen in the figures, in most cases the constant-parameter VAR-SV model is able to capture the dynamics of monetary policy shocks relatively well, with the dotted lines contained within the shaded areas for most countries. Albeit there are some differences. For instance, for Canada we find the estimated response of the exchange rate in short horizons and the response of output in long horizons to be slightly more negative in the earlier part of the sample in the constant-parameter VAR-SV setting. For Norway, we find that the exchange rate does not respond to policy shocks even in short horizons. In fact, the same result for Norway is seen in some of our robustness checks with the TVP-VAR-SV setting, as discussed later. Overall, these findings suggest that while modeling stochastic volatility is clearly very important, time variation in the VAR parameters may not have played an important role in the dynamic effects of monetary policy shocks in these small open economies.

4.2 Uncovered interest parity (UIP)

In this section, we focus on examining whether there are deviations from UIP conditional on monetary policy shocks. There is strong evidence in the literature that UIP does not hold unconditionally in the data (see Fama, 1984; Engel, 1996; Burnside et al., 2006; Burnside, 2019). Nevertheless, what is more relevant for monetary policymakers is whether UIP holds conditional on monetary policy shocks. The literature provides mixed evidence with Eichenbaum and Evans (1995) and Faust and Rogers (2003) finding that it does not hold, while Bjørnland (2009) suggests that monetary policy shocks generate exchange rate movements largely consistent with UIP. In contrast, Scholl and Uhlig (2008) find that UIP (conditional on monetary policy shocks) fails to hold in the U.S. data even when (by construction) there is no delayed overshooting puzzle. Scholl and Uhlig (2008) argue that the forward discount puzzle, which implies a failure of the UIP, is not just a 'twin appearance' of the delayed overshooting puzzle but a standalone phenomenon.

To investigate this further, we follow Eichenbaum and Evans (1995) and Bjørnland (2009) and define ψ_t as the ex-post difference in return between holding one period of foreign bonds or one period of domestic bonds. Measured in domestic currency, ψ_t is then given by

$$\psi_t = R_t^* - R_t + 4 * (s_{t+1} - s_t) \tag{4.2}$$

where s_t is the nominal exchange rate and s_{t+1} is the one-quarter ahead forecast of the exchange rate.[17] One implication of UIP is that

$$E_t \psi_{t+j} = 0 \tag{4.3}$$

for all $j \geq 0$, where E_t denotes the expectations operator given the information available at time t (conditional expectations).

Figures 8-9 report the median and 68% credible intervals of the dynamic response function (4.3) based on the estimated VAR impulse responses.[18] Under UIP, these responses ought to be equal to zero. The figures shows that, with the exception of Australia and New Zealand, we can reject the hypothesis that the response functions equal zero. In most countries, after a contractionary monetary policy shock, the expected returns from investing in foreign short-term bonds fall relative to the returns from investing in domestic bonds. The excess return stays negative for about a quarter in Norway. In Canada, Sweden and the United Kingdom, there are instantaneous negative deviations from zero, but thereafter the responses mostly fluctuate around zero. On the other hand, in Australia and New Zealand, the responses essentially fluctuate around zero, consistent with UIP. We also find quantitatively similar results when estimating a constant-parameter VAR with stochastic volatility – the dotted

[17] The exchange rate is multiplied by 4 to be annualized since the interest rate is measured in annual terms.
[18] Note that we have to adjust for the effect of policy shocks on prices to obtain the effect on the nominal exchange rate, which is given by $s_t = re_t - p_t^* + p_t$. However, as in Bjørnland (2009), we can only correct for domestic prices as foreign prices are not included in the VAR. As Bjørnland (2009) points out, this restriction is equivalent to assuming that domestic monetary policy has a negligible effect on foreign prices, which is a plausible small open economy assumption.

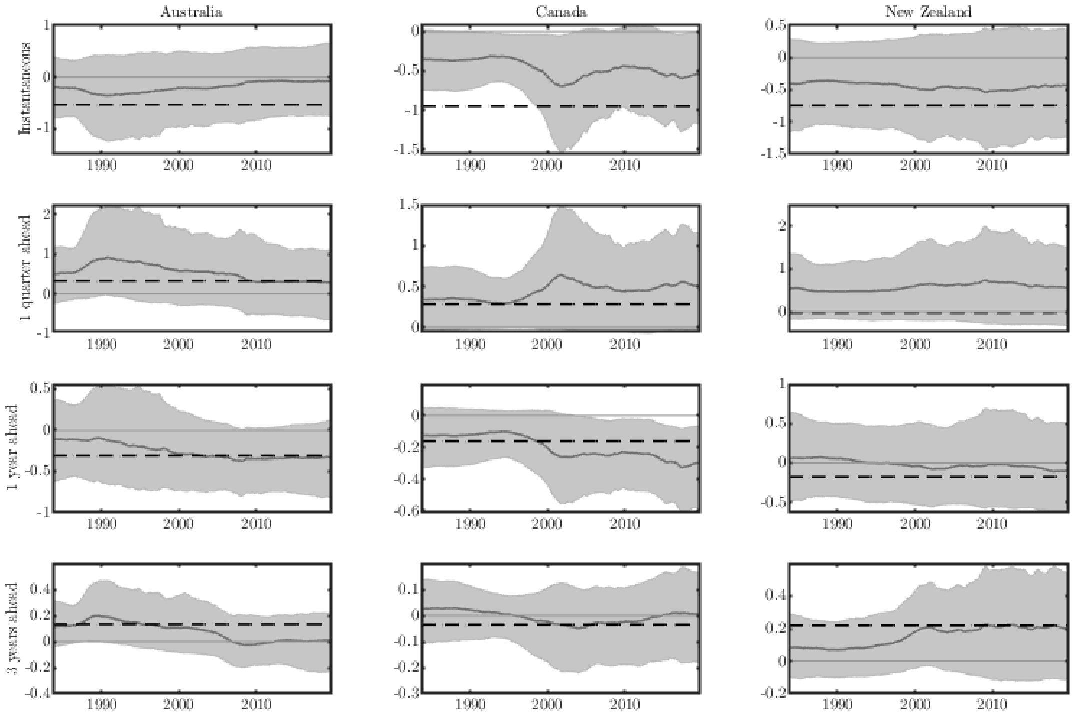

Figure 8: Conditional excess returns – Australia, Canada and New Zealand. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

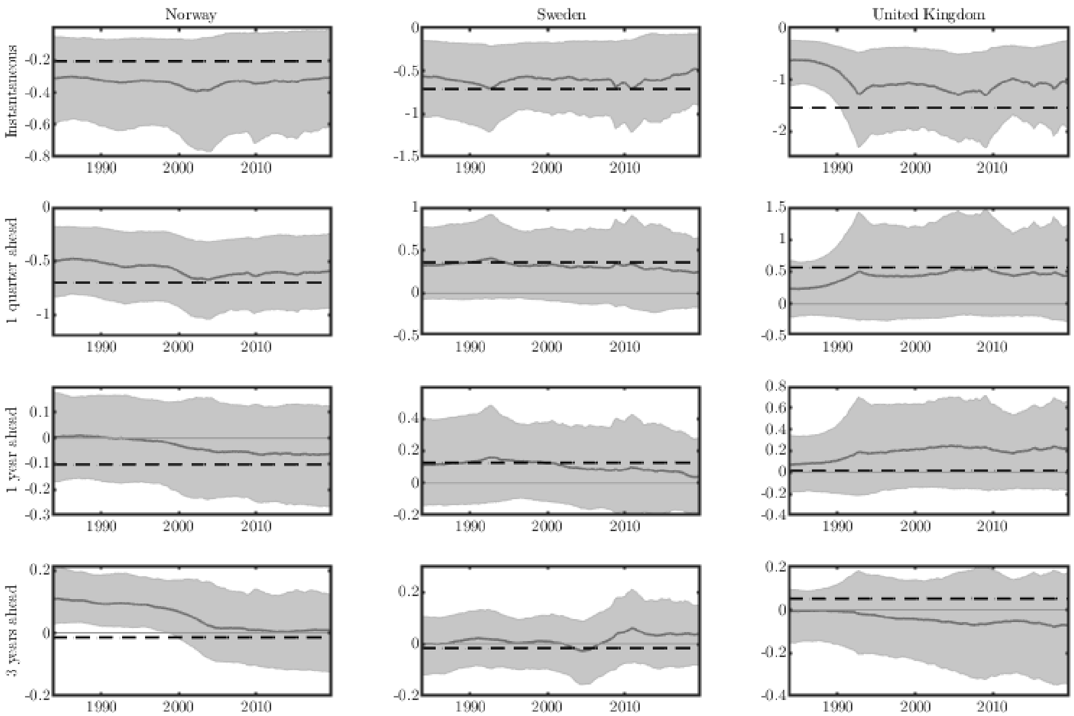

Figure 9: Conditional excess returns – Norway, Sweden and the United Kingdom. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

lines in Figures 8-9 plot the posterior median estimates. With the exception of Canada where the excess returns are slightly more negative on impact in the earlier part of the sample, the findings turn out to be quite similar. Overall, our results point toward deviations from UIP in most countries, particularly in short horizons. Our results are in line with Scholl and Uhlig (2008) who show evidence of the forward discount puzzle even without delayed overshooting.

4.3 Monetary policy and exchange rate volatility

To investigate how much monetary policy shocks account for exchange rate volatility, we study the fraction of the forecast error variances of the variables that are explained by monetary policy shocks. Figures 10-15 plot the forecast error variance decompositions (FEVDs) for monetary policy shocks for the six small open economies at different horizons. As before, the solid lines depict median responses while the shaded areas show 68% credible intervals from the TVP-VAR-SV.

The figures show that monetary policy shocks explain a non-trivial fraction (around 20-60%) of exchange rate fluctuations in the 1980s. Thereafter, there has been a dramatic decline in the importance of policy shocks in explaining exchange rate fluctuations since the 1990s, which coincides with the adoption of inflation-targeting in many of the countries in our sample, and an accompanying decline in the volatility of monetary policy shocks. In fact, policy shocks literally have not explained exchange rate volatility in Australia, Norway and Sweden since the 2000s and in Canada and the United Kingdom since the 2010s. Our results stand in sharp contrast to Bjørnland (2009) who find that policy shocks explain, on average, a large fraction of exchange rate volatility in several small open economies. Instead our results suggest that once stochastic volatility is accounted for, monetary policy shocks are no longer an important driver of exchange rate fluctuations in small open economies, particularly since the 2000s. This result occurs primarily because of the substantial decline in the estimated volatility of monetary policy shocks over the sample period. Failure to take into account this decline over time, as in Bjørnland (2009), leads to averaging out the time-varying contributions and misleadingly overestimating the contribution of monetary policy shocks in explaining exchange rate fluctuations.

Regarding the remaining variables, our results show that monetary policy shocks explain only a small fraction of output and inflation volatility, which are in line with the monetary policy literature. In addition, the contributions of policy shocks in explaining inflation and output volatility have also fallen over time, such that policy shocks are almost negligible in explaining inflation and output volatility in most countries in the post-2000s. Overall, our findings suggest that monetary policy in small open economies has become less idiosyncratic over time, particularly since the adoption of inflation-targeting, thereby leading to a decline in the volatility of monetary policy shocks and an accompanying reduction in the importance of policy shocks in driving both macroeconomic fluctuations and exchange rate volatility.

Figures 10-15 also depict the posterior medians of the FEVDs in the constant-parameter VAR-SV setting (as dotted lines). The fact that the dotted lines align quite well with the estimations from the TVP-VAR-SV highlights the importance of stochastic volatility as the main driver of these findings.

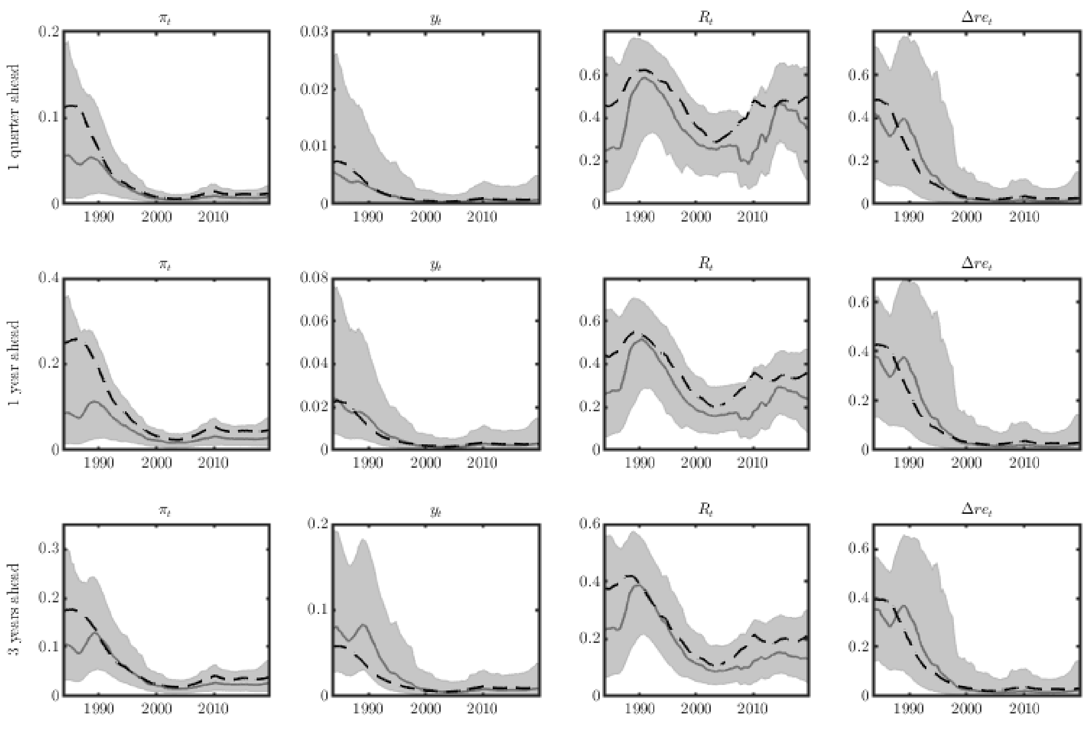

Figure 10: Australia – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

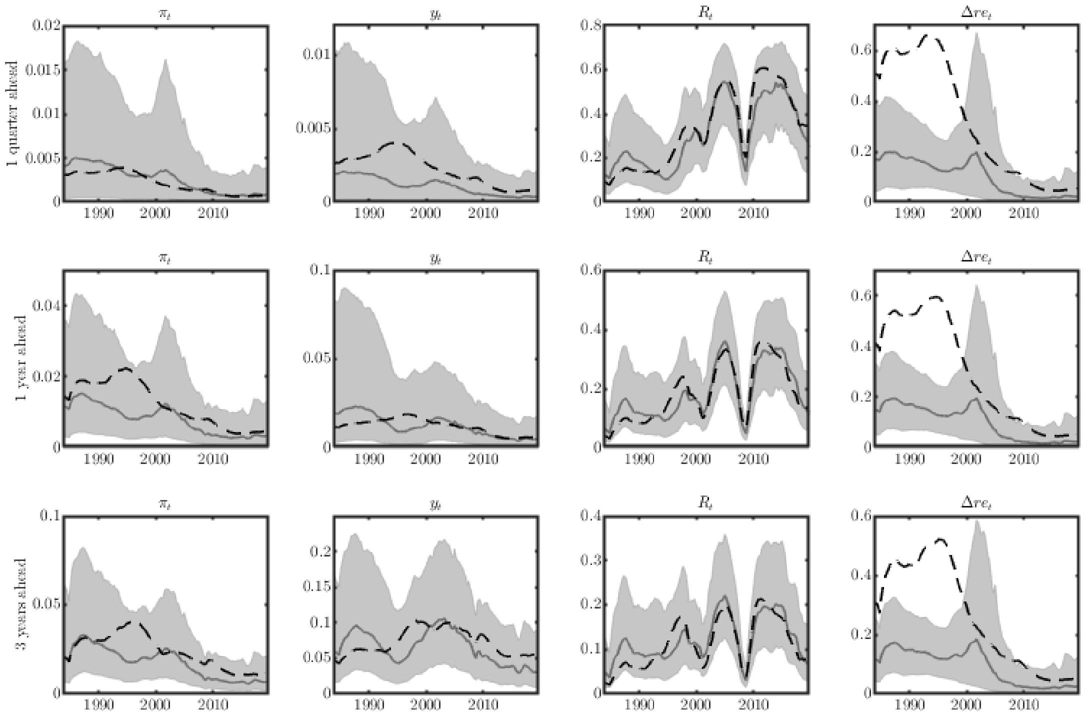

Figure 11: Canada – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

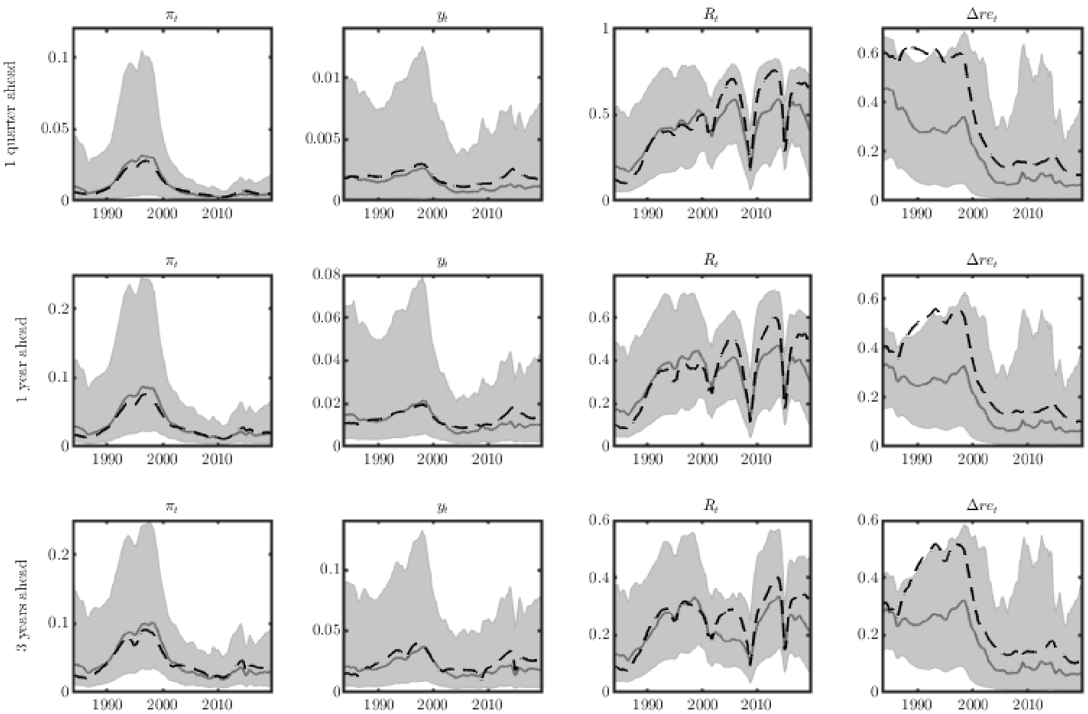

Figure 12: New Zealand – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

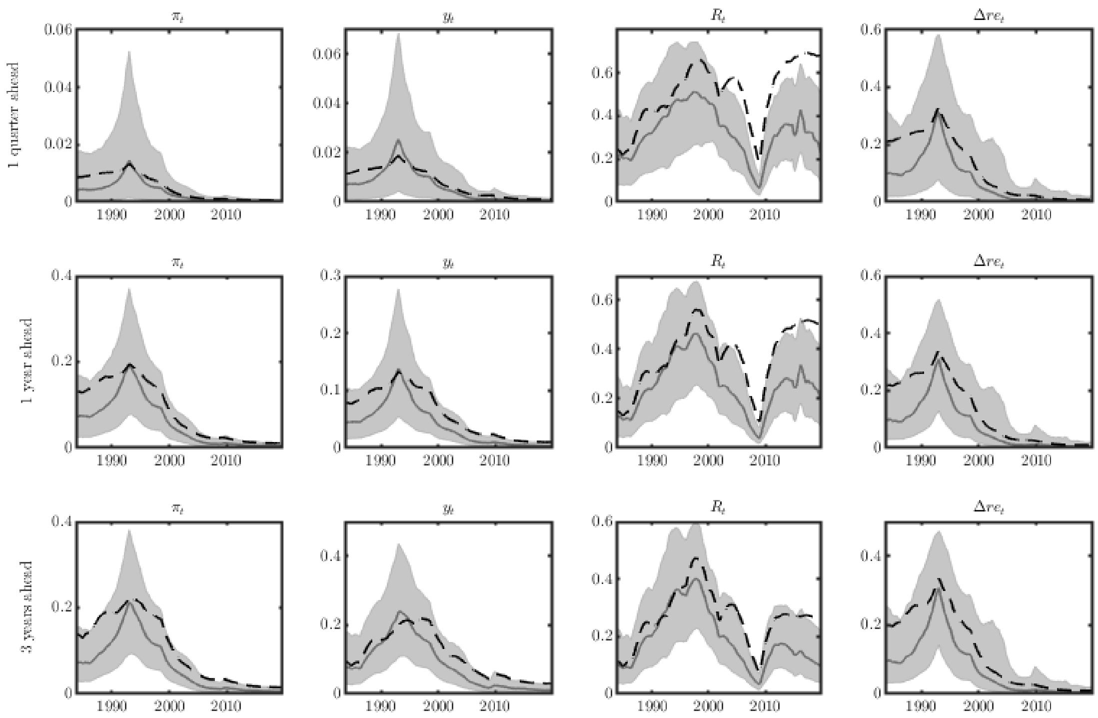

Figure 13: Norway – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

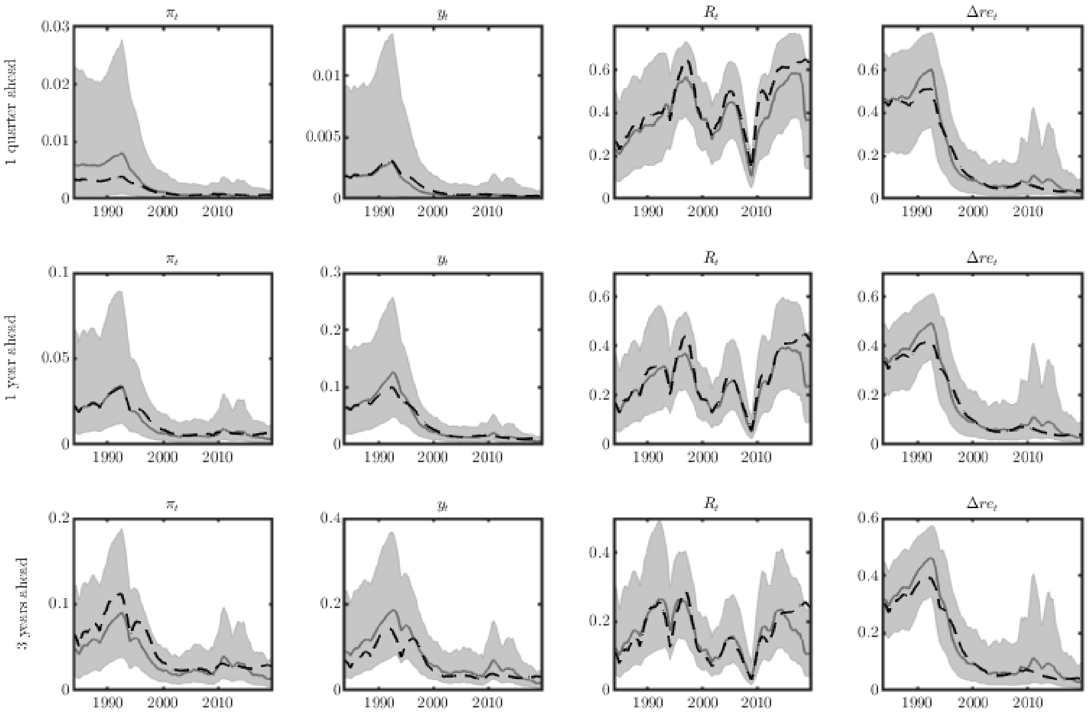

Figure 14: Sweden – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

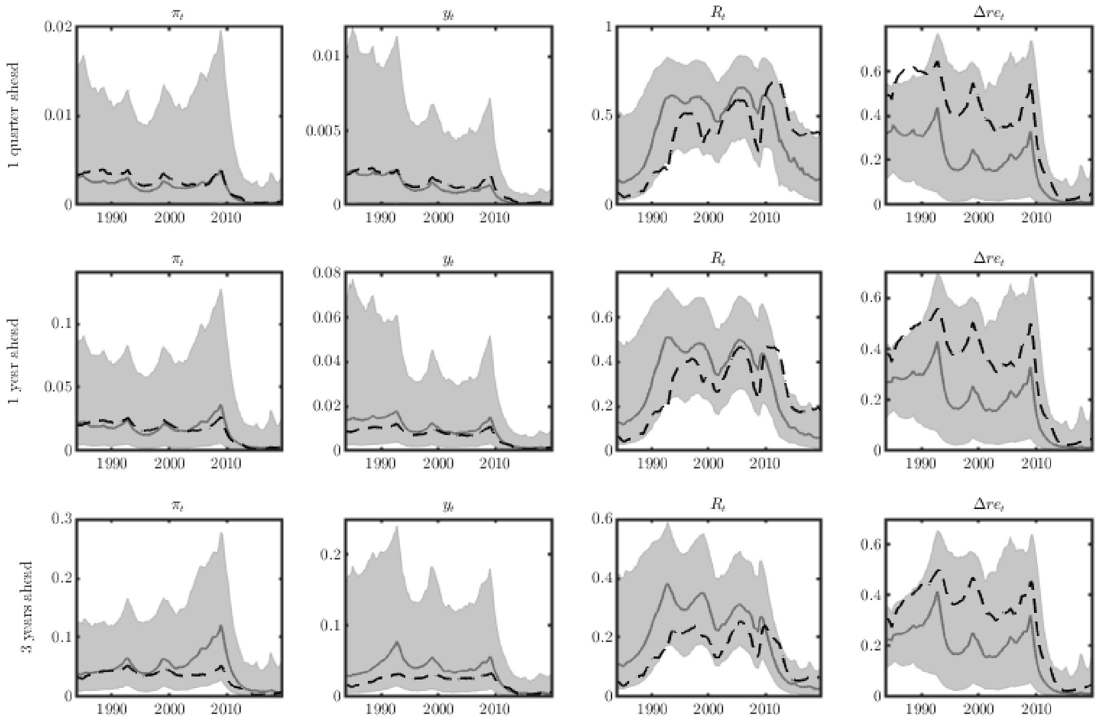

Figure 15: United Kingdom – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

5 Robustness checks

We check the robustness of our results in the following dimensions: (i) model specification, (ii) lag length, (iii) priors, and (iv) additional variable. With regards to the specification, we do not detrend the data before estimation except for output (which we detrend to get the output gap). Next, we check the robustness to the lag length, using two instead of three lags in the estimated TVP-VARs, as in Cogley and Sargent (2005) and Primiceri (2005). Then, we check the robustness to the priors used. As discussed earlier, the hyper-parameter priors for the VAR coefficients are chosen so as to make the VARs stable at each point in time. Hence, we leave this prior unchanged but use a tighter prior for the variance and covariance states. Our baseline results suggest significant time variation in the volatility of monetary policy shocks. Since the hyper-parameters govern the rate at which the parameters vary over time, a tighter prior allows us to check whether we still find substantial drifts in the volatility of policy shocks over time. Finally, we check the robustness of our results to the inclusion of oil price in the VAR. Oil price is an important leading indicator that monetary policymakers may react to. Moreover, as discussed in Bjørnland and Halvorsen (2014), some of the countries in our study – Canada, Norway and the United Kingdom – are net oil exporters and therefore oil price fluctuations in these countries may affect exchange rates. In particular, we include the growth rate of oil price in the estimated VAR and assume it to be the most exogenous variable (as these are small open economies). The estimations remain very similar to the baseline with the exception that we need to use a tighter prior for the hyper-parameters governing drifts in the VAR coefficients. This is because adding additional variables in a TVP-VAR make it harder to impose a stability constraint on the VAR coefficients (see DelNegro, 2003) and as a compromise we tighten the prior to make the estimations feasible.

Figures 16-29 in the Appendix show the results from these robustness exercises for all six countries. As in the baseline analysis, we plot the impulse responses (Figures 16-21), the conditional excess returns (Figures 22-23) and the FEVDs (Figures 24-29) for each country. In each figure, we plot the baseline results and overlay the estimated posterior medians from the robustness exercises. Clearly the main results are robust to these changes. In particular, we do not find any evidence of the exchange rate puzzle or delayed overshooting. Nonetheless, we do find evidence of the forward discount puzzle in some countries conditional on monetary policy shocks, which suggests a violation of UIP in these countries. Moreover, there is a substantial decrease in the importance of monetary policy shocks in explaining exchange rate and macroeconomic volatility since the 1990s. Notable changes are found when we add oil price as an additional variable, as now the estimated exchange rate responses in Australia and Norway are not statistically different from zero throughout the entire sample. Another exception is with regards to the model specification for Australia with insignificant exchange rate and output responses. Note that even in our baseline analysis, the response of the exchange rate was statistically insignificant in the post-2000s in these two countries.

6 Conclusion

This paper investigates the time-varying effects of monetary policy shocks for six small open economies. We do this by considering time-varying parameter VAR models with stochastic volatility that are estimated within a Bayesian framework. Identification is achieved using a combination of short-run and long-run restrictions, which preserves the contemporaneous interaction between the interest rate and the exchange rate.

We find that a contractionary monetary policy shock causes the exchange rate to appreciate instantaneously in most countries, providing evidence against the exchange rate puzzle. We also find that the maximum impact of the policy shock on the exchange rate occurs almost instantaneously with the exchange depreciating back to its long-run level thereafter, providing evidence against the delayed overshooting hypothesis. As such, our results suggest little evidence for both the exchange rate puzzle and the delayed overshooting puzzle, and suggest that these hold not just on average – as shown in previous studies – but also across time. However, we find evidence of the forward discount puzzle, suggesting violation of UIP conditional on monetary policy shocks in four of the six countries. The only exceptions are Australia and New Zealand, where the responses are consistent with UIP. Hence, our findings show the presence of the forward discount puzzle even without delayed overshooting, confirming that the former is not merely a 'twin appearance' of delayed overshooting but rather a standalone feature in many countries.

We also document substantial decline in the estimated volatility of monetary policy shocks in all countries, while time variations in the VAR parameters seems to play a minor role. In addition, a significant decrease in the contribution of monetary policy shocks in driving exchange rate volatility is observed since the 1990s, which coincides with the adoption of inflation-targeting and central bank independence in most countries. Finally, our findings suggest that the contributions of policy shocks in explaining inflation and output volatility have also fallen over time in all countries. Overall, our study sheds new light on the puzzles in the empirical open-economy literature.

References

Benati, L. and T. A. Lubik (2014a). Sales, inventories and real interest rates: A century of stylized facts. *Journal of Applied Econometrics 29*(7), 1210–1222.

Benati, L. and T. A. Lubik (2014b). The time-varying Beveridge curve. In *Advances in Non-Linear Economic Modeling*, pp. 167–204. Springer.

Binning, A. (2013). Underidentified SVAR models: A framework for combining short and long-run restrictions with sign-restrictions. Technical report, Norges Bank.

Bjørnland, H. C. (2009). Monetary policy and exchange rate overshooting: Dornbusch was right after all. *Journal of International Economics 79*(1), 64–77.

Bjørnland, H. C. and J. I. Halvorsen (2014). How does monetary policy respond to exchange rate movements? New international evidence. *Oxford Bulletin of Economics and Statistics 76*(2), 208–232.

Burnside, C. (2019). Exchange rates, interest parity, and the carry trade. In *Oxford Research Encyclopedia of Economics and Finance.*

Burnside, C., M. S. Eichenbaum, I. Kleshchelski, and S. Rebelo (2006). The returns to currency speculation.

Canova, F. and L. Gambetti (2009). Structural changes in the US economy: Is there a role for monetary policy? *Journal of Economic Dynamics and Control 33*(2), 477–490.

Chowdhury, I., M. Hoffmann, and A. Schabert (2006). Inflation dynamics and the cost channel of monetary transmission. *European Economic Review 50*(4), 995–1016.

Clarida, R., J. Gali, and M. Gertler (2001). Optimal monetary policy in open versus closed economies: An integrated approach. *American Economic Review 91*(2), 248–252.

Cogley, T. and T. J. Sargent (2001). Evolving post-World War II US inflation dynamics. *NBER Macroeconomics Annual 16*, 331–373.

Cogley, T. and T. J. Sargent (2005). Drifts and volatilities: monetary policies and outcomes in the post WWII US. *Review of Economic Dynamics 8*(2), 262–302.

Cushman, D. O. and T. Zha (1997). Identifying monetary policy in a small open economy under flexible exchange rates. *Journal of Monetary Economics 39*(3), 433–448.

DelNegro, M. (2003). Discussion of Cogley and Sargent's Is "Drifts and volatilities: Monetary policies and outcomes in the post WWII U.S.". FRB Atlanta Working Paper 2003-26, Federal Reserve Bank of Atlanta.

Dornbusch, R. (1976). Expectations and exchange rate dynamics. *Journal of Political Economy 84*(6), 1161–1176.

Eichenbaum, M. and C. L. Evans (1995). Some empirical evidence on the effects of shocks to monetary policy on exchange rates. *The Quarterly Journal of Economics 110*(4), 975–1009.

Engel, C. (1996). The forward discount anomaly and the risk premium: A survey of recent evidence. *Journal of empirical finance 3*(2), 123–192.

Fama, E. F. (1984). Forward and spot exchange rates. *Journal of Monetary Economics 14*(3), 319–338.

Faust, J. and J. H. Rogers (2003). Monetary policy's role in exchange rate behavior. *Journal of Monetary Economics 50*(7), 1403–1424.

Grilli, V. and N. Roubini (1995). Liquidity and exchange rates: puzzling evidence from the G-7 countries. Technical report.

Haque, Q. and L. M. Magnusson (2021). Uncertainty shocks and inflation dynamics in the us. *Economics Letters 202*, 109825.

Haque, Q., L. M. Magnusson, and K. Tomioka (2021). Empirical evidence on the dynamics of investment under uncertainty in the US. *Oxford Bulletin of Economics and Statistics 83*(5), 1193–1217.

Kim, S. (2003). Monetary policy, foreign exchange intervention, and the exchange rate in a unifying framework. *Journal of International Economics 60*(2), 355–386.

Kim, S. and K. Lim (2018). Effects of monetary policy shocks on exchange rate in small open economies. *Journal of Macroeconomics 56*, 324–339.

Kim, S. and N. Roubini (2000). Exchange rate anomalies in the industrial countries: A solution with a structural VAR approach. *Journal of Monetary Economics 45*(3), 561–586.

Kim, S.-H., S. Moon, and C. Velasco (2017). Delayed overshooting: Is it an '80s puzzle? *Journal of Political Economy 125*(5), 1570–1598.

Lindé, J. (2003). Monetary policy shocks and business cycle fluctuations in a small open economy: Sweden 1986-2002.

Marcellino, M. and C. A. Favero (2004). Large datasets, small models and monetary policy in Europe.

Mojon, B. and G. Peersman (2001). A VAR description of the effects of monetary policy in the individual countries of the euro area. In *European Central Bank Working Paper Series*, Volume 92, pp. 1–49. European Central Bank.

Mumtaz, H. and L. Sunder-Plassmann (2013). Time-varying dynamics of the real exchange rate: An empirical analysis. *Journal of Applied Econometrics 28*(3), 498–525.

Nakajima, J. (2011). Time-varying parameter VAR model with stochastic volatility: An overview of methodology and empirical applications. *Monetary and Economic Studies 29*(1), 107–142.

Nelson, E. (2003). 7. UK monetary policy, 1972-97: a guide using Taylor rules. *Central Banking, Monetary Theory and Practice: Essays in Honour of Charles Goodhart 1*, 195.

Peersman, G. and F. Smets (2001). The monetary transmission mechanism in the euro area: More evidence from VAR analysis. *ECB-Working Paper Series No 91*, 1–37.

Primiceri, G. E. (2005). Time varying structural vector autoregressions and monetary policy. *The Review of Economic Studies 72*(3), 821–852.

Ravenna, F. and C. E. Walsh (2006). Optimal monetary policy with the cost channel. *Journal of Monetary Economics 53*(2), 199–216.

Rubio-Ramirez, J. F., D. F. Waggoner, and T. Zha (2010). Structural vector autoregressions: Theory of identification and algorithms for inference. *The Review of Economic Studies 77*(2), 665–696.

Scholl, A. and H. Uhlig (2008). New evidence on the puzzles: Results from agnostic identification on monetary policy and exchange rates. *Journal of International Economics 76*(1), 1–13.

Sims, C. A. (2001). Evolving post-World War II US inflation dynamics: comment. *NBER Macroeconomics Annual 16*, 373–379.

Svensson, L. E. (2000). Open-economy inflation targeting. *Journal of International Economics 50*(1), 155–183.

Yang, Y. and J. Zhang (2021). Effects of monetary policy on the exchange rates: A time-varying analysis. *Finance Research Letters*, 102–114.

Appendix

A Data Sources

All data are retrieved from the Federal Reserve Economic Data (FRED).

A.1 Australia

- **Consumer Price Index of All Items in Australia**

  https://fred.stlouisfed.org/series/AUSCPIALLQINMEI

- **Constant Price Gross Domestic Product in Australia**

  https://fred.stlouisfed.org/series/AUSGDPRQDSMEI

- **3-Month or 90-day Rates and Yields: Interbank Rates for Australia**

  https://fred.stlouisfed.org/series/IR3TIB01AUM156N

- **Real Effective Exchange Rates Based on Manufacturing Consumer Price Index for Australia**

  https://fred.stlouisfed.org/series/CCRETT01AUM661N

A.2 Canada

- **Consumer Price Index of All Items in Canada**

  https://fred.stlouisfed.org/series/CANCPIALLMINMEI

- **Gross Domestic Product by Expenditure in Constant Prices: Total Gross Domestic Product for Canada**

  https://fred.stlouisfed.org/series/NAEXKP01CAQ189S

- **3-Month or 90-day Rates and Yields: Interbank Rates for Canada**

  https://fred.stlouisfed.org/series/IR3TIB01CAM156N

- **Real Effective Exchange Rates Based on Manufacturing Consumer Price Index for Canada**

  https://fred.stlouisfed.org/series/CCRETT01CAM661N

A.3 New Zealand

- **Consumer Price Index: All Items for New Zealand**
  https://fred.stlouisfed.org/series/NZLCPIALLQINMEI

- **Leading Indicators OECD: Reference Series: Gross Domestic Product: Original Series for New Zealand**
  https://fred.stlouisfed.org/series/LORSGPORNZQ661S;

- **3-Month or 90-day Rates and Yields: Interbank Rates for New Zealand**
  https://fred.stlouisfed.org/series/IR3TIB01NZM156N

- **Real Effective Exchange Rates Based on Manufacturing Consumer Price Index for New Zealand**
  https://fred.stlouisfed.org/series/CCRETT01NZM661N

A.4 Norway

- **Consumer Price Index: All Items in Norway**
  https://fred.stlouisfed.org/series/NORCPIALLMINMEI

- **Real Gross Domestic Product for Norway**
  https://fred.stlouisfed.org/series/CLVMNACSCAB1GQNO

- **3-Month or 90-day Rates and Yields: Interbank Rates for Norway**
  https://fred.stlouisfed.org/series/IR3TIB01NOM156N

- **Real Effective Exchange Rates Based on Manufacturing Consumer Price Index for Norway**
  https://fred.stlouisfed.org/series/CCRETT01NOM661N

A.5 Sweden

- **Consumer Price Index: All Items in Sweden**
  https://fred.stlouisfed.org/series/SWECPIALLMINMEI

- **Leading Indicators OECD: Reference Series: Gross Domestic Product: Original Series for Sweden**

  https://fred.stlouisfed.org/series/LORSGPORSEQ661S

- **3-Month or 90-day Rates and Yields: Interbank Rates for Sweden**

  https://fred.stlouisfed.org/series/IR3TIB01SEM156N

- **Real Effective Exchange Rates Based on Manufacturing Consumer Price Index for Sweden**

  https://fred.stlouisfed.org/series/CCRETT01SWM661N

A.6 United Kingdom

- **Consumer Price Index of All Items in the United Kingdom**

  https://fred.stlouisfed.org/series/GBRCPIALLMINMEI

- **Gross Domestic Product by Expenditure in Constant Prices: Total Gross Domestic Product for the United Kingdom**

  https://fred.stlouisfed.org/series/NAEXKP01GBQ652S

- **3-Month or 90-day Rates and Yields: Interbank Rates for the United Kingdom**

  https://fred.stlouisfed.org/series/IR3TIB01GBM156N

- **Real Effective Exchange Rates Based on Manufacturing Consumer Price Index for the United Kingdom**

  https://fred.stlouisfed.org/series/CCRETT01GBM661N

A.7 Additional Data

- **Trade-weighted foreign interest rate.**

  We follow Bjørnland and Halvorsen (2014) in constructing data for the foreign interest rate. For Australia, New Zealand, Norway and Sweden, the foreign interest rate is a weighted average of the interest rates in the major trading partners, based on data from the respective central banks. For Canada and the UK, the foreign interest rate is assumed to be the Federal Funds rate since the U.S. comprises the bulk of the foreign trade weight in these countries.

- **Spot Crude Oil Price: West Texas Intermediate (WTI)**
  https://fred.stlouisfed.org/series/WTISPLC#0

B Additional Results

B.1 Impulse Responses

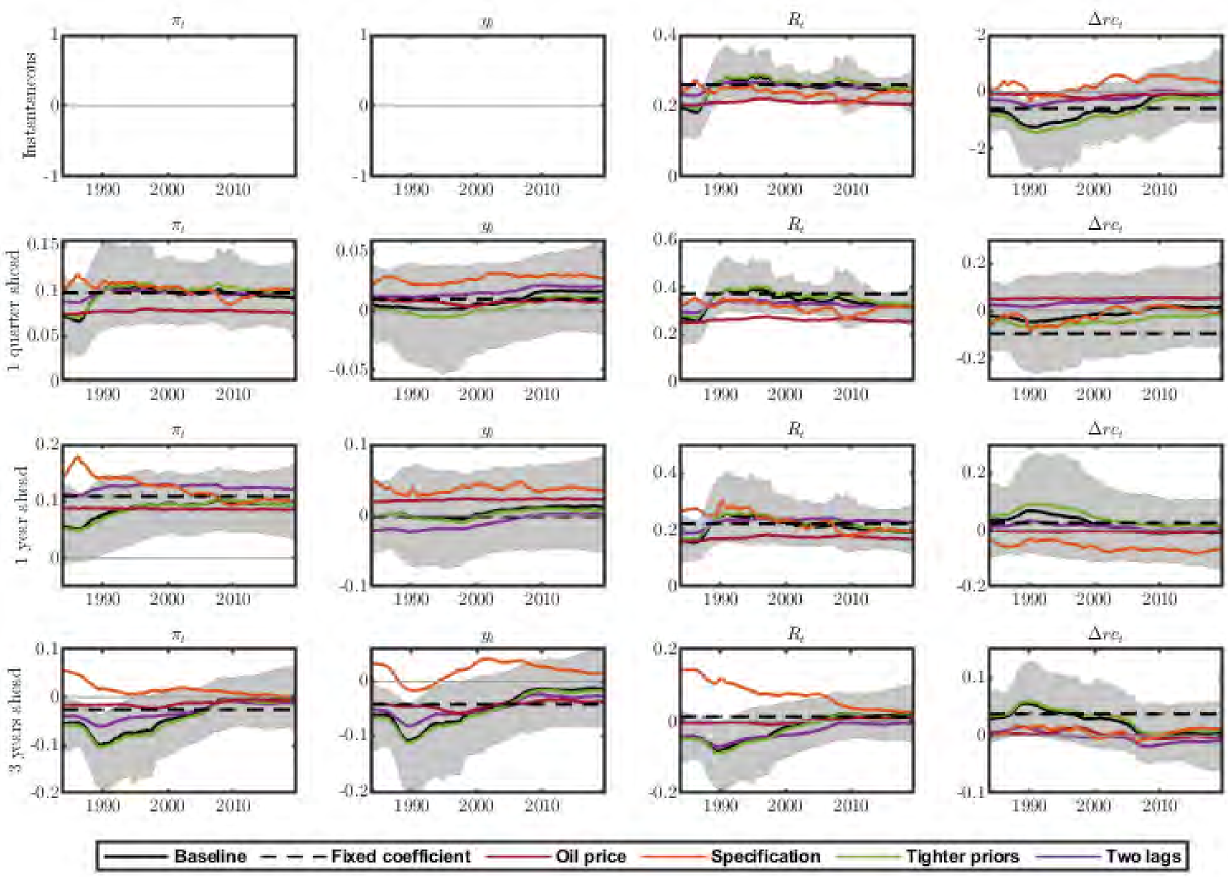

Figure 16: Australia – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

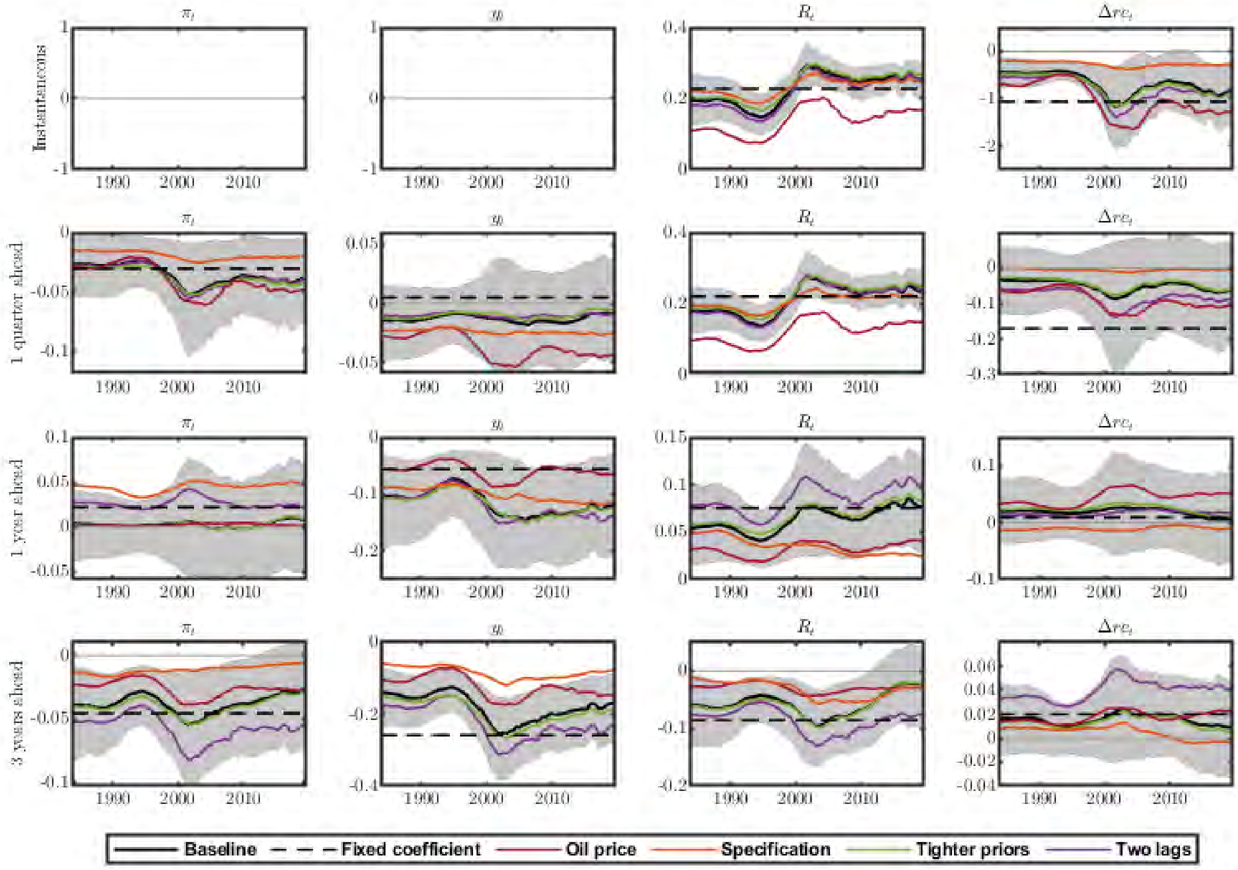

Figure 17: Canada – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

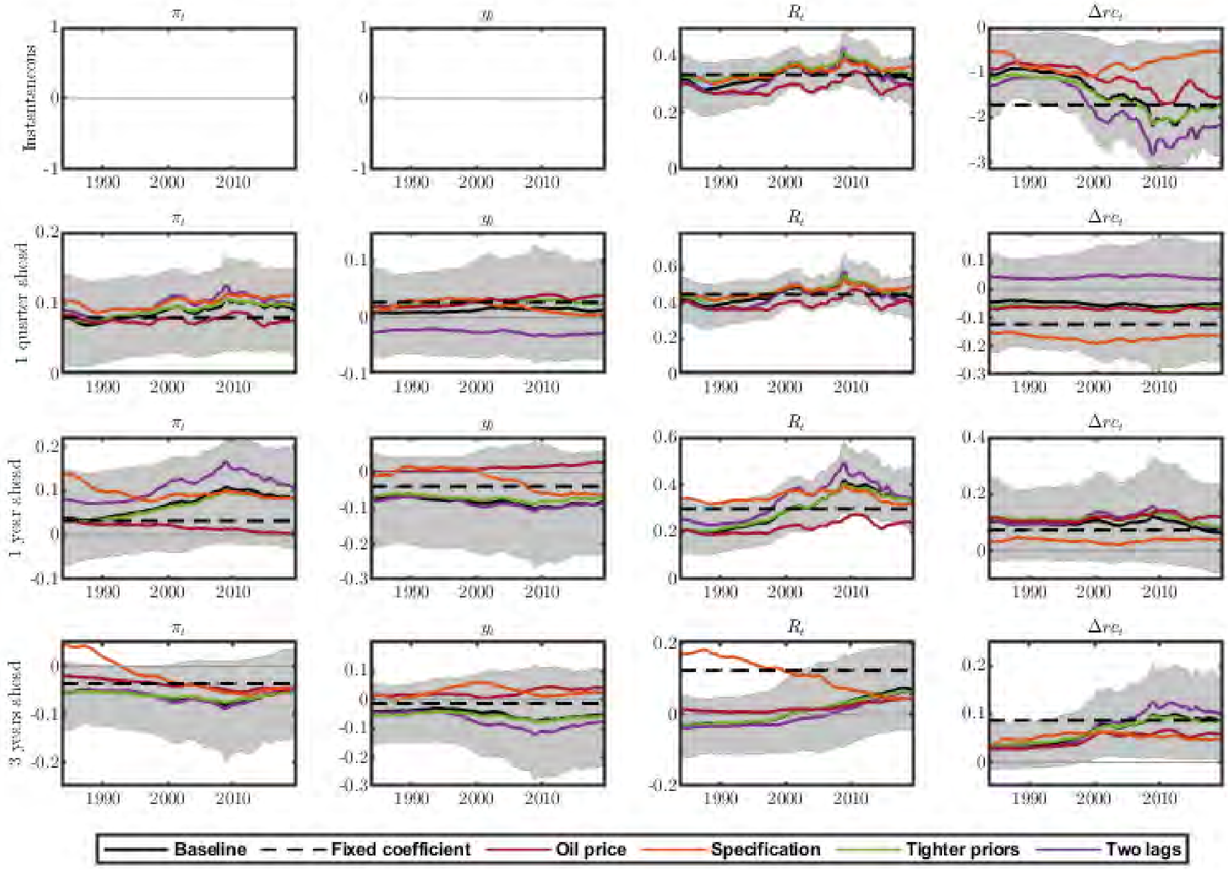

Figure 18: New Zealand – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

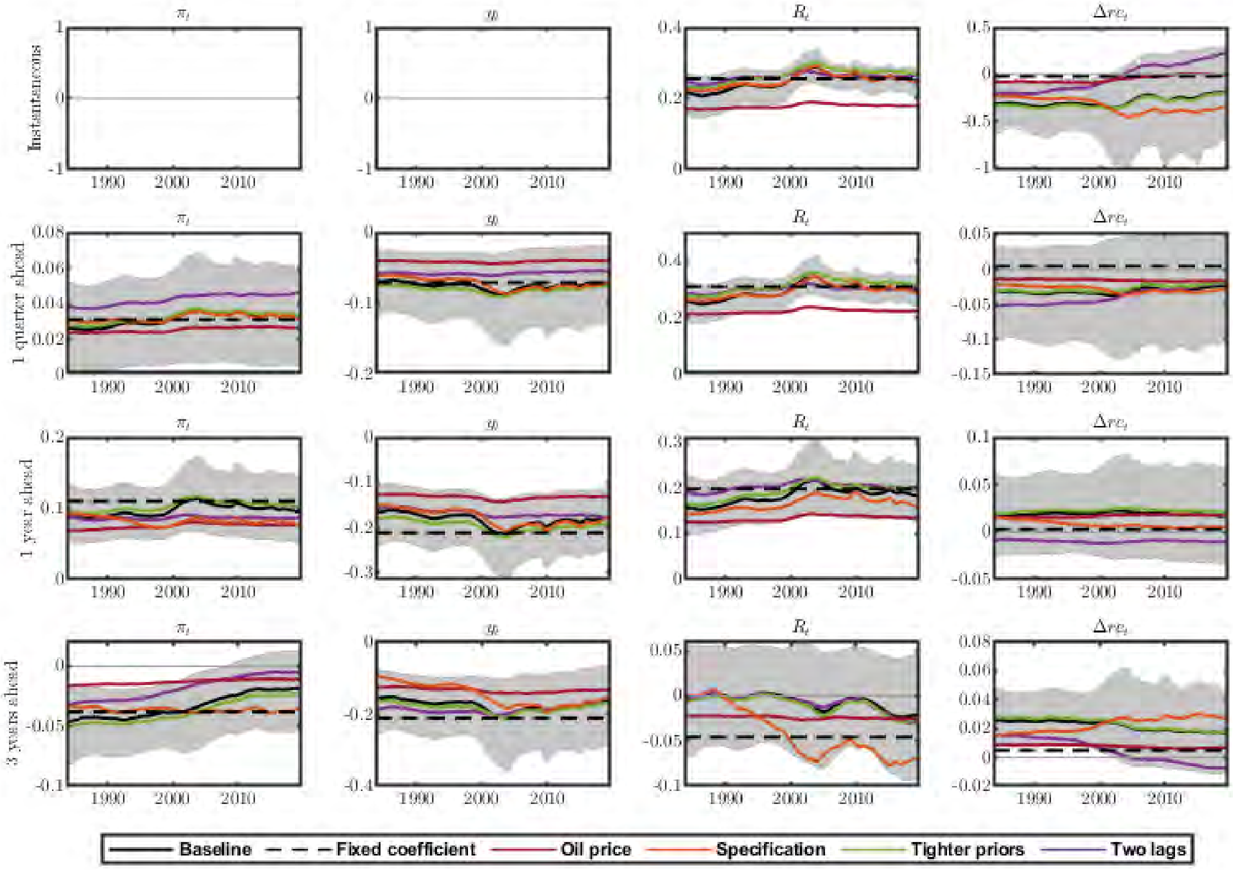

Figure 19: Norway – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

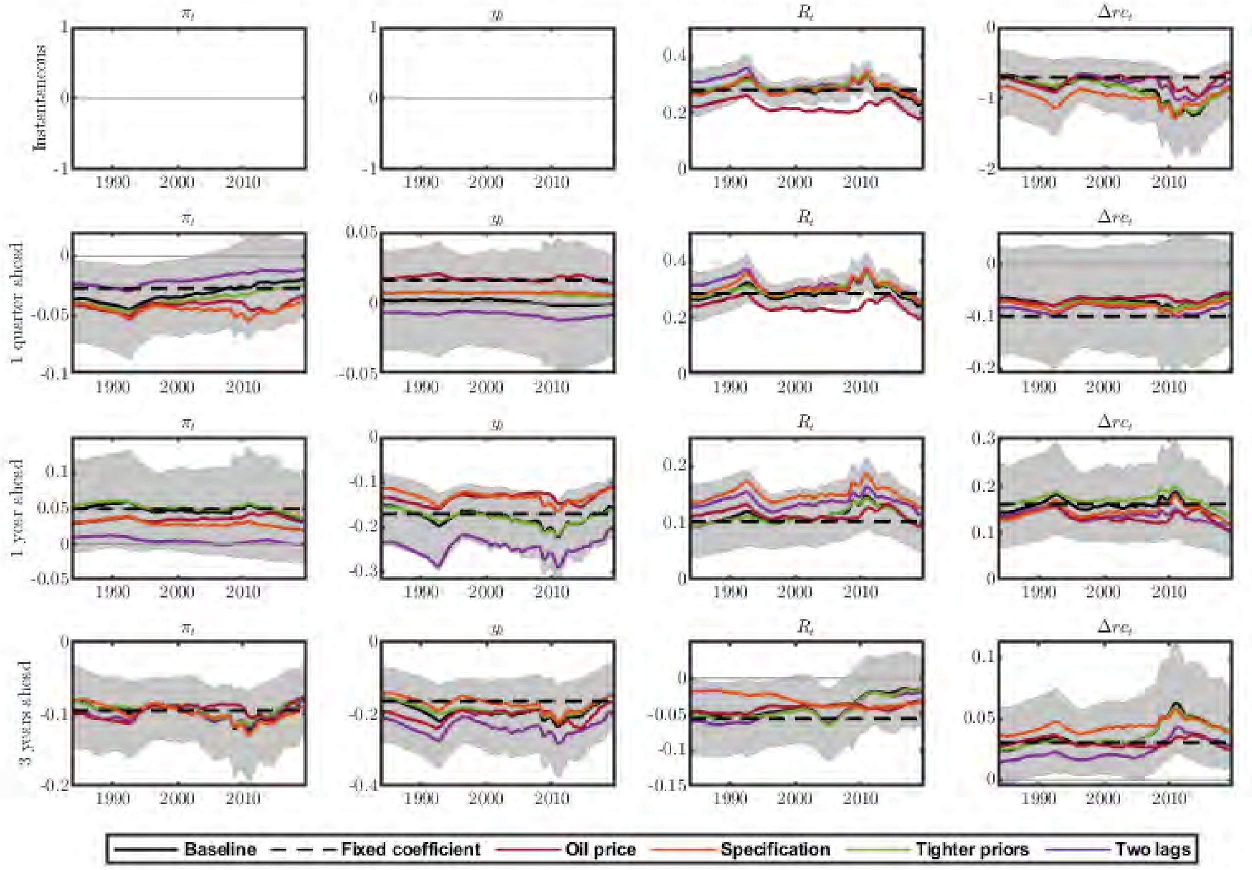

Figure 20: Sweden – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

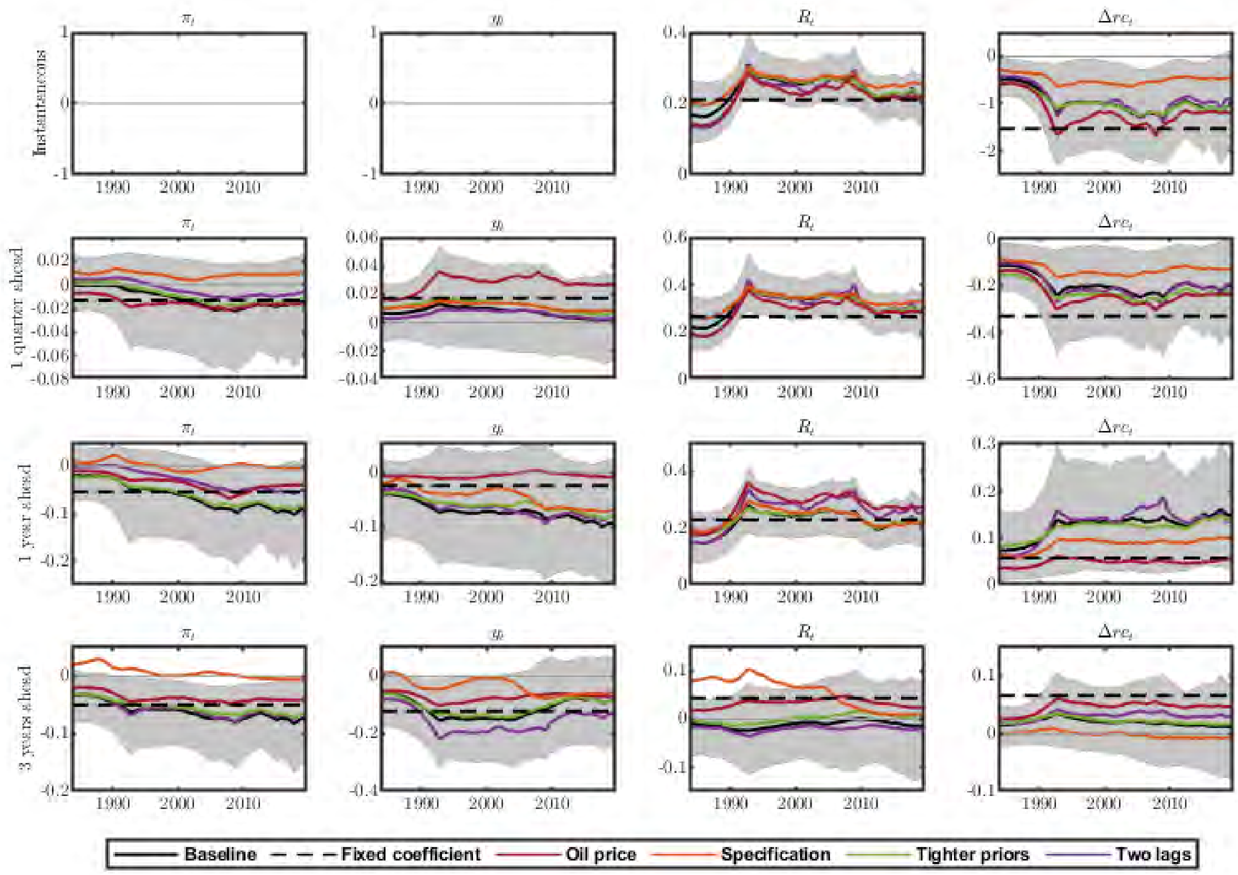

Figure 21: United Kingdom – impulse responses to a monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

B.2 Conditional Excess Returns

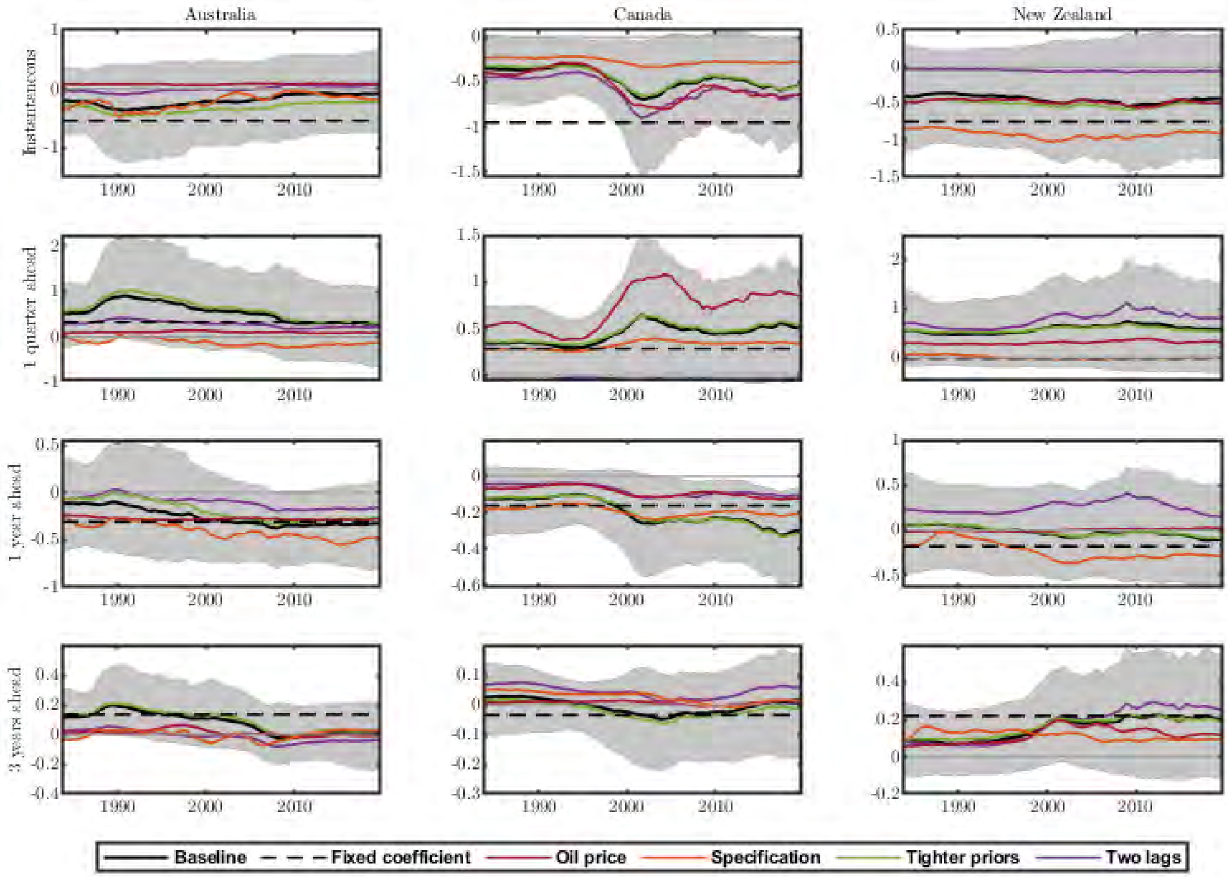

Figure 22: Conditional excess returns – Australia, Canada and New Zealand. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

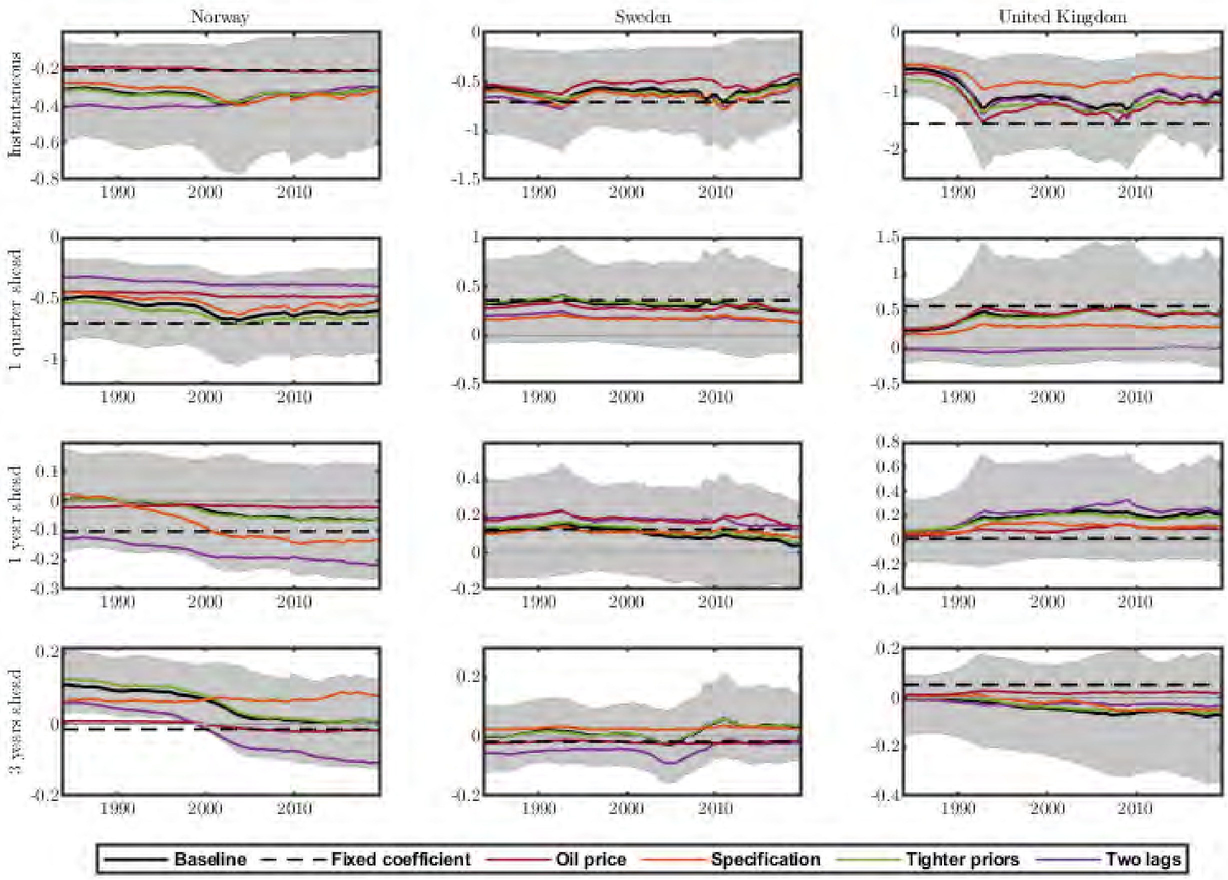

Figure 23: Conditional excess returns – Norway, Sweden and the United Kingdom. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

B.3 Forecast Error Variance Decompositions

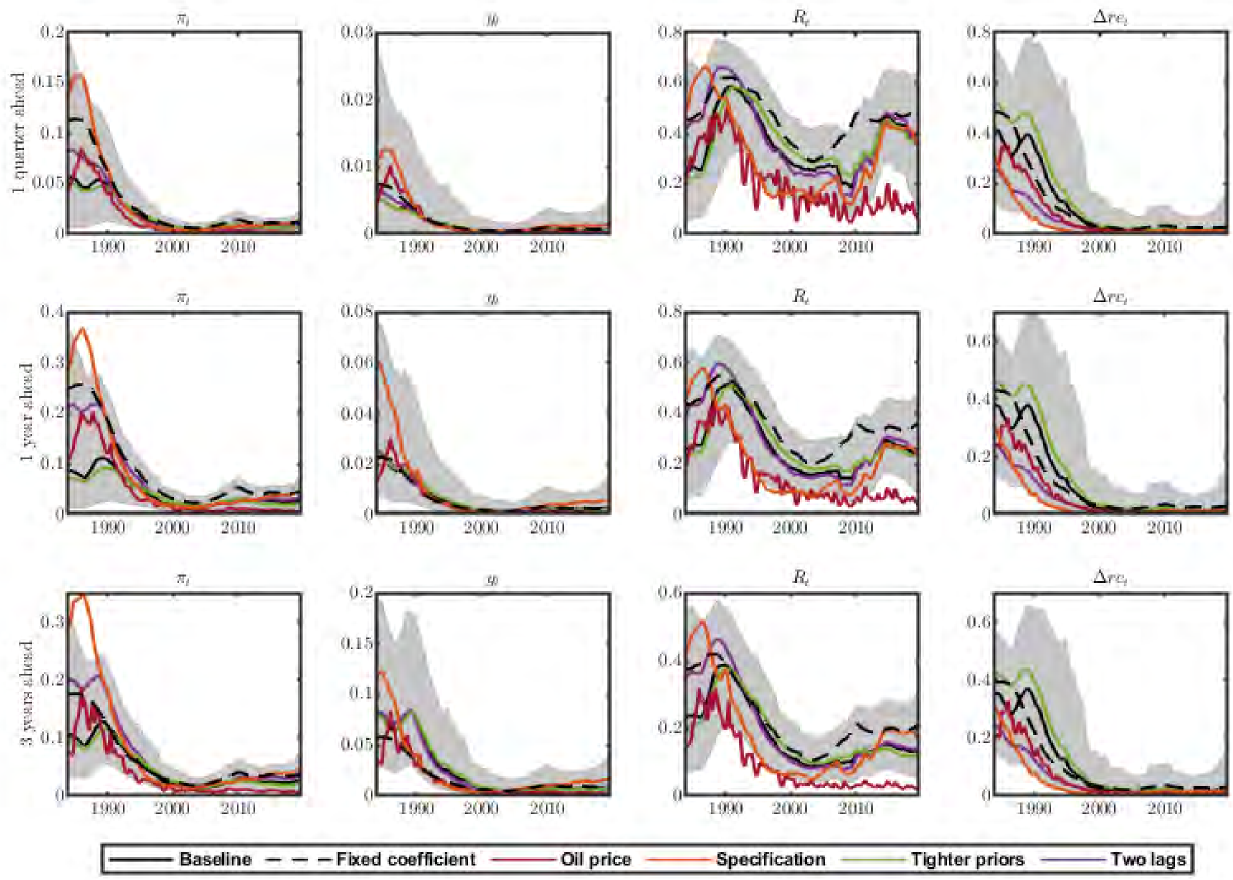

Figure 24: Australia – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

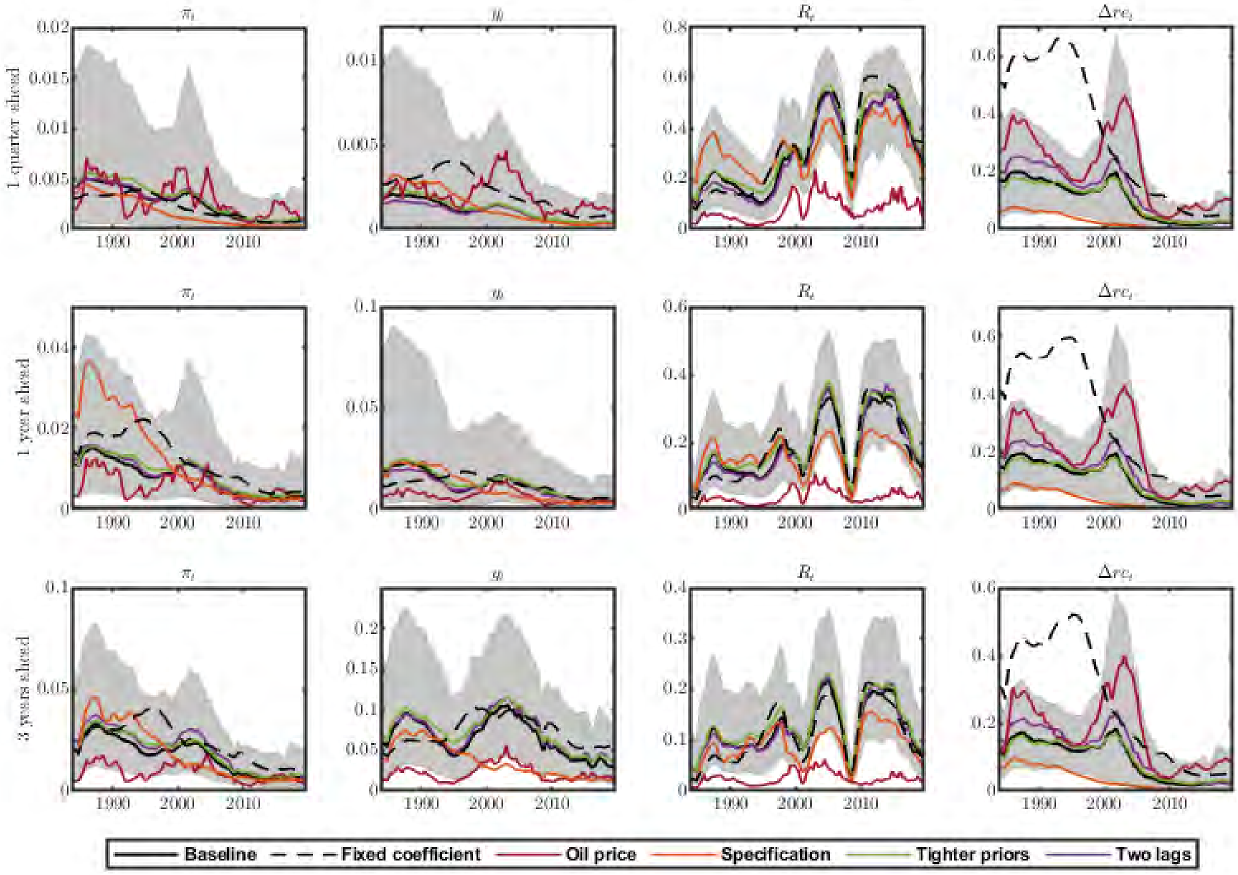

Figure 25: Canada – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

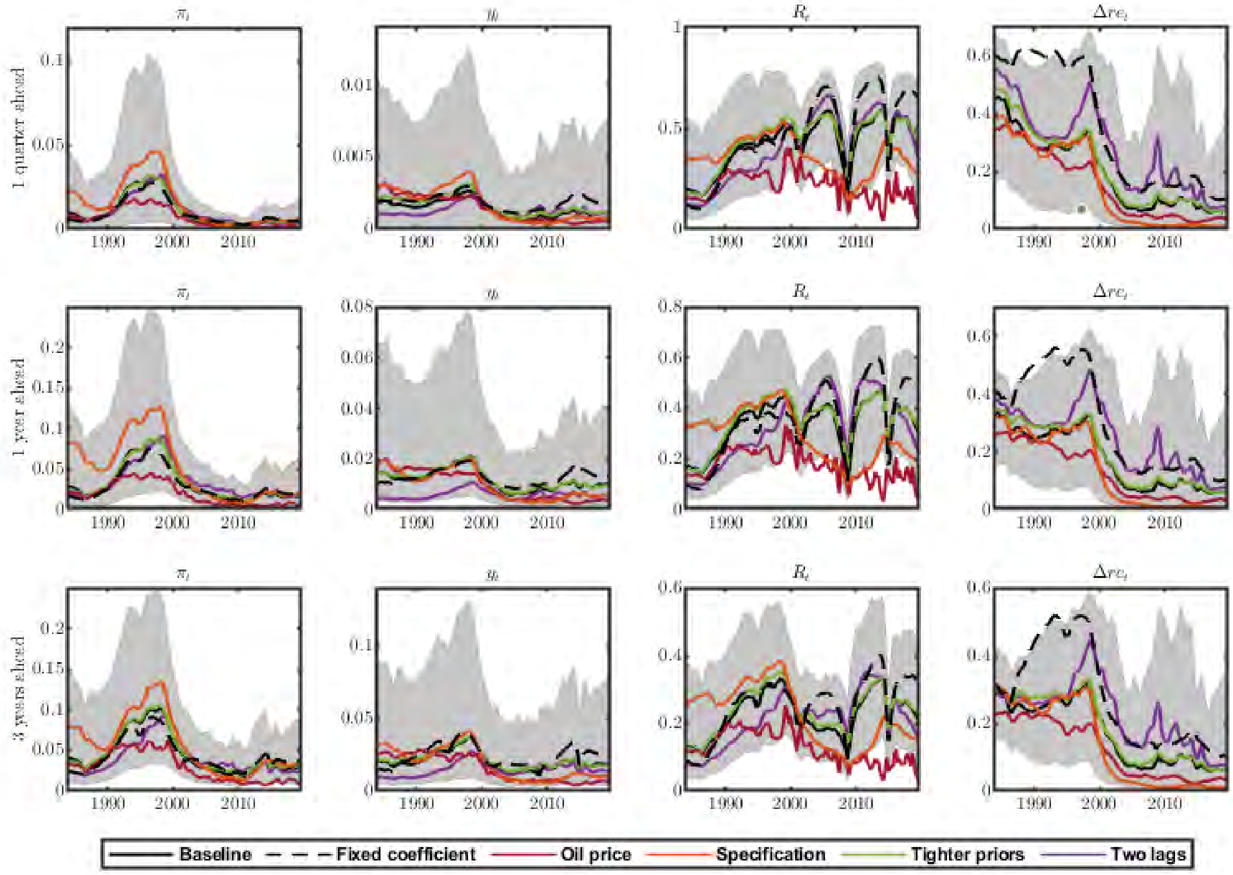

Figure 26: New Zealand – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

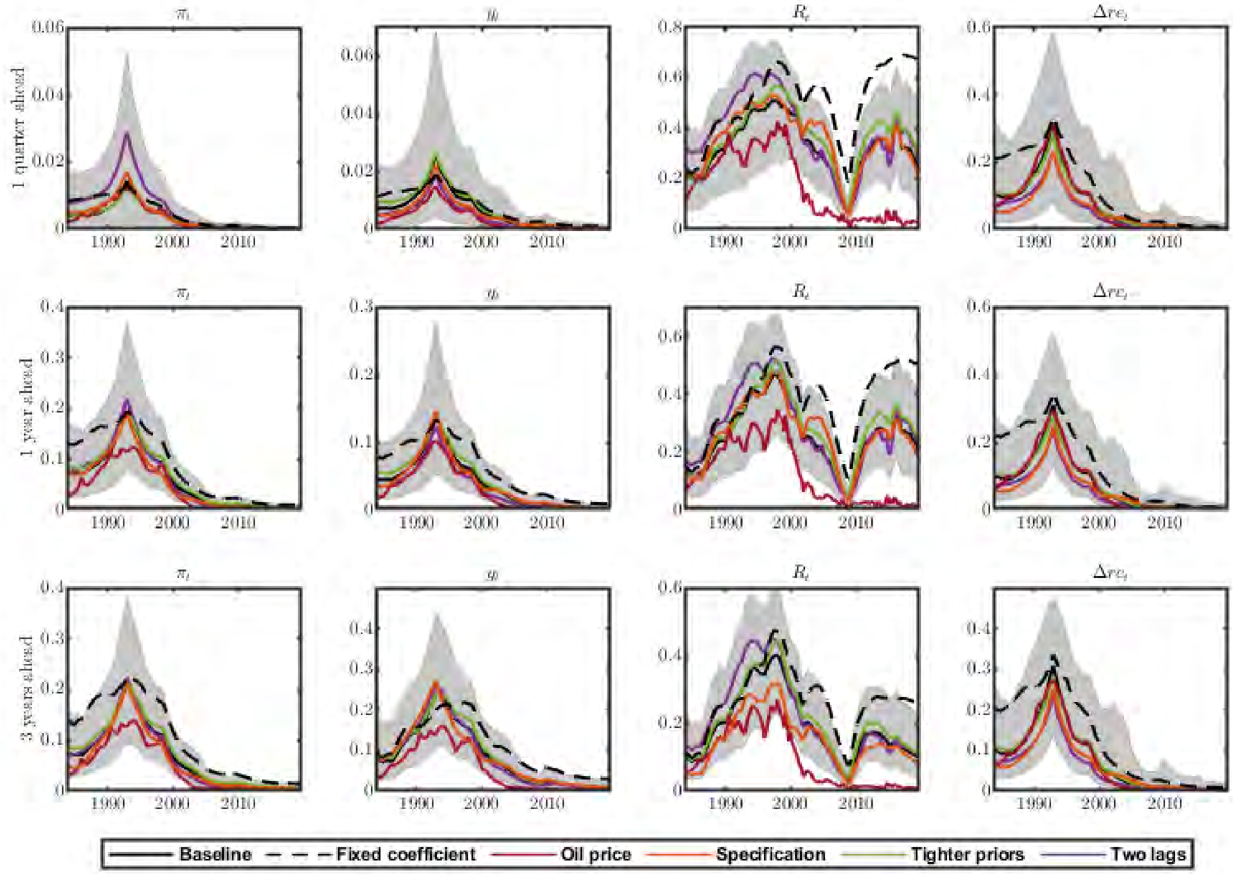

Figure 27: Norway – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

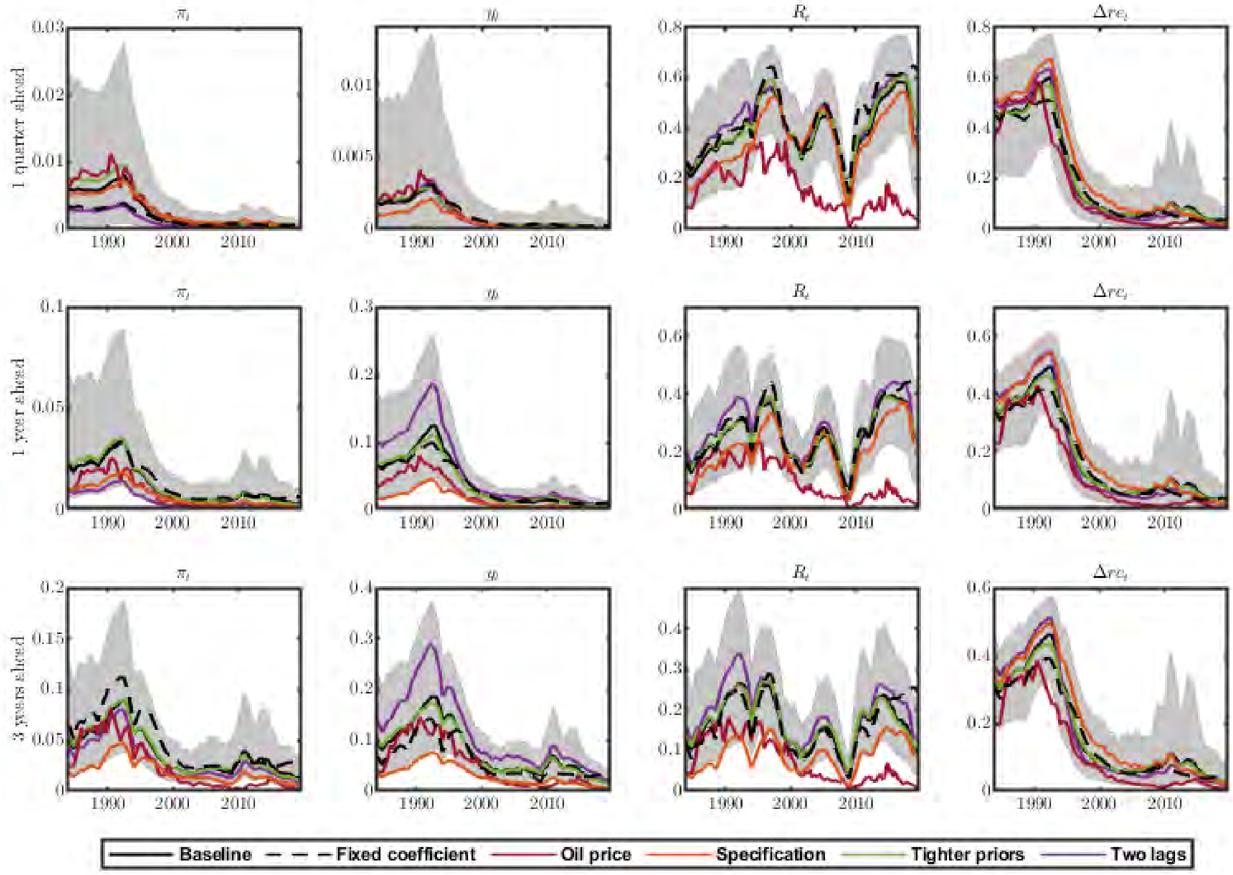

Figure 28: Sweden – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.

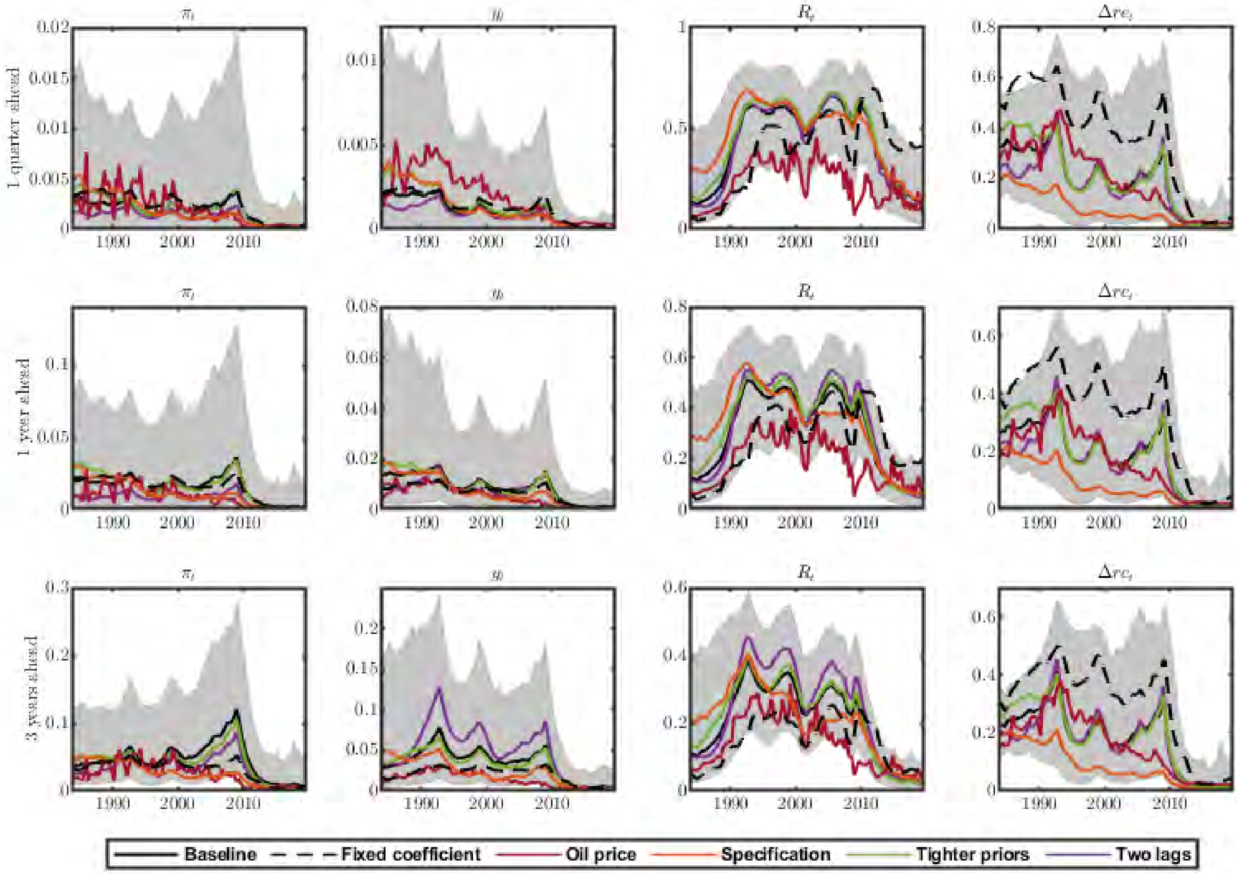

Figure 29: United Kingdom – FEVD for monetary policy shock. Solid lines depict the posterior median estimates from the TVP-VAR-SV model while the gray shaded area represents 68% posterior credible intervals around the posterior median. Dotted lines show the posterior median estimates from the constant-parameter VAR with stochastic volatility. Sample period 1983Q1-2019Q4.