GREDI

Groupe de Recherche en Économie et Développement International

Cahier de recherche / Working Paper
22-03

Forward guidance and the exchange rate: A theoretical sign restricted VAR analysis

Fabrice DABIRÉ

Université de Sherbrooke

Forward guidance and the exchange rate: a theoretical sign restricted VAR analysis

Fabrice Dabiré*[1]

[1] *Université de Sherbrooke & GREDI*

November 29, 2022
First draft January 2020

Abstract

This paper uses zero and signs restrictions to study the effect of the U.S. forward guidance and unanticipated monetary policy on four U.S. bilateral nominal exchange rates and net exports. I find that although the U.S. forward guidance easing depreciates the exchange rate, the policy does not transmit to the real activity via an *"expenditure-switching effect"* on the net exports. The use of narrative sign restrictions improves the identification method. The complementary results are as follows: a VAR model augmented with interest rate forecasts contains at least enough information to identify the forward guidance and unanticipated monetary shocks; the nominal bilateral exchange rates depreciate by two to four percent after a 25 basis point forward guidance easing in a hump-shaped pattern without any deviation from the Uncovered Interest rate Parity condition; both shocks explain between 7.3 percent to 27.9 percent of the exchange rates variance, and the forward guidance shock contributes to at least half of this variance decomposition; finally, forecasters perceive the forward guidance shock as future deviation from the Taylor rule.

JEL identification:E52, E58, F31, F41.
Keywords: Monetray policy, Forward guidance, Exchange rate, Sign restrictions.

* *Dabiré*:Ph.D. Candidate, Department of Economics, Université de Sherbrooke & GREDI
Email: fabrice.anicet.dabire@usherbrooke.ca.

1 Introduction

This paper empirically examines how the Federal Reserve (henceforth Fed) communications on future policy rate affect the U.S. economy via the nominal bilateral exchange rate. In their works, Mishkin (1995), Taylor (1995), Bernanke and Gertler (1995), Boivin et al. (2010) list four transmission channels of monetary policy on the real economy: the interest rate channel, the consumption-based channel, the credit channel, and the exchange rate channel. The exchange rate one which is linked to the international effects of a country's monetary policy is highlighted in the Mundell-Fleming model. In this model, a domestic country's currency depreciation following a monetary easing leads to an *"expenditure-switching effect"* towards domestic goods, and thus increases the country's trade competitiveness and net exports (Friedman et al., 1953; Cumby and Obstfeld, 2007). In the aftermath of the 2008 financial crisis, the Fed was accused of engaging in *"currency wars."* The strong policy measures used such as quantitative easing and forward guidance potentially improved the U.S. competitiveness according to some Emerging Markets Economy's policymakers (see e.g., Wheatley and Garnham, 2010). However, Bernanke (2017) looking at data on the net exports contribution to U.S. GDP argues that exports did not drive the U.S. post-crisis growth. Furthermore, he adds that the U.S. monetary policies tend to mainly increase global aggregate demand. A natural question arises in this context: is there empirical evidence of an improvement in U.S. net exports after U.S. monetary policies, particularly the U.S. forward guidance? To answer the question, first, I identify anticipated shifts in U.S. monetary policy caused by the Fed statements labelled in the literature as *"forward guidance."* I use a structural vector autoregressive (SVAR) model with quarterly data and apply zero and signs restrictions to identify the forward guidance and unanticipated monetary shocks. Thereafter, I compare their effects on the exchange rate and net exports. The data comprise U.S. and foreign variables, four bilateral nominal exchange rates (U.S. dollar against U.K. pounds, Canadian dollars, Euro, and Japan Yen) and the U.S. 3-month treasury bill (T-bill) rate forecasts. I define the forward guidance shock as a shift in the 3-month T-bill rate forecasts that immediately affects the real GDP, CPI, and exchange rates but, has no contemporaneous impact on the current 3-month T-bill rate. The shock is defined in this way because economic agents have information about future policy, that potentially affect their expectations and forecasts of future fundamentals such as the interest rate.

This paper contributes to the empirical literature on forward guidance in two ways. First, I show that although a 25 basis point U.S. forward guidance easing immediately increases the U.S. real GDP and depreciates the U.S. dollar in a range of two to four percent, it does not improve the U.S. net exports. Second, I propose an improvement of the shock identification with quarterly data via narrative signs restrictions following Antolín-Díaz and Rubio-Ramírez (2018) and data from Sutherland (2020). As pointed by Swanson (2021), estimating the effects of forward guidance on macroeconomic variables should be a top priority. Therefore, improving the quarterly data approach is crucial because previous works rely on high frequency data to identify the forward guidance shocks. As a result, they mainly measure the responses of financial variables because of the lower frequency of macroeconomic data. The remaining complementary findings are as follows: a sufficient information test shows that a VAR model augmented with interest rate forecasts contains at least enough information to identify the shocks. As predicted by theory, the exchange rates overshoot after a U.S. unanticipated monetary shock, i.e., following the unanticipated monetary easing, the maximum depreciations occur immediately and are followed by subsequent appreciations. Conversely, the exchange rates depreciate in a hump-shaped manner similar to a delayed overshooting pattern after a forward guidance easing, except for the U.S. dollar against Japan Yen. I argue that one should expect this exchange rate pattern following a forward guidance shock as the shock affects market expectations. So, instead of anticipating future appreciations after the initial depreciations, the forward guidance easing steers market expectations toward further depreciations. A missing hump-shaped responses could therefore be considered confusing in the case of a forward guidance. The cumulative contribution of the two monetary shocks to the exchange rates variance is in a range of 7.3 percent to 27.9 percent, and the forward guidance shocks contributes to at least half of the variance decomposition coming from both policies. I find no systematic excess return after both shocks. This is not surprising for a forward guidance since it steers market expectations in the opposite direction to what one would expect with the uncovered interest rate parity (UIP) condition. However, for the unanticipated shock, I attribute the missing excess return to the fact that the sample is mostly dominated by the post-Volcker era data. I find evidence of positive spillovers from the U.S. forward guidance on the U.K. and Canada based on the positive responses of their respective real GDP. The real GDP in both countries increases by about 0.5 percent after the U.S. forward guidance. Finally, forecasters perceive the identified forward guidance shocks as credible deviation from the Taylor rule since they affect the responses of the GDP and CPI forecasts in the opposite direction to what the Taylor rule predicts.

This paper is linked to the vast empirical and theoretical literature on the link between exchange rate and the U.S. forward guidance and their spillovers effects[1],[2]. The empirical approaches in the previous works mainly use high-frequency data to identify the forward guidance shocks on very short time intervals after the news announcements. They look at how daily changes in the exchange rate

[1]The empirical and theoretical literature on forward guidance in closed economy includes: Gürkaynak (2005), Campbell et al. (2012), Del Negro et al. (2012), D'Amico and King (2015), McKay et al. (2016), Best and Kapinos (2016), Gomes et al. (2017), Kaplan et al. (2018), Gabaix (2020) Ben Zeev et al. (2020) among others. Their results support the effectiveness of forward guidance on the current state of the U.S. economy with a *"forward guidance puzzle"*, that is, the New-Keynesian model tends to overestimate the effect of long horizon forward guidance on the economy than what is found in the data.

[2]There is also much empirical evidence documenting the effect on unanticipated monetary policy on the exchange rate starting with the seminal paper from Eichenbaum and Evans (1995), Clarida and Gali (1994), Faust and Rogers (2003), Scholl and Uhlig (2008), Bjørnland (2009), Bouakez and Normandin (2010), Kim et al. (2017) among others.

relate to change in the Fed funds futures rate on days in which the actual Fed funds stays constant. Using this approach, Fatum and Scholnick (2006), Hausman and Wongswan (2011), Ferrari et al. (2017) and Curcuru et al. (2018a) find strong evidence that when markets increase their expectations of the Fed funds rate, the dollar appreciates. Inoue and Rossi (2019) estimate a VAR with exchange rates and raw yield curves at different maturities. They conclude to identical effects in terms of magnitude and shape of large-scale assets purchases (LSAPs) and forward guidance on exchange rates to those in the periods outside of the zero lower bound. Rogers et al. (2018) estimate a SVAR with U.S. and foreign interest rates to identify the forward guidance shocks and other monetary shocks. They use high-frequency monetary policy surprises as an external instrument and find that U.S. forward guidance easing depreciates the dollar with little evidence of delayed overshooting, and an effect on the risk premium. Galí (2020) finds that the anticipated real interest rate differential between the U.S. and the Euro area at different horizons affects the bilateral real exchange rate. He also finds that contrary to the benchmark small open economy New-Keynesian (SOE-NK) model predictions, in the data the effect of forward guidance is stronger when the future interest rate differentials are supposed to happen in the near future. He named this mismatch between the theory and the data, *"forward guidance exchange rate puzzle."* Finally Swanson (2021) extends Gürkaynak (2005) approach to identify U.S. unanticipated monetary, forward guidance and LSAPs policy with high frequency data. He finds that forward guidance and LSAPs had substantial and persistent effects on a variety of financial assets including exchange rate, and that they are effective substitutes for conventional monetary policy. Although they find strong evidence of the forward guidance effect on the exchange rate, all the aforementioned papers do not discuss the empirical effectiveness of an *"expenditure-switching effect"* after the shock. However, some theoretical works assess the exchange rate channel transmission of the forward guidance and its spillovers. Cook and Devereux (2016) use a New-Keynesian two-country framework to study the effect of forward guidance at the zero lower bound (ZLB). They show that an optimal credible forward guidance i.e., central bank's commitment to accommodative monetary policy in the future is a useful tool to activate the monetary policy exchange rate channel transmission with potential spillovers. André and Traficante (2020) using a SOE-NK with risk premium find that forward guidance is more powerful in the open economy than the closed economy due to the real exchange rate. Yet, to the best of my knowledge, there is still no evidence indicating whether this mechanism exists in the data. in regards to the international spillovers of the U.S. forward guidance shock, Rajan (2015), Jones et al. (2018), Curcuru et al. (2018b), Rudel and Tillmann (2018), Albagli et al. (2019) find that the U.S. unconventional policies including forward guidance have some potential destabilizing real and financial spillovers onto other economies, mostly emerging markets and developing economies.

My work suggests that although forward guidance shocks have positive effects on the real economy, the data do not show any amplification effects of the policy on the real economy via the exchange rate channel. The loose shocks depreciates the nominal exchange rate, but the real quantities exported by the U.S. do not significantly exceed the quantities imported to improve net exports. Therefore, the forward guidance easing does not reduce the competitiveness of the U.S.'s developed trading partners to the benefit of the U.S. economy.

The rest of the paper is structured as follows. Section 2 presents the sign of the responses the main variables of a two-country New-Keynesian model to a forward guidance shock and the underlying intuition. Section 3 presents the VAR model, the data and discusses the sufficient information test and the identification of the forward guidance. Section 4 presents the estimation results. Section 5 presents the narrative sign restrictions results and some robustness analyses. Finally, section 6 concludes.

2 The two symmetric countries New Keynesian (NK) model

The model is an extension based on the small open economy framework of Gali and Monacelli (2005). It comprises two symmetric countries: Home (H) and Foreign (F). Both countries are populated with a continuum of unit mass households $h \in [0, 1]$ and $f \in [1, 2]$ respectively. Households in each country have access to a complete set of domestically and internationally traded contingent claims (complete financial markets) and goods. Firms in the world economy produce the differentiated goods in a monopolistic competition market and face nominal price rigidities à la Calvo (1983). Finally, the model always assumes that the law of one price holds for each individual's goods, but the purchasing power parity holds for a certain degree of trade openness.

2.1 The log-linearized six equations for the two-country model

The above setup is solved and log-linearized around the steady state. Appendix A gives the model complete derivation and the definition of the structural parameters. The model is here summarized by the following equations:

$$\tilde{y}_t = \mathrm{E}_t\left(\tilde{y}_{t+1}\right) - \frac{1}{\sigma_\omega}\left\{i_t - \mathrm{E}_t\left(\pi_{H,t+1}\right)\right\} + \frac{\omega_2}{\omega_2+1}\left\{\mathrm{E}_t\left(\tilde{y}^*_{t+1}\right) - \tilde{y}^*_t\right\} + \frac{1}{\sigma_\omega} r^n_t \tag{1}$$

$$\tilde{y}^*_t = \mathrm{E}_t\left(\tilde{y}^*_{t+1}\right) - \frac{1}{\sigma_\omega}\left\{i^*_t - \mathrm{E}_t\left(\pi^*_{F,t+1}\right)\right\} + \frac{\omega_2}{\omega_2+1}\left\{\mathrm{E}_t\left(\tilde{y}_{t+1}\right) - \tilde{y}_t\right\} + \frac{1}{\sigma_\omega}(r^n_t)^* \tag{2}$$

$$\pi_{H,t} = \beta \mathrm{E}_t\left(\pi_{H,t+1}\right) + \kappa_\omega\left(\tilde{y}_t + \tilde{y}^*_t\right) + i_t \tag{3}$$

$$\pi^*_{F,t} = \beta \mathrm{E}_t\left(\pi_{F,t+1}\right) + \kappa_\omega\left(\tilde{y}^*_t + \tilde{y}_t\right) + i^*_t \tag{4}$$

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left(\phi_\pi \pi_{H,t} + \phi_{\tilde{y}} \tilde{y}_t\right) + v_t \tag{5}$$

$$i^*_t = \rho_{i^*} i^*_{t-1} + (1-\rho_{i^*})\left(\phi^*_\pi \pi^*_{F,t} + \phi^*_{\tilde{y}^*} \tilde{y}^*_t\right) + v^*_t \tag{6}$$

Equations (1) and (2) are the Home and Foreign dynamic IS (DIS) curve respectively. Equations (3) and (4) are the Home and Foreign New-Keynesian Phillips curve (NKPC) respectively, and equations (5) and (6) are the Home and Foreign monetary policy Taylor rule. The variables are define such that $\tilde{y}_t$ and $\tilde{y}_t^*$ are the Home and Foreign country output gap respectively, $\pi_{H,t}$ and $\pi_{F,t}^*$ are the Home and Foreign country domestic inflation respectively, i_t and i_t^* are the Home and Foreign country nominal interest rate respectively, and r_t^n and $(r_t^n)^*$ are the Home and Foreign country real natural interest rate respectively. The complete financial markets at both domestic and international levels assumption allows to complete the above six equations with the following log-linearized version of the uncovered interest rate parity (UIP) condition:

$$i_t - i_t^* = \mathrm{E}_t(e_{t+1}) - e_t \tag{7}$$

where e_t is the log nominal exchange rate expressed as the price of the Foreign country currency in terms of the Home's country currency. An increase in e_t is thus a depreciation of the Home country currency. The difference equation (7) is solved forward for e_t and yields[3]:

$$e_t = \mathrm{E}_t\Big\{\sum_{k=0}^{\infty}(i_{t+k} - i_{t+k}^*)\Big\} + \lim_{T\to\infty} \mathrm{E}_t(e_T) \tag{8}$$

As stated by Galí (2020) equation (8) summarizes the principal mechanism through which forward guidance affects the nominal exchange rate channel. The current nominal exchange rate depends on current ($k = 0$) and anticipated interest rate differentials and the long-term exchange rate ($\lim_{T\to\infty} E_t(e_T)$). So, a communication about future interest rate affects future interest rate differential expectations which in turn immediately affect the current nominal exchange rate. Similarly, and assuming for expository purpose only that the foreign variables are zero, one can solve equations (1) and (3) and show that they also depend on future the discounted sum of current and future interest rate:

$$\tilde{y}_t = -\frac{1}{\sigma_\omega}\Big\{\sum_{k=0}^{\infty} \mathrm{E}_t\left(i_{t+k} - \mathrm{E}_{t+k}\left(\pi_{H,t+k+1}\right) - r_{t+k}^n\right)\Big\} \tag{9}$$

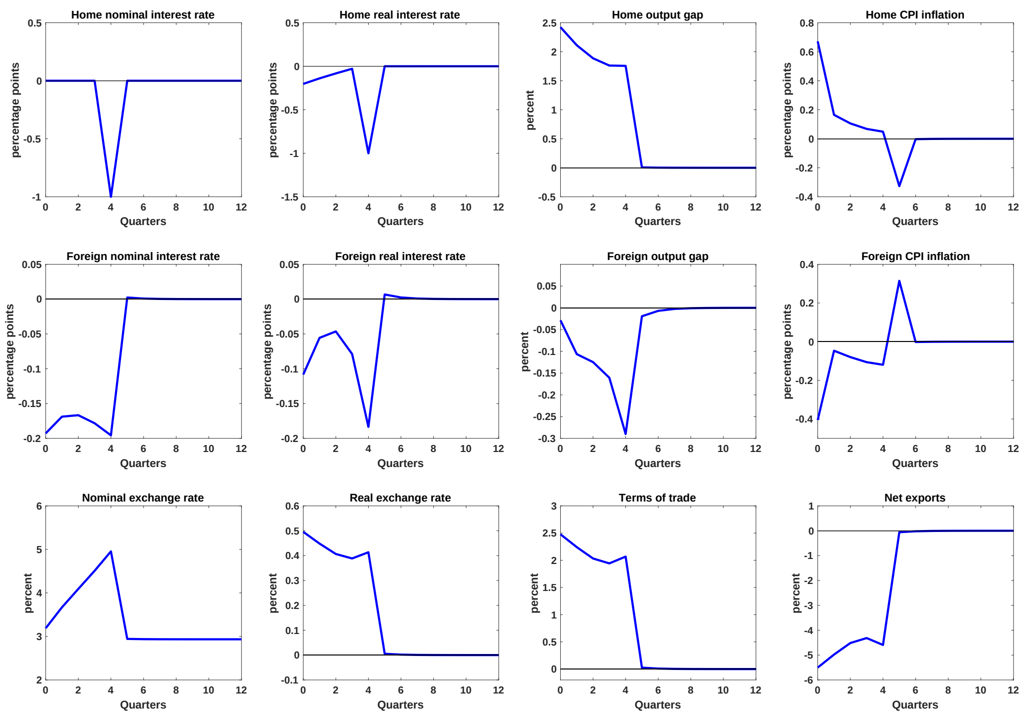
$$\pi_{H,t} = \sum_{k=0}^{\infty} \beta^k \mathrm{E}_t\left(\tilde{y}_{t+k}\right) \tag{10}$$

[3] A real version of equation (8) can also be obtained by solving forward the real exchange rate equation $q_t = \mathrm{E}_t(q_{t+1}) + (i_t^* - \pi_{F,t+1}^*) - (i_t - \pi_{H,t+1})$

2.2 Calibration and simulation

In this section, I analyze the effect of a Home forward guidance shock on the Home economy and the nominal exchange rate. The complete parameters calibration of the model is listed in the last section of appendix A. Some parameters are calibrated using Cacciatore and Traum (2018) estimation for the U.S. (Home economy) and the Euro area (Foreign economy), and the remaining parameters are standard in the literature.

Figure 1: SOE-NK model response to a four quarters ahead credible forward guidance shock.



The model is simulated using a standard central bank announcement of a future monetary shock to happen t-quarters in the future (Del Negro et al. (2012), McKay et al. (2016),mil, Best and Kapinos (2016), Galí (2020)). Specifically, suppose that at time $t = 0$, the Home central bank announces a one-period decrease in the nominal interest rate of 25 basis points to happen at time $t = 4$. It also commits to keep the nominal interest at its initial steady state level (0) between time $t = 0$ and $t = 3$ independently of the reaction the economy during this period (i.e., the Home central bank will not follow the Taylor rule only during this period). The Home monetary policy shock can thus be defined as:

$$v_t = \epsilon_t^v + \sum_{h=1}^{H} \mu_{t-h} \tag{11}$$

The mean-zero i.i.d disturbance ϵ_t^v is the unanticipated shock, and μ_{t-h} is the forward guidance or anticipated monetary shock known by agents in period t but materializes only h-quarters ahead. Figure 1 shows the model responses and the subsequent economic dynamics of the model. The first row of the figure reports the Home country responses. Following the central bank announcement of a monetary easing in four quarters ahead, the Home output gap immediately increases since it is equal to the cumulative sum of future nominal (real) interest rate. The future monetary easing announcement generates expectations of lower future interest rates. Agents anticipate the future expansionary effect by increasing their current consumption and investment, which in turn immediately increase inflationary pressures as reflected by equation (10). This result in an immediate decrease in real interest rate (first row, second column). Since the real and nominal exchange rates also depends on the cumulative sum of current and future interest rate differential, they immediately depreciate as we can see from the third row of the figure. According to Galí (2020), in a general equilibrium setup, the overall effect of the forward guidance shock on the exchange rate is the result of the impact on output and aggregate demand of the change in consumption and real exchange rate previously described, and their subsequent effect on inflation. The second row shows the spillovers effects of the Home central bank forward guidance on the foreign country. Having two symmetric countries with respect to some parameters, the foreign country responds in the opposite way of the Home country. Output and inflation decrease and the Foreign central bank responds accordingly. The last column of the third row shows the net exports response in percentage of GDP. Although the forward guidance here contracts the net exports, one should not take this sign as a general conclusion of the model. Indeed, for this variable, the sign of its response in the model is ambiguous and depends on the parameters calibration while for the other variables, the sign of their responses do not depend on the calibration. Only the magnitude is affected by another calibration.

To sum up. A forward guidance easing immediately raise domestic output and inflation, and depreciates the nominal exchange rate. The signs of these theoretical responses will be used in the empirical part of the paper to identify the U.S. forward guidance shocks. Also note this model suffers from Galí (2020) *"forward guidance exchange rate puzzle."* Changes in expected real interest rate differentials in the more distant future are associated with much larger variations in the nominal exchange rate than changes anticipated to take place in the near future. However, this problem nor the calibration do not alter the qualitative results about the sign of the impulse responses used later. Finally, appendix B shows that the conclusion of the model to a forward guidance policy at the ZLB stays the same.

3 The VAR model

In this section I present the VAR specification and briefly discuss why the presence of news about future policy may give misleading interpretation of the SVAR shocks. I then present the data and discuss the sufficient information test and the zero and sign restrictions used.

3.1 The VAR specification

3.1.1 The model

Consider the structural $VAR(p)$

$$B_0 y_t = \sum_{i=1}^{p} y_{t-i} B_i + \varepsilon_t, \qquad \varepsilon_{\mathbf{t}} \sim \mathbf{iid}(\mathbf{0}, \mathbf{\Sigma}_\varepsilon) \tag{12}$$

where y_t is a $(k \times 1)$ observable vector of endogenous variables; p the lag order selected using the AIC criteria; B_0 is a $(k \times k)$ impact matrix that governs the instantaneous relationships in the model and finally, $B_i, i = 1, \ldots, p$ are $(k \times k)$ matrices of structural parameters. Each element of the $k \times 1$ vector of white noise ε_t corresponds to mutually uncorrelated structural shocks which are assumed to have unit variance. The corresponding reduced form of the above $SVAR(p)$ is expressed as

$$y_t = \sum_{i=1}^{p} y_{t-i} A_i + u_t \tag{13}$$

where $A_i = B_0^{-1} B_i$ for $i = 1, \ldots, p$ are $(k \times k)$ matrices of parameters. The reduced form innovation $u_t = B_0^{-1} \varepsilon_t$ is assumed to be a $k - dimensional$ vector of iid process such that $\mathbb{E}_t(u_t) = 0$ and $\mathbb{E}_t(u_t u_t') \equiv \Sigma_u = B_0^{-1}\, \mathbb{E}_t(\varepsilon_t \varepsilon_t') B_0^{-1\prime} = B_0^{-1} \Sigma_\varepsilon B_0^{-1\prime}$. For the structural shocks to be uniquely and fully identified, one needs to find good estimate of the instantaneous relationship's matrix $\mathbf{B_0}$ from (12) conditional on some economic restrictions.

3.1.2 Non-fundamentalness problem

One can write the moving average (MA) process of the model (13) by defining the $(k \times k)$ matrix polynomial in lag operator $A(L) \equiv \Sigma_{i=0}^{\infty} A_i L^i$

$$y_t = A(L) u_t \tag{14}$$

u_t and y_t span the same space if the matrix polynomial $A(L)$ is invertible. This will be the case if the eigenvalues of A have no pole inside the unit circle (less than unity), which requires that $det(A(z)) \neq 0 \; for \; \mid z \mid \leq 1$. In this context, y_t is driven by the past and present values of u_t, and the corollary holds. The moving average representation (14) clearly shows that we only need past values of the observable y_t to identify the structural shocks of the model if $A(L)$ is invertible. In this case, u_t is $y_t - fundamental$. However, when the economic agents have news about future economic variables or policy, the econometrician information set becomes smaller. This creates a wedge between y_t and u_t space and the model becomes *non-fundamental*: the SVAR (12) does not contain enough information to identify the structural shocks. This is a consequence of economic agents reacting in advance and incorporating in their today decisions all the news they have. It thus becomes difficult to distinguish which shocks (unanticipated or news) dictate the current behavior of the model. Formally, consider an observable vector X_{1t} driven by deterministic trend vector x_{1t}, and a vector of shocks ε_t composed of an unanticipated and a one period ahead anticipated part u_t and η_{t-1} respectively[4]:

$$X_{1t} = x_{1t} + \varepsilon_t \Rightarrow \varepsilon_t = X_{1t} - x_{1t} \text{ and } \; \varepsilon_t = u_t + \eta_{t-1} \tag{15}$$

X_{1t} data generating process is not fundamental because of the anticipated shocks η_{t-1}. Since by construction inverting a VAR yields a fundamental MA, the econometrician can identify the unanticipated component as $u_t = \varepsilon_t + \eta_{t-1} = X_{1t} - x_{1t} + \eta_{t-1}$. Thus, the identified unanticipated shocks also capture the anticipated component not observable. Taking the lead of X_{1t} yields $\eta_t = X_{1t+1} - x_{1t+1} - u_{t+1}$. We can clearly see that the anticipated shocks are only in the future of the observable vector which by definition is unobservable by the econometrician.

Two approaches are proposed in the literature to overcome this non-fundamental problem. The first one involves using the Blaschke matrices to transform the fundamental MA into a non-fundamental one. The second approach used in this paper consists in adding more information to the set of observable as suggested by Beaudry and Portier (2006), Barsky and Sims (2012). Since non-fundamental problem can be summarized as a missing information problem, the type of variables considered here must convey some information about private sector expectations of future economic indicators and policies (future fundamental, survey forecast of variables, consumer confidence, stock prices, yield curve).

[4]For more details on the formal definition of fundamentalness and related problems, see Forni et al. (2009), Kilian and Ltkepohl (2017), Fernández-Villaverde et al. (2007), Sims (2012), Leeper et al. (2013) and Canova and Hamidi Sahneh (2018).

3.2 Data

As a baseline specification, the vector of observable y_t in (12) is composed by quarterly data of a foreign and U.S. block and the corresponding nominal bilateral exchange rate (U.S. dollar against U.K. pound (USD/GBP), Canadian dollar (USD/CAD), Euro (USD/EUR), and Japan Yen (USD/JPY)). The foreign block is alternatively composed by the United Kingdom (U.K.), Canada (Ca), Euro Union (E.U.) and Japan (Jp) real GDP and nominal interest rate ($RGDP^*$ and i^*). The U.S. block is composed of the real GDP ($RGDP$), the CPI, the 3-month T-bill rate, real monetary stock ($M3$) and the four quarters ahead mean forecast of the 3-month T-bill rate from the Philadelphia Federal Reserve bank Survey of Professional Forecasters ($SPF - T - bill$). This last variable serves as a proxy of the private sector expectations of the future monetary policy that capture the forward guidance shocks. The different bilateral nominal exchange rates are expressed as units of U.S. dollar for 1 unit of foreign countries' currencies so that an increase means a depreciation of the U.S. dollar.

In total, I estimate four different specifications with data samples from $1981q3 - 2019q4$ for USD/GBP, USD/CAD, USD/JPY and $1995q1 - 2019q4$ for USD/EUR The starting dates of the $SPF - T - bill$ which is $1981q3$ and the starting date of the Euro dictate the different samples starting dates. Appendix C presents the variables, data sources and treatment.

3.3 Sufficient information test

Common solutions to increase a VAR information set consist in using Factor Augmented VAR models (FAVAR) or large-scale Bayesian VAR (BVAR) (e.g., Forni and Gambetti (2014), Bańbura et al. (2010)). However, these two approaches present some limitations. First, the information summarized in the FAVARs is unclear and makes it difficult to impose identification restrictions on them. Second, one needs to adjust the priors in large-scale BVAR to deal with degrees of freedom limitation and this can distort the estimates as well as the impulse responses. Here, I follow D'Amico and King (2017) and judiciously choose a small number of variables forecasts that matter to a central bank following a Taylor rule. These variables should contain the economic information needed to capture the forward guidance shocks. In their paper, they identify the forward guidance shocks labeled *"credible"* forward guidance using a closed economy VAR model for the U.S. augmented with the forecasts of the U.S. GDP, CPI and T-bill rate. They impose that in response to a "credible" forward guidance easing, the forecasts of the GDP and CPI increase while current interest rate moves in the opposite direction. This combination of variables and restrictions is designed to help distinguish between the U.S. unanticipated monetary policy; the expected endogenous policy response to future economic activity (*"Delphic"* or state-contingent forward guidance) and a commitment to future stimulative deviation not related to future economic activity (*"Odyssean"* or *"credible"* forward guidance)[5].

In this paper, I do not emphasize on such distinction but rather identify forward guidance as just any communication by the central bank about future policy that forecasters credibly believe will happen. Three reasons justify this choice. First, Sutherland (2020), shows that the history of U.S. forward guidance from 1991 to 2020 has been predominantly information about future state-contingent or time-contingent policy. Thus, there are not enough cases of *"Odyssean"* forward guidance to provide robust estimates of its influence. The second reason is that using private sector forecasts to capture forward guidance means that one captures the intended credibility of the policy as perceived by market participants (Campbell et al. (2017), p.327). It is therefore important to know by how much forward guidance affects forecasters' expectations. Sutherland (2020) also provides an answer to this matter and shows that forecasters significantly revise their short-term interest rate forecasts after a forward guidance in U.S.. However, they place a full weight on their inflation and growth expectations rather than those of the central bank[6]. I consequently assume that interest rate forecast captures most of the Fed future policy communications perceived as credible by the market regardless of its superior information on future economic activity. Therefore, adding supplementary restrictions with the GDP and CPI forecasts becomes irrelevant. Finally, the open economy structure of the VAR requires to include foreign variables in the observable. Since I use quarterly data, using only the T-bill forecasts allows to minimize the size of the VAR and hence deals with degree of freedom limitation. I thus go with the assumption that adding only the interest rate forecasts is enough to capture the forward guidance shocks in the model.

To support my assumption, I check if my vector of observable y_t contains enough information to capture the forward guidance shocks compared to a vector augmented with the U.S. GDP and CPI forecasts also. I use Forni and Gambetti (2014) sufficient information test to test the null hypothesis that the VAR augmented only with interest rate forecast (restricted model) contains at least the same information as the VAR augmented with the GDP and CPI forecasts also (full

[5]The distinction between *"Delphic"* forward guidance and *"Odyssean"* forward guidance comes from (Campbell et al., 2012) finding that Fed news about future lower rates decreases survey expectations of GDP and inflation. They argued that this likely reflects private sector interpreting accommodative signals by the Fed as *"Delphic"* forward guidance which conveys negative information about future economic activity. Conversely, *"Odyssean"* forward guidance is a commitment to future stimulative policy as a future deviation from the historical policy rule suggestion.

[6]For his whole sample, he finds that in response to a change in forward guidance, forecasters revise their interest rate forecasts in the intended direction by five basis points on average, and the effect is not attributable to central bank information effects. It is also not possible to detect any meaningful difference between the influence state-contingent or time-contingent forward guidance on forecasts.

model)[7],[8]. Suppose that the information set of the full model is given by the $k \times 1$ vector of all possible observable z_t driven by the shocks ε_t^z. k being large, the econometrician needs to reduce it to a sub-vector y_t driven by a sub-vector of the shocks ε_t^z say ε_t^y. If x_t is the vector of omitted observable, one can define the moving average representation of z_t as

$$z_t = \begin{pmatrix} y_t \\ x_t \end{pmatrix} = \begin{bmatrix} A_{yy}(L) & A_{yx}(L) \\ A_{xy}(L) & A_{xx}(L) \end{bmatrix} \begin{pmatrix} \varepsilon_t^y \\ \varepsilon_t^x \end{pmatrix} = A(L)\varepsilon_t^z \tag{16}$$

If x_t Granger causes y_t ($A_{yx}(L) \neq 0$), then y_t is not informationally sufficient and ε_t^y is not y_t-fundamental. Conversely, if x_t does not Granger cause y_t ($A_{yx}(L) = 0$), then ε_t^y is y_t-fundamental and the shocks can be recovered. So, I basically test if the GDP and CPI forecasts (x_t) Granger cause my vector of restricted observables y_t. The null hypothesis (H_0) is:

$$\mathrm{H}_0 : A_{yx}(L) = 0.$$

The test is done using Gelper and Croux (2007) multivariate out-of-sample test for Granger causality, which compares the out of sample forecast error of the full model (u_t^z) against the out of sample forecast error of the restricted model (u_t^y) with three different statistics tests listed from the less to the most powerful one: mean squared forecast errors (MSFE), Reg and canonical correlations (CC)[9].

Table 1 lists the p-values of the different statistic tests for the four different specifications. It emerges that for all specifications, the p-values are well above 5% significance level except for the CC and Reg p-values for the USD/EUR specification. For all the p-values above 5%, we cannot reject the null hypothesis, meaning that the three out-of-sample tests give weak evidence for Granger causality. Since the statistical behavior of the different tests is related to the size of the sample, I suspect that the result for the USD/EUR can be related to the small sample. Nevertheless, based on this result, I consider as baseline specification the model with only interest rate forecast, and later add the remaining variables for robustness. Even if the models can be considered as informationally sufficient, I still need a good identification scheme to identify the shocks. It is the main focus of the next section.

[7] The original idea of Forni and Gambetti (2014) is to test whether a number P of principal components from a large data set x_t Granger cause a sub-vector y_t. Here I do not use any principal components since my interest is in testing if a restricted model with only the interest rate forecasts is informationally sufficient compared to a full model with the GDP and CPI forecasts. The general test procedure is presented in appendix D

[8] Note that the test only tells if there is at least the same information in the restricted model as in the full model to unveil all the relevant shocks given the appropriate identification strategy.

[9] See appendix D for more details on Gelper and Croux (2007) algorithm, statistic tests and critical p-value computation

Table 1: Sufficient information test

Model	Test p-values		
	MSFE	Reg	CC
USD/GBP	0.998	0.27	0.1926
USD/CAD	0.9802	0.8652	0.9444
USD/EUR	0.9844	0.0276	0
USD/JPY	0.98	0.0848	0.1220

Note: The critical values and p-values are computed by a residual based bootstrap method over 5000 new times series generated.

3.4 Identification

In practice, the federal open market committee (FOMC) announcements contain news about unanticipated monetary policy, future policy, and future economic activities. Disentangle the effects of the unanticipated monetary shocks from those of the forward guidance is therefore not an easy task. Most previous works identify the forward guidance shocks as a shift in high-frequency financial markets data in a narrow window around the policy announcements (Kuttner (2001),Gürkaynak (2005) and Campbell et al. (2012)). In this paper, I use zero and sign restrictions on the structural parameters to identify the fed unanticipated monetary shocks and the forward guidance shocks[10]. From the best of my knowledge, D'Amico and King (2017) are the first to propose this approach to identify a *"credible"* forward guidance shocks in a closed economy VAR model for the U.S.. Table 2 gives a summary of the sign imposed based on the two-country NK model responses.

Forward guidance shock: In response to a forward guidance easing, the interest rate forecast must decrease at horizon 0. To remain agnostic about their contemporaneous responses, I impose that current real GDP, CPI, monetary stock (M3) and exchange rate increase at the exact period at which the shock is supposed to happen (horizon 3)[11]. In addition, the current interest rate must not respond within three periods (horizons 0 to 2) to reflect the central bank communicating about future policy. The responses of the foreign country variables are left unrestricted.

Unanticipated monetary shock: In response to an unanticipated monetary easing, the current interest rate must decrease at horizon 0 while the current real GDP, CPI, M3 and exchange rate increase at horizon 0. The responses of the remaining variables are left unrestricted.

[10]See Faust (1998), Faust and Rogers (2003), Canova and De Nicolo (2002), Uhlig (2005), Scholl and Uhlig (2008) for a discussion on sign-restricted VARs to identify conventional monetary policy shocks and their impact on the US economy or exchange rate.

[11]Imposing the sign at horizon 3 for the real GDP, CPI, M3 and exchange rate is plausible if one assumes that a shift in the four quarter ahead interest rate forecasts means a communication about a shock that is supposed to happen in four quarter. Appendix G shows that the results are also robust to imposing all restrictions contemporaneously.

Table 2: Sign and zero restrictions

Shocks	Endogenous variables responses						
	Foreign variables	3m T-bill	SPF-3m T-bill	RGDP	CPI	M3	Ex. rate
For. shocks	*	*	*	*	*	*	*
UMP shock	*	-	*	+	+	+	-
FG shock	*	0	-	+	+	+	-
Remai. US var.	*	*	*	*	*	*	*

Note: For the forward guidance shock, The sign restriction on the SPF-T-bill is imposed at horizon zero. The zero restriction on current T-bill is imposed at horizons 0,1,2 and the sign restrictions on the remaining U.S. variables at horizon 3. For the unanticipated monetary shock, the sign and zero restrictions are imposed at horizon 0. The stars denote unrestricted variables.

3.5 Estimation

The models parameters $B(L_p)$ and Σ_ε are estimated using a Bayesian approach with in an uninformative Normal-Inverse-Wishart à la Uhlig (1994). This prior assumes a normal prior for the VAR coefficients and an inverse Wishart prior for the covariance matrix. All models include constant and time trend, with 2 lags following the AIC criterion.

$$\alpha|\Sigma_\varepsilon \sim N(\alpha^*, V \bigotimes \Sigma_\varepsilon), \quad with \quad \alpha = Vec(B(L_p))$$

and

$$\Sigma_\varepsilon \sim IW_K(S_*, n)$$

I draw across the models impulse response functions (IRFs) using Arias et al. (2014) algorithm to check the sign restrictions[12]. Inference statements are based on 10 000 draws from the posteriors satisfying the sign and zero restrictions on the impulse responses. Standard in the sign restriction approach, I typically report the point-wise median as well as the 16% and 84% percentiles of the distribution for the impulse response functions[13].

4 Results

This section analyses the main impulse response functions (IRFs) of the VAR model. The remaining variable are left in the appendix.

[12] Arias et al. (2014) show that most previous sign restrictions algorithms do not remain agnostic in that they impose additional restrictions on the responses of other variables.

[13] Fry and Pagan (2011) discuss what they call *"multiple model problem"* and some concerns about how to summarize the information of sign restrictions responses

4.1 The effects of the forward guidance and unanticipated monetary policy shock

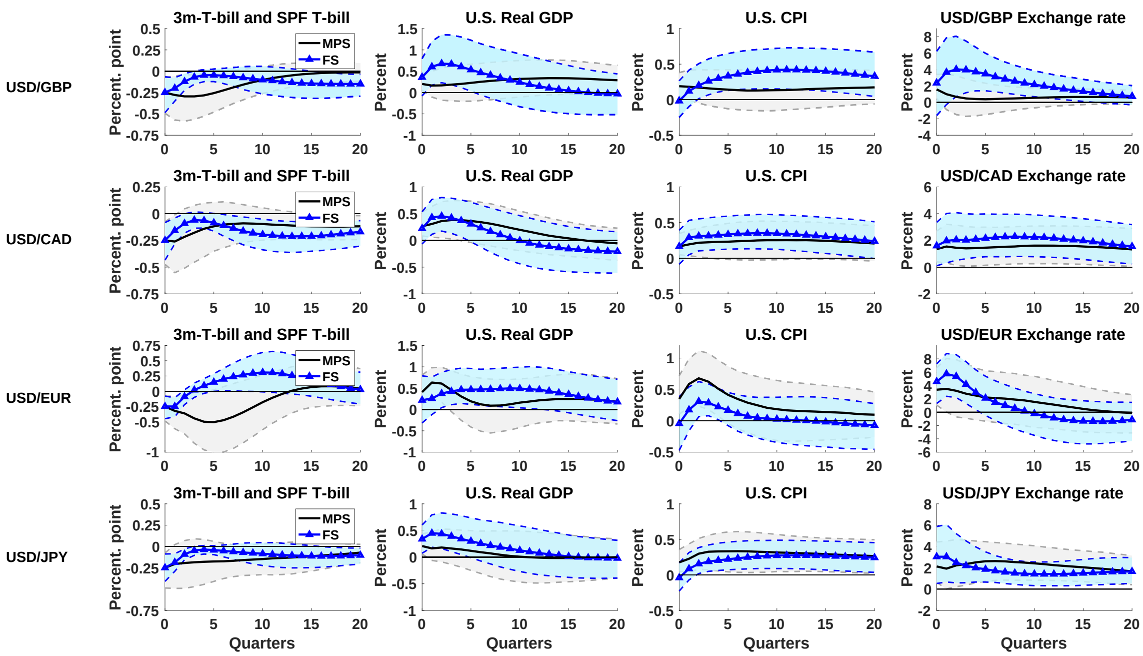
Figure 2 shows the impulse response functions (IRFs) of the policy variables (SPF-T-bill and 3m-T-bill), the real GDP, CPI, and the nominal bilateral exchange rates in columns 1 to 4 respectively. The IRFs are normalized to be responses to a 25 basis points unanticipated monetary (solid black lines) and forward guidance shocks (solid triangle blue lines). The magnitude of the impact median depreciations of the nominal exchange rates (fourth column) varies across the currency pairs but are slightly the same following both shocks. The U.S. dollar depreciates in a range of two to three percent after the unanticipated monetary easing and two to four percent after the forward guidance easing. However, the shape of the responses differs across the shocks and specifications. Except for the USD/JPY specification, the U.S. dollar peak depreciation happens instantaneously after the unanticipated monetary shock and then appreciates in line with Dornbusch (1976) overshooting theory. This theory predicts that a tighter (loose) monetary policy shock generates a large initial appreciation (depreciation) followed by subsequent depreciations (appreciations). Indeed, if the UIP condition holds, a decrease in the interest rate differential ($i_t - i_t^*$) after a domestic monetary easing should also decrease $\mathrm{E}_t(e_{t+1}) - e_t$. For this to happen, the exchange rate impact depreciation at time t must be maximum and then followed by subsequent appreciation between t and $t+1$ (a decrease in $\mathrm{E}(e_{t+1})$) as we can see from the impulse responses of the exchange rate in solid black lines. Intuitively, an unanticipated monetary policy causes a decrease in the return of U.S. assets relatively to foreign assets. To keep U.S. assets attractive and at the same time maintain the UIP condition, the U.S. dollars must be expected to appreciate in order to pay the same expected return as an investment in the foreign assets converted in U.S. dollar. In fact, this result following the unanticipated monetary shock goes against the findings of Eichenbaum and Evans (1995), Scholl and Uhlig (2005), Steinsson (2008) and Bjørnland (2009). They find that the maximum effect of the U.S. unanticipated monetary shock on the U.S. dollar is not contemporaneous but happen within three to five quarters after the shock (*"delayed overshooting"*). However, Faust and Rogers (2003), Kim et al. (2017) and Inoue and Rossi (2019) conclude that there is no robust evidence to support the delayed overshooting after a U.S. unanticipated monetary shock. Particularly, Kim et al. (2017) using sign restrictions on U.S. monthly bilateral exchange rate data from 1976 to 2007 find that the exchange rate systematically overshoots as predicted by the UIP in the post-Volcker era (1988:1 onward). However, in the Volcker era (1979:8 to 1987:12) and the entire sample, the delayed overshooting appears. They conclude that the delayed overshooting apparent persistence in the entire sample period is primarily driven by the behavior of exchange rates during the Volcker era. The episode is severe enough to contaminate the entire sample period, thereby misleading previous empirical studies to prematurely conclude the failure of the overshooting theory. Their results is complemented by Castelnuovo et al. (2022). They use a combination of sign, zero, and policy coefficient restrictions to identify the exchange rate response to a U.S. monetary policy shock. They also find that the exchange rate overshoot after an unanticipated increase in the policy rate and that the Volcker's regime is associated with a delayed overshooting. I thus conclude that the UIP condition and thereby the overshooting theory hold after the unanticipated monetary shock in my data mostly dominated by a larger post-Volcker era sample. Conversely, after the forward guidance easing shock, the U.S. dollar depreciation shows a little hump-shaped response as a *"delayed overshooting"* pattern. The only exception again is for the USD/JPY nominal exchange rate. The peak depreciation is reached between quarter two and eight for a maximum depreciation in a range of four to six percent before reverting sign. This result is consistent with Rogers et al. (2018) who also find little delayed overshooting of the U.S. dollar after a forward guidance shock except for the USD/JPY exchange rate also[14]. Intuitively, forward guidance affects the current exchange rate by modifying anticipation. Suppose that at time t, economic agents expect a one-period decrease in the interest rate differential at time $t+4$ (i.e., a future Home nominal interest rate decrease). The other reason why nominal exchange rate immediately depreciates aside from the cumulative sum of the interest rate difference is an expectation of future subsequent depreciation. The central bank communication steers market's expectations toward future exchange rate depreciation which in turn depreciates more slightly the exchange rate between t and $t+1$ than the unanticipated monetary policy and causes a hump-shaped response like the *"delayed overshooting."* In this sense, the likely *"delayed overshooting"* responses following the forward guidance shock should be the one expected, and should not be taken as a UIP failure since this policy changes market expectations. Furthermore, its absence as in USD/JPY exchange rate can be considered puzzling.

The IRFs of the real GDP and CPI are given in column two and three. The responses after the unanticipated monetary and forward guidance easing are conventional with the existing literature and the intuition given in the theoretical section. The U.S. real GDP immediately increases in a hump-shaped manner after both shocks except for the USD/GBP and USD/JPY where it immediately increases at a peak before falling. The CPI also rises after both shocks, however, in most cases, the median impact response after the forward guidance shock is close to zero before rising compared to the contemporaneous increase after the unanticipated shock. The remaining U.S. variables responses to both shocks are given in appendix F. It is, however, worth mentioning that on one hand, according to the data, the fed unanticipated monetary easing feeds into the market expectations as captured by the decrease of the SPF-T-bill after this shock. On the other hand, the current 3m-T-bill exactly decreases at horizon four as intended by the central bank communication except for USD/EUR specification.

Since both shocks depreciate the U.S. dollar, I now check the existence of an exchange rate channel transmission of the U.S. monetary policies that amplifies the U.S. real GDP response.

[14]Note that a robustness check in appendix G with signs applied contemporaneously shows that the results are qualitatively the same and that these patterns are not simple results of the sign being applied at horizon four.

Figure 2: IRFs of U.S. variables and exchange rate to U.S. monetary shocks



Note: The solid black lines are the median estimated IRFs (in percent) to a 25 basis points unanticipated monetary easing. The solid blue triangle lines are the median estimated IRFs (in percent) to a 25 basis points forward guidance easing. The shaded areas and dotted lines indicate the 16% and 84% credible sets. The first column reports the median responses of the 3m-T-bill and the SPF-T-bill to their respective shock. The fourth column reports the U.S dollar exchange rate responses following both shocks. Each row of the figure corresponds to the different bilateral exchange rate specifications.

This channel emphasizes that a domestic country currency depreciation can cause an *"expenditure-switching effect."* Indeed, the decrease in the value of the domestic country currency makes foreign goods more expensive relatively to domestic goods for domestic households giving them an incentive to revert toward more consumption of domestically produced goods (decrease in imports). At the same time, for foreigners, domestic goods become less expensive than their respective goods, and thus they should increase their consumption of domestically produced goods too (increase in exports). The result is an increase in the domestic country net exports and GDP. From the best of my knowledge, most of the previous literature focus on the existence of the exchange rate channel after an unanticipated monetary shock. They find no clear evidence of an impact increase in net exports following a U.S. depreciation due to this shock (Magee (1973), Rose and Yellen (1989), Moffett (1989), Bahmani-Oskooee and Brooks (1999), Bahmani-Oskooee and Ratha

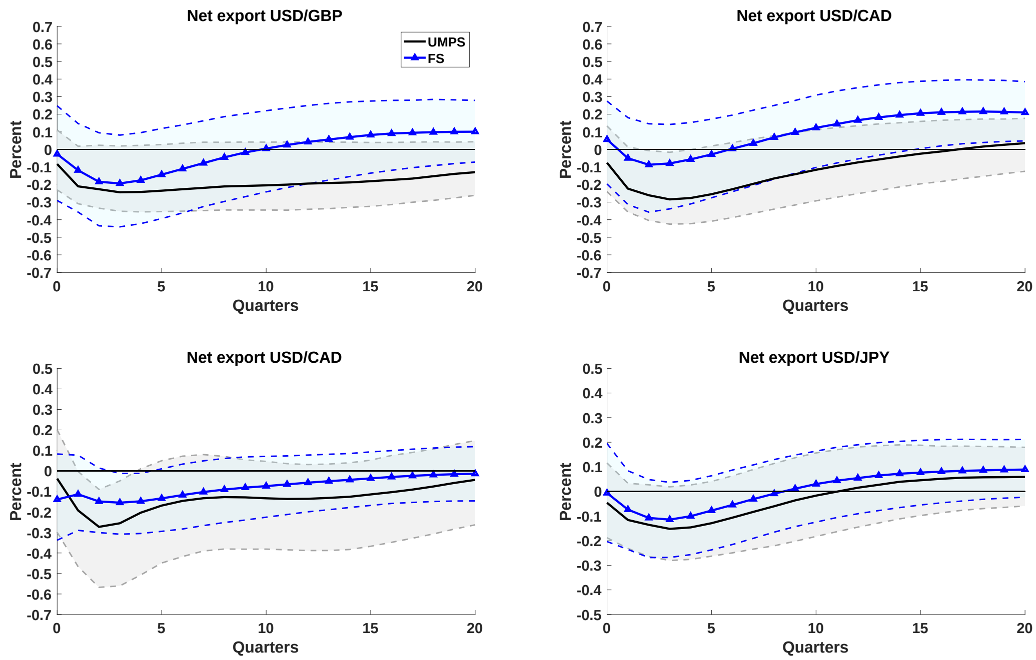
(2004), McKinnon (2007), Chiu et al. (2010))[15]. Bernanke (2017) considering the 2010 debates that the Federal Reserve has chosen policies that weakened the dollar during the financial crisis thus unfairly increased U.S. competitiveness shows that empirically, evidence that the U.S. has relied on net exports for growth, or that U.S. monetary easing has an adverse effect on the exports of trading partners are weak. To check if such effect exists after the U.S. forward guidance shock, I estimate the baseline model with the U.S. total real net exports in percentage of the real GDP. The identification is done with the same restrictions as before, however, no sign is applied on the response of the net exports to both shocks. The IRFs are given in figure 3. The median responses after both shocks show the classical J-curve adjustment response of net exports. The dollar depreciation initially worsens the net exports before they increase in the long run. However, the credible sets contain zero for all the impulse responses horizon except for the USD/CAD specification where there is an improvement of U.S. net exports following the forward guidance shock after fourteen quarters. Based on this result, I conclude that there is no exchange rate channel transmission of the U.S. unanticipated monetary and forward guidance policy on the U.S. economy. This lack of an effect of the exchange rate depreciation on the net exports is related to the *"exchange rate disconnect"* of Rogoff and Obstfeld (2000) which encapsulates two puzzles. The first one is that the exchange rate variation seems to have only small effects on the real economy as we can see with the net exports. The second one is related to the monetary policy contribution to the exchange rate fluctuations as I discuss in the next section.

4.2 Monetary shocks and exchange rate fluctuation

Table 3 reports the contribution of the two identified monetary shocks to the mean-squared error of a one quarter ahead forecast of the exchange rate. The forward guidance shock explains between 3.89 percent to 10.95 percent of the U.S. dollar variance for the median estimate, and the unanticipated monetary policy explains between 3.41 percent to 16.95 percent of the variance. The result for the unanticipated shock is in line with Kim and Roubini (2000), Faust and Rogers (2003), Scholl and Uhlig (2008) and Kim et al. (2017) finding that unanticipated monetary shocks have small contribution (between 2 and 10 percent) in explaining exchange rate fluctuations. However, these previous works focus on unanticipated monetary shocks only, and since the Fed has past experience with forward guidance, they possibly minimize the overall effect of monetary shocks on exchange rate fluctuations. Indeed, the cumulated median contribution of both shocks to the exchange rate variance varies in a range of 7.3 percent to 27.9 percent, and the forward guidance contributes to at least half of the role played by the monetary policy. Also note that except for the USD/CAD, the

[15] Note that in the two-country NK model, the net exports improvement after a monetary easing depends on the relation between the terms of trade and net exports. More generally, since the sign of the relationship between net exports and the terms of trade is ambiguous and depends on the relative sign of some of the model parameters, the theoretical sign of the net exports response will also be ambiguous.

Figure 3: U.S. Net exports IRFs to the U.S. monetary shocks.



Note: The solid black line is the median estimated impulse response (in percent) to a 25 basis point unanticipated monetary easing. The solid blue triangle line is the median estimated impulse response (in percent) to a 25 basis point forward guidance easing. Shaded areas indicate the 16% and 84% credible sets.

impact variation of the U.S. dollar is mostly explained by the forward guidance shock. This can reflect the fact that exchange rate is more sensitive to news about future economic fundamentals. As mentioned by Engel (2016), since the exchange rate is forward-looking, when economic agents have news beyond the current realization of the economic fundamentals, the variance of the real (nominal) exchange rate increases. The correlation of the exchange rate and the current fundamentals also decreases for this reason creating the second puzzle of Rogoff and Obstfeld (2000) that there seems to be very little evidence that the unanticipated monetary policy explains a huge part of the exchange rate movements.

4.3 Uncovered interest rate parity

The exchange rate responses analyzed in figure 2 show the presence of a hump-shaped response like a delayed overshooting after the forward guidance shock in three out of four of the specifications. If

Table 3: Forecast error variance decomposition of exchange rate

Quarters	USD/GBP FS	USD/GBP MPS	USD/CAD FS	USD/CAD MPS	USD/EUR FS	USD/EUR MPS	USD/JPY FS	USD/JPY UMPS
1	**7.23**	**4.81**	**3.89**	**11.54**	**10.95**	**6.55**	**10.91**	**3.41**
	(0.70, 27.32)	(0.37, 22.22)	(0.28, 17.10)	(1.30, 34.08)	(1.71, 27.48)	(0.64, 24.56)	(0.93, 34.66)	(0.24, 16.84)
5	**7.66**	**8.39**	**4.26**	**10.96**	**9.32**	**5.23**	**7.60**	**5.18**
	(1.77, 27.41)	(1.53, 26.43)	(0.72, 18.37)	(1.46, 31.90)	(2.08, 22.95)	(0.91, 22.32)	(1.12, 26.32)	(0.90, 20.01)
10	**9.80**	**10.24**	**6.30**	**13.02**	**7.70**	**6.28**	**6.99**	8.58
	(3.02, 28.01)	(2.25, 27.08)	(1.42, 21.30)	(2.59, 34.31)	(2.16, 17.60)	(1.35, 21.93)	(1.83, 21.49)	(2.10, 23.54)
15	**10.62**	**10.82**	**7.53**	**15.42**	**8.17**	**6.90**	**7.52**	**11.39**
	(3.45, 27.73)	(2.77, 26.68)	(1.79, 22.80)	(3.88, 36.17)	(2.53, 17.07)	(1.64, 21.74)	(2.31, 19.29)	(3.43, 25.52)
20	**10.79**	**10.86**	**8.11**	**16.95**	**8.72**	**7.19**	**8.29**	**12.78**
	(3.63, 26.37)	(3.12, 25.95)	(1.95, 22.50)	(4.73, 36.43)	(2.81, 18.25)	(1.86, 20.73)	(2.79, 19.18)	(4.09, 26.57)

Notes: Each row corresponds to the different horizon. The columns report the variance decomposition for the corresponding bilateral exchange rate following the forward guidance (FS) and the unanticipated monetary shocks (MPS). The bold numbers are the median variance decomposition, and the numbers in bracket are the 16 and 84 percentiles variance decomposition.

such responses are inconsistent with the UIP condition, one can expect the presence of an expected foreign exchange excess returns. Also, according to Sims (1992) and Grilli et al. (1995) there may be an expected foreign exchange excess returns even without a delayed overshooting. So, in this section, using the estimates from the VAR, I compute the expected impulse response of the foreign exchange excess returns after the forward guidance and unanticipated monetary shocks. Following Engel (2016), I define λ_t as the excess return between the expected return of an investment in foreign currency converted in U.S. dollars and an investment directly in U.S. dollars.

$$\lambda_t = i_t^* - i_t + \{E_t(e_{t+1}) - e_t\} \tag{17}$$

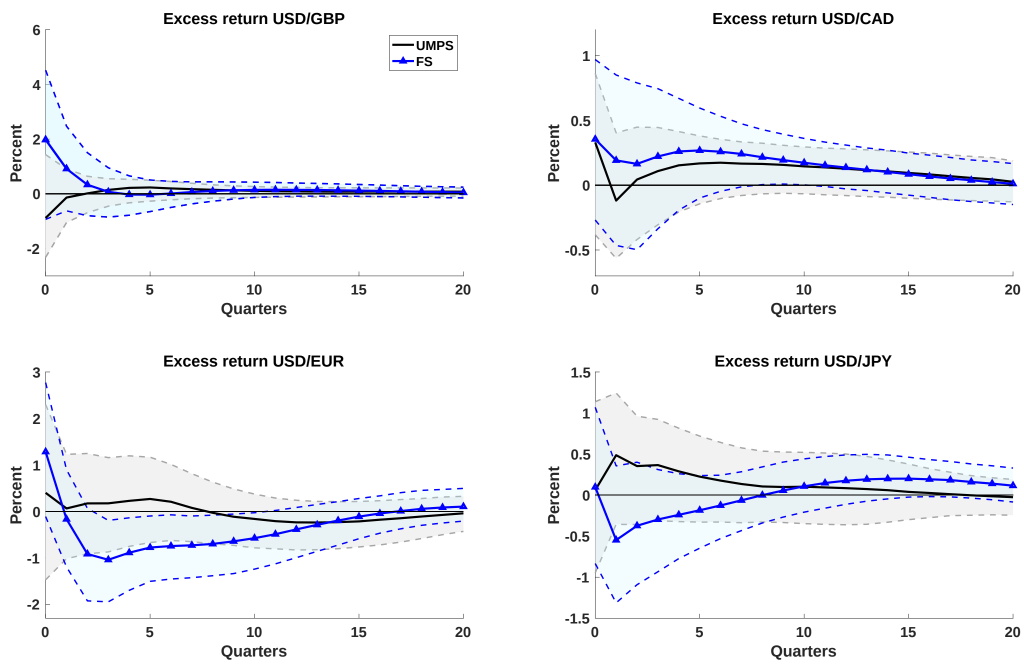
Under the UIP condition, $\lambda_t = 0$. Assuming that equation 17 holds, and since it is a linear combination of the variables in the VAR, the response of λ_t k-periods after the shock is computed as:

$$\lambda_{t\to k} = i_{t\to k}^* - i_{t\to k} + E_t\Delta e_{t\to k+1} \tag{18}$$

The corresponding median impulse responses as well as the credible sets are reported in figure 4. Under the UIP condition, these responses must be equal to zero. Following the forward guidance shock, the median responses of the excess returns (solid triangle blue lines) increase on impact and then decrease to remain close to zero reflecting the absence of a predictable movement of the expected excess returns. Note also that all the credible sets contain zero for all horizon except for the USD/EUR specification where it becomes negative between quarters 3 and 10. The expected excess return can be the result of a some carry trade operation where investors demand an additional amount of money (risk premium) to be compensated for an expected depreciation of the currency, in which they hold a long position (here the foreign currencies). However, in the case of the forward guidance shock, investors clearly anticipate an appreciation instead of a depreciation suppressing in the way any currency risk. So, the exchange rate responses following the forward guidance shock do not reflect a UIP deviation but rather a change in market expectations.

Following the unanticipated monetary shock (solid black line), the median excess returns also remain close to zero with the credible sets containing zero over all horizons. This result is closely related to the observed absence of a delayed overshooting following the unanticipated monetary shock. As discussed in the previous section, this can be explained by a sample mostly dominated by the post Volcker era. Overall, the absence of a predictable movement of the expected excess returns means that the UIP condition holds in both cases.

Figure 4: Excess return IRFs to the monetary shock.



Note: The solid black lines are the median computed IRFs (in percent) to a 25 basis point unanticipated monetary easing. The solid blue triangle lines are the median computed IRFs (in percent) to a 25 basis point forward guidance easing. The shaded areas indicate the 16% and 84% credible sets.

4.4 U.S. monetary shock spillovers

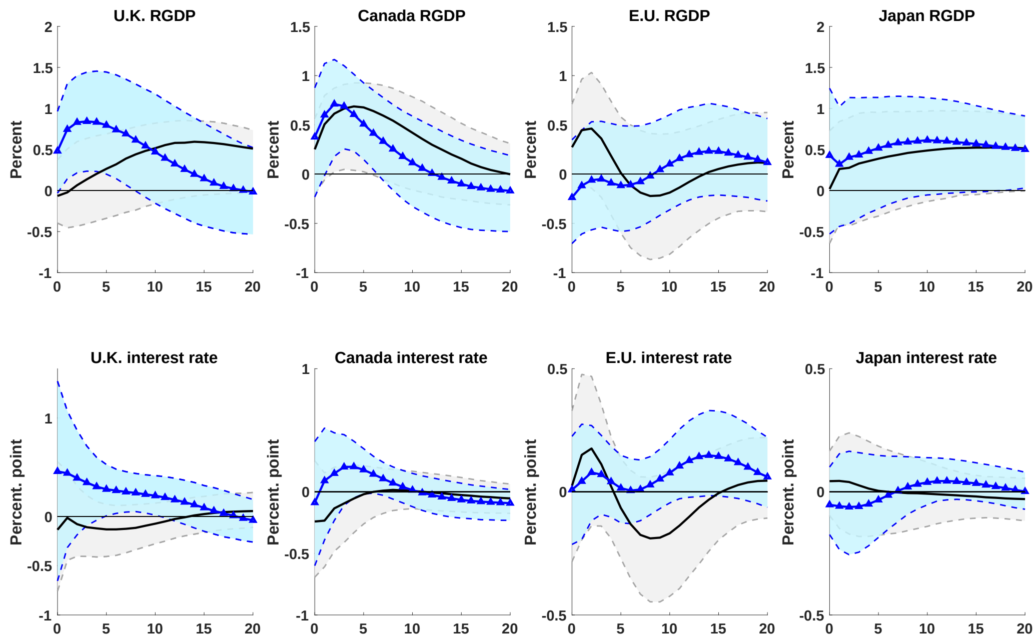
U.S. monetary policies (conventional and unconventional) are potential sources of spillovers onto other countries (Ilzetzki and Jin (2013), Rajan (2015), Dedola et al. (2015), Albagli et al. (2019), Curcuru et al. (2018b), Rudel and Tillmann (2018)). According to the Mundell-Fleming model developed to study this kind of issue, the international transmission of monetary shocks can occur through two channels. The first one is the demand effect whereby domestic monetary easing usually leads to an increase in domestic incomes, which in turn raises home consumption of foreign goods and services and change the demand for world output (*"expenditure augmenting effect"*). The second one is the *"expenditure switching effect"* previously analyzed. As discussed by Bernanke (2017), The net effect of the monetary policy spillovers on other countries consequently depends on the relative magnitudes of the two mechanisms. Figure 5 reports in its first row the median responses of foreign real GDP, and in the second row the foreign interest rates. The U.S. forward guidance easing (triangle blue lines) immediately increases U.K., Canada, and Japan real GDP by about 0.5% for the median estimates, with the monetary policy in the first two countries slightly reacting according to the Taylor rule. Note, however, that the credible set for Japan real GDP includes zero up to 17 quarters. The Euro area is less affected by the U.S. forward guidance with an impact negative median estimate which remains close to zero for all horizons. For the U.S. unanticipated monetary easing (solid black lines), the median foreign real GDP IRFs increase but in a delayed fashion for U.K. and Japan, but all credible sets contain zero. Overall, I conclude that in terms of spillovers, the *"expenditure-augmenting effect"* of the U.S. forward guidance policy is the most important for U.S. developed trade partners. This result combined with the previous one of no *"expenditure-switching effects"* are in line with Bernanke (2017) conclusion that the *"expenditure-augmenting"* effects of U.S. monetary policies tend to offset the *"expenditure-switching effects."* Once one takes into account the expenditure-augmenting effects, U.S. monetary easing has no adverse effect on the exports of trading partners.

5 Robustness

5.1 Narrative sign restrictions

The initial idea of sign restrictions as developed by Uhlig (2005) is to assess the effects of an identified shock on macro aggregates while remaining agnostic. Indeed, sign restrictions are relatively weak compared to other identification methods and are sometimes criticized because not much can be concluded since one does not pin down a unique parameter but a set of parameters (see Fry et al. (2007) for a detailed discussion on issues related to sign restrictions). Another concern with this

Figure 5: Foreign GDP and interest rate IRFs to U.S monetary shocks



Note: The solid black lines are the median estimated IRFs (in percent) to a 25 basis points unanticipated monetary easing. The solid blue triangle lines are the median estimated IRFs (in percent) to a 25 basis points forward guidance easing. The Shaded areas indicate the 16% and 84% credible sets.

approach is whether sign restrictions recover the correct impulse responses, or, no? Since the type of restrictions chosen to identify the shocks are not testable within the VAR model, one way to evaluate the plausibility of the sign is to check if the model can recover the good sign of the response of the interest variable to the desired shock while restraining the responses of the remaining variables. However, as discussed by Paustian (2007) and Inoue and Kilian (2013) for this approach to work, the variance of the structural shock of interest must be higher than seems empirically plausible otherwise, without all available identifying restrictions, the model tends to be uninformative. One thus needs additional restrictions to narrow the set of plausible model and remain agnostic about some variables responses. In this section, I combine the previous sign and zero restrictions with narrative sign restrictions to identify the shocks of interest while leaving the response of the exchange rate free. The narrative sign restrictions are based on Antolín-Díaz and Rubio-Ramírez (2018) algorithm and constrain the structural shocks and the historical decomposition of some variables to match key historical events[16]. From the best of my knowledge, this is the first attempt to use such approach to improve the forward guidance shock identification in a VAR model. I use three events corresponding to three different types of U.S. forward guidance based on Sutherland (2020) data:

Narrative restriction 1: The forward guidance shock for 2003q4 (*"qualitative forward guidance"*), 2011q4 (first *"time contingent forward guidance"*) and 2013q1 (first *"state contingent forward guidance"*) must be negative (easing)[17].

Narrative restriction 2: The unanticipated monetary policy shocks for the 2011q4 and 2013q1 periods (Zero Lower Bound period (ZLB)) are the least important driver of the observed unexpected movements in the exchange rate[18].

Appendix I reports the posterior distribution of the shocks in the corresponding period. Since the shocks are historically negative during these periods (easing), we can clearly see that the narrative sign restrictions help to squeeze the distribution of the shocks in the negative part compared to the pure zero and sign restrictions. Figure 6 reports the corresponding impulse responses of the different bilateral nominal exchange rate to the forward guidance easing only. We can see from the solid blue lines which correspond to the baseline zero and sign restrictions that in most cases, the median responses go in the right direction. However, the corresponding credible sets contain zero. The only exception is for the USD/JPY specification where the median exchange shows an initial slight appreciation before reverting sign. Once I add the narrative sign restrictions, the corresponding median responses and credible sets of the exchange rate recover the good sign without ambiguity in most cases while remaining completely agnostic on the exchange rates responses. However, the estimate for the USD/EUR is less precise and conclusive. This can be related to the small sample size of this specification. Also note that the impact depreciations of the U.S. dollar are stronger with this approach.

5.2 The Zero Lower Bound: the shadow short sate as a monetary stance

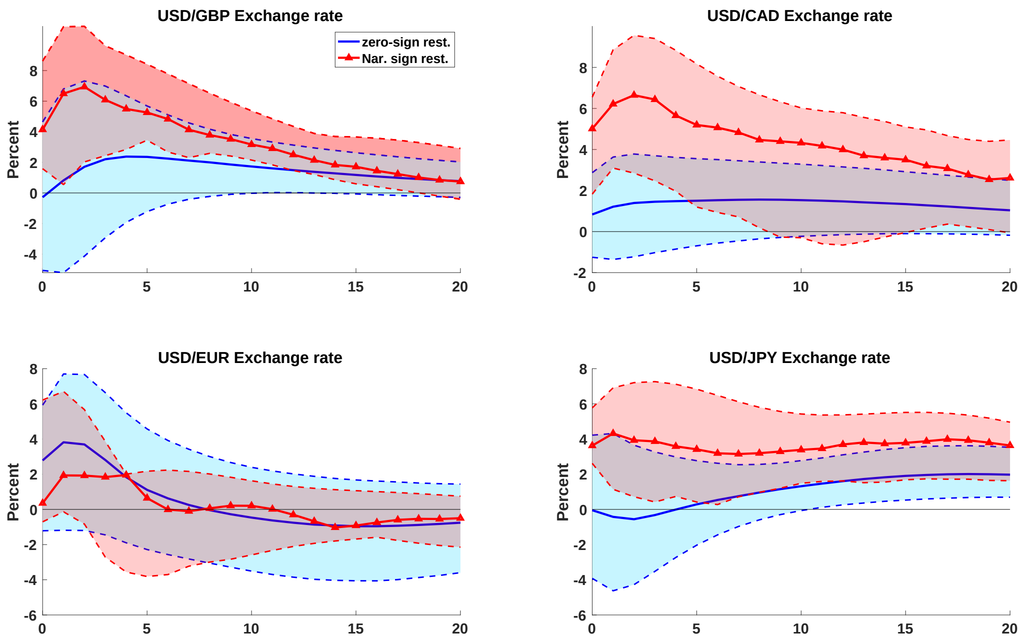
After 2008, nominal interest rates in the U.S. and other countries felt quite close to zero. This zero lower bound creates a break in the data since nominal interest rates do not carry any information about the real stance of the economy and monetary policy. However, Krippner (2013) and Wu

[16]In practice, narrative sign restrictions help shrink the set of admissible structural parameters and allow to reach clear economic conclusions. See Antolín-Díaz and Rubio-Ramírez (2018) for more details as well as the algorithm.

[17]Appendix H gives an overview of the corresponding FOMC statement and How I choose the corresponding quarters.

[18]It is obvious that since the federal fund rate was stuck at the ZLB, the conventional monetary policy became inactive and thus could not contribute to macro fluctuations.

Figure 6: Narrative sign restrictions



Note: The solid blue lines are the median estimated impulse response (in percent) to a 25 basis points forward guidance easing with zero and sign restrictions. The solid red triangle lines are the median estimated impulse response (in percent) to a 25 basis point forward guidance easing with zero, sign restrictions and narrative sign restrictions. The shaded areas indicate the 16% and 84% credible sets. The responses are computed using 50 000 draws respecting the sign restrictions and 1 000 000 draws for the importance weight (see Antolín-Díaz and Rubio-Ramírez (2018) for more details). The total number of of draws respecting both sign and narrative sign restrictions is around 5% for each specifications.

and Xia (2016) propose an alternative way to capture the monetary stance with the *"shadow short rate"* (henceforth ssr) based on Black (1995) work. According to Black (1995), so long as investors can hold currency, the nominal short rate cannot be negative. Indeed, the existence of currency as a store value may prevent investors to hold instruments bearing negative interest rates. Defining currency as an option, he introduced the ssr which can be positive or negative. When the nominal short rate is stuck at zero for a time, one can follow the ssr and whenever it becomes positive, it just reflects the nominal short rate. The instantaneous risk-free rate i_t is then given by the greater of the ssr and zero:

$$i_t = max\{0, ssr_t\}$$

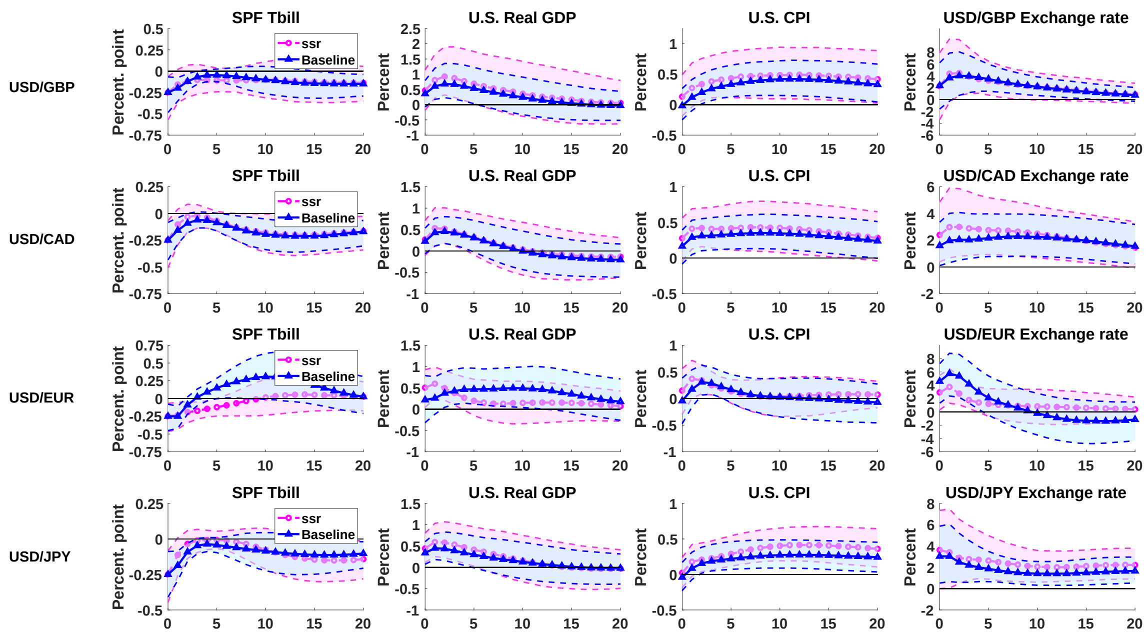
As mentioned by Bullard et al. (2012), Wu and Xia (2016) and Krippner (2013), the ssr reflects the effects of quantitative easing on longer-maturity interest rate securities and thus the economy. To compensate for the break in the data and filter out for the quantitative easing, I replace for the effective lower bound period the 3m-T-bill as well as the respective foreign interest rate by Krippner (2020) robust $ssrs$ estimates in the four baseline specifications[19]. The different $ssrs$ for each country are reported in appendix J. When the economy is away from the zero lower bound, the $ssrs$ and the conventional short-term nominal interest rates are almost similar. But as soon as the economies reach the zero lower bound, the conventional short-term interest rates are stuck to zero while the $ssrs$ go negative. The negativity can be interpreted as more monetary easing from the central banks using unconventional policies such as quantitative easing. Figure 7 shows the impulse response functions to a 25-basis point forward guidance shock with the ssr alongside the baseline estimated results. Overall, we can see that the main responses qualitatively stay the same as before.

5.3 Shocks analysis

As discussed previously, the estimated VAR contains at least the same information to unveil the forward guidance shocks as a VAR augmented with judiciously chosen fundamental forecasts. Another way to check whether the identified forward guidance shocks are indeed structural is to analyze their orthogonality with respect to the additional variables' forecasts. This analysis also contributes to the huge debate in the forward guidance empirical literature on the fact that central bank communications on future policy rate can be dependent or not on its superior information on the future economic activity. As discussed in section 3, forecasters significantly revise their short-term interest rate forecasts after a forward guidance in the U.S., but they place a full weight on their own inflation and growth expectations rather than those of the central bank. One can think of this as private sector perceived credibility about central bank news on future policy not being related to the Fed superior information about future economic activity. Nevertheless, it can be related to the private sector own expectations about the future and thus still be perceived as a future Taylor rule related policy. To see how private forecasters mostly perceive the Fed forward guidance, I assume that if the identified shocks are not related to the GDP and CPI forecasts containing either central bank news about future economic development or forecasters own expectations, in this case, the shocks must be orthogonal to these forecasts. To test this hypothesis, I estimate a simple equation, via ordinary least square, where the dependent variables are the estimated forward guidance shocks (FS_t), and the explanatory variables are the first difference of the four quarters ahead real GDP

[19] Krippner (2020) estimated the $ssrs$ for all the four country present in the present work. The data are available at the following link Krippner international shadow short rates. Since the estimated $ssrs$ are only available startinf from 1995, I only replace the corresponding nominal rates when zero lower bound is binding by the ssr.

Figure 7: IRFs with the SSR



Note: The pink circle lines are the median estimated impulse response (in percent) to a 25 basis point forward guidance easing with the *ssrs*. The solid blue triangle lines are the median estimated impulse response of the baseline model (in percent) to a 25 basis point forward guidance easing. Shaded areas indicate the 16% and 84% credible sets.

(SPF_GDP_t) and inflation rate (SPF_CPI_t) forecasts from the Survey Professional Forecasters. Note that due to changes in the base year in the sample, I first transform the CPI forecasts data to the same U.S. base year and then calculate the real GDP forecasts[20]. The regression equation is written as:

$$FS_t = A + B * SPF\_GDP_t + C * SPF\_CPI_t + \varepsilon_t \tag{19}$$

If the private sector perceives the communication as a future deviation from the Taylor rule, the coefficients B and C should not be significant. In addition, this test can be a way to purge the identified shocks from the future economic activity information they may contain. In this case, the residuals of the regression ε_t will be *"purged"* shocks and thus present a different pattern. Table 4 reports the estimated coefficients for each bilateral exchange rate specification. First, in all specification the coefficients are not significant except for the USD/GBP and USD/CAD

[20]Since the dependant variable (the shocks) is stationary, it cannot follow integrated explanatory variables on their non-stationary, so a regression on the model in level must be misspecified. To avoid spurious regression I differentiate the model as suggested by Granger and Newbold (1974)

specifications where the GDP forecast are barely significant. Second, the estimated coefficients signs even though not significant, goes in the opposite direction of what the Taylor rule suggests i.e., an increase in GDP and CPI expectations decreases market expectations of future policy. Appendix K also shows that there is no difference between the pattern of the identified shocks in the VAR and the *"purged"* shocks. One can think of these results as private sector mostly perceiving Fed communications as credible future deviation from the Taylor rule and supplement proof that the VAR with only interest rate forecast is able to unveil the shocks.

Table 4: Test of the identified dif shocks

	(1) USD/GBP	(2) USD/CAD	(3) US/EUR	(4) USD/JPY
Drgdpfor	-11.45*	-10.72*	-12.25	-7.517
	[5.929]	[6.157]	[7.528]	[6.384]
Dcpifor	-3.933	-7.856	-7.816	0.452
	[6.750]	[7.009]	[9.419]	[7.268]
_cons	0.0961	0.111	0.116	0.0412
	[0.0867]	[0.0901]	[0.100]	[0.0934]
N	152	152	98	152
adj. R^2	0.012	0.008	0.009	-0.001
F	1.914	1.591	1.427	0.907

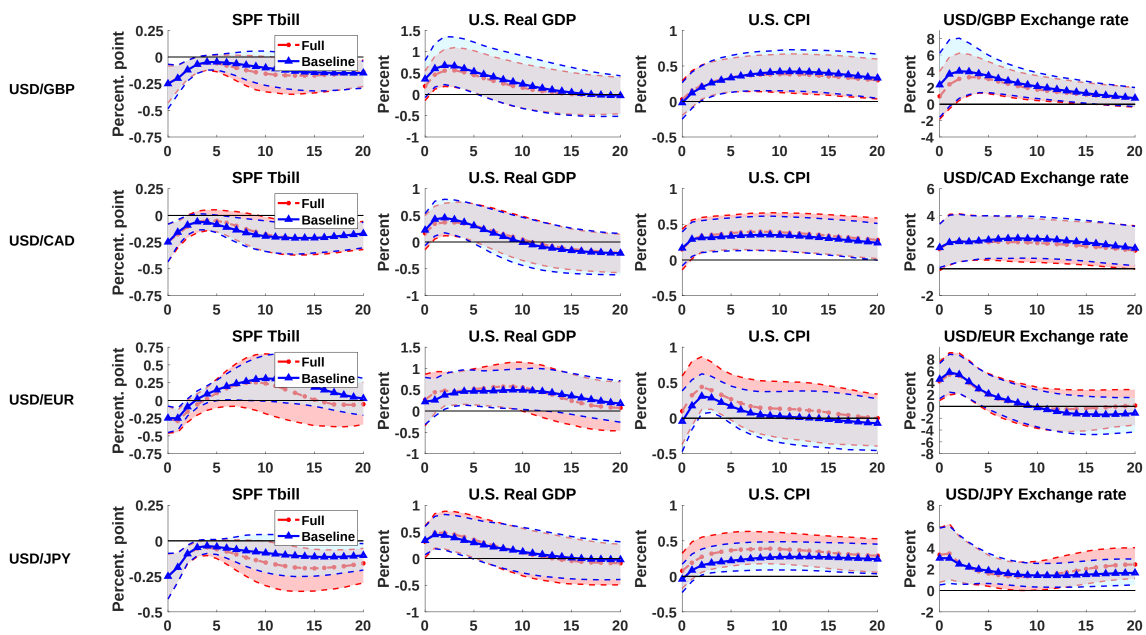
Standard errors in brackets

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.4 Adding information to the VAR and alternative forecast horizon

Since some of the coefficients in the previous section are at least significant at 10%, I check here if the estimated IRFs change with additional information on GDP and CPI forecast in the VAR (full model). Figure 8 shows the IRFs of the baseline model, and the IRFs of the model augmented with GDP and CPI forecasts. No additional sign restrictions are imposed on the responses of the additional variables to the forward guidance and unanticipated monetary shocks. As we can see there is qualitatively no difference between the IRFs. This specification also gives the opportunity to check if adding additional sign restrictions as in D'Amico and King (2015) (henceforth DK) approach to identify *"credible"* forward guidance shocks change the results. They argue that in response to a *"credible"* forward guidance easing, current GDP and CPI must increase, and expected GDP and CPI must also increase in contrast to what the Taylor would predict. The results reported in appendix L show that there is again no qualitative difference between the IRFs. Moreover, appendix M shows that the GDP and CPI forecasts both increase in the model with and without the additional restrictions. However, the credible sets of the GDP and CPI forecast in the model with additional restrictions are narrower. This result suggests that the VAR with only interest rate forecast, and zero restrictions performs relatively well to identify the perceived credible forward guidance shocks by forecasters. As a last exercise, I also check whether the results are affected or not by different forecast horizon. The results available upon request shows that using different forecast horizon from 1 quarter to 3 quarter ahead for the 3m-Tbill qualitatively delivers the same results as in baseline model. This suggests that the different forecast horizon carries the similar information in terms of news.

Figure 8: Baseline identification VS full model restrictions



Note: The red circle-dotted lines are the median estimated impulse response (in percent) to a 25 basis point forward guidance easing with the model augmented with SPF real GDP and CPI. The blue triangle lines are the median estimated impulse response of the baseline model (in percent) to a 25 basis point forward guidance easing. Shaded areas indicate the 16% and 84% credible sets.

6 Conclusion

This work analyzed the existence of an exchange rate channel transmission of the U.S. forward guidance on the U.S. economy using four U.S bilateral exchange rate: U.S. dollar against U.K. pounds, Canadian dollar, Euro, and Japan yen. Using zero and sign restrictions from a two-country NK model, I mainly contribute to the forward guidance literature by showing that there is no exchange rate channel transmission of the shock to the U.S. economy and I propose a first attempt to improve the shock identification via narrative sign restrictions. As related results, I find that first, a VAR model augmented with interest rate forecasts contains at least enough information to identify the shocks as a VAR with judiciously chosen forecasts of fundamentals that matter to a central bank following a Taylor rule (real GDP and inflation rate forecasts). Second, following a 25 basis points forward guidance easing, the nominal bilateral exchange rates immediately depreciate in a range of two to four percent compared to an impact depreciation of two to three percent after the unanticipated monetary easing. The real GDP and CPI also immediately increase. Third, I find no robust evidence to support the delayed overshooting after a U.S. unanticipated monetary shock. Conversely, the exchange rates present some hump-shaped responses like a delayed overshooting pattern after the forward guidance shock except USD/JPY. I argue that this should be the expected pattern of the exchange rate following this shock so that its absence can be seen as puzzling. Fourth, the cumulated contribution of both monetary shocks to the exchange rates variance is in a range of 7.3 percent to 27.9 percent, and the forward guidance contributes to at least half of the role played by the monetary policy. Fifth, related to the absence of delayed overshooting, there is no systematic excess return following both shocks. This is not surprising for the forward guidance shock since it is designed to steer market expectations in the opposite direction of what is expected with the uncovered interest rate parity (UIP) condition. However, for the unanticipated shock, since the results are mitigated in the literature, I argue that the absence is due to a sample mostly dominated by the post-Volcker era. Sixth, I find some evidence of U.S. forward guidance spillovers on U.K. and Canada mostly dominated by the *"expenditure-augmenting effect"*. Seventh, the identified shocks are perceived by the market as being credible since they affect GDP and CPI forecasts in the opposite direction of the Taylor rule.

Possible future research areas include testing whether the results change during the Volcker era and focus more specifically one the ZLB period. Since quantifying both the effects on the exchange rate and real GDP requires quarterly data, a possible approach can use regime switching VAR with zero and sign restrictions to compensate for small sample. One can also expand the narrative sign restriction to assess if there is a difference in the type of forward guidance used in the U.S. according to Sutherland (2020) data set. Another interesting research will be to assess the existence of the exchange rate channel in the data for other small economies that experienced forward guidance or if the U.S. results change vis à vis to emerging markets. Finally, a simultaneous identification of forward guidance in a two-country VAR model could be interesting to see if the results change depending on the two countries using forward guidance. Sutherland (2020) data set could be a good starting point for these analyses.

References

(????).

Albagli, Elias, Luis Ceballos, Sebastian Claro, and Damian Romero (2019), "Channels of us monetary policy spillovers to international bond markets." *Journal of Financial Economics*, 134, 447–473.

André, Marine-Charlotte and Guido Traficante (2020), "Forward guidance in small open economy."

Antolín-Díaz, Juan and Juan F Rubio-Ramírez (2018), "Narrative sign restrictions for svars." *American Economic Review*, 108, 2802–29.

Arias, Jonas, Juan Francisco Rubio-Ramirez, and Daniel F Waggoner (2014), "Inference based on svars identified with sign and zero restrictions: Theory and applications."

Bahmani-Oskooee, Mohsen and Taggert J Brooks (1999), "Bilateral j-curve between us and her trading partners." *Weltwirtschaftliches Archiv*, 156–165.

Bahmani-Oskooee, Mohsen and Artatrana Ratha (2004), "The j-curve dynamics of us bilateral trade." *Journal of Economics and Finance*, 28, 32–38.

Bańbura, Marta, Domenico Giannone, and Lucrezia Reichlin (2010), "Large bayesian vector auto regressions." *Journal of applied Econometrics*, 25, 71–92.

Barsky, Robert B and Eric R Sims (2012), "Information, animal spirits, and the meaning of innovations in consumer confidence." *American Economic Review*, 102, 1343–77.

Beaudry, Paul and Franck Portier (2006), "Stock prices, news, and economic fluctuations." *American Economic Review*, 96, 1293–1307.

Ben Zeev, Nadav, Christopher Gunn, and Hashmat Khan (2020), "Monetary news shocks." *Journal of Money, Credit and Banking*, 52, 1793–1820.

Bernanke, Ben S (2017), "Federal reserve policy in an international context." *IMF Economic Review*, 65, 1–32.

Bernanke, Ben S and Mark Gertler (1995), "Channel of monetary policy." *The Journal of Economic Perspectives*, 9, 27–48.

Best, Gabriela and Pavel Kapinos (2016), "Monetary policy and news shocks: are taylor rules forward-looking?" *The BE Journal of Macroeconomics*, 16, 335–360.

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

Black, Fischer (1995), “Interest rates as options.” *the Journal of Finance*, 50, 1371–1376.

Boivin, Jean, Michael T Kiley, and Frederic S Mishkin (2010), “How has the monetary transmission mechanism evolved over time?” In *Handbook of monetary economics*, volume 3, 369–422, Elsevier.

Bouakez, Hafedh and Michel Normandin (2010), “Fluctuations in the foreign exchange market: How important are monetary policy shocks?” *Journal of International Economics*, 81, 139–153.

Bullard, James B et al. (2012), “Shadow interest rates and the stance of us monetary policy.” Technical report.

Cacciatore, Matteo and Nora Traum (2018), “Trade flows and fiscal multipliers.” *The Review of Economics and Statistics*, 1–44.

Calvo, Guillermo A (1983), “Staggered prices in a utility-maximizing framework.” *Journal of monetary Economics*, 12, 383–398.

Campbell, Jeffrey R, Jonas DM Fisher, and Alejandro Justiniano (2012), “Monetary policy forward guidance and the business cycle.” *Manuscript, Federal Reserve Bank of Chicago*.

Campbell, Jeffrey R, Jonas DM Fisher, Alejandro Justiniano, and Leonardo Melosi (2017), “Forward guidance and macroeconomic outcomes since the financial crisis.” *NBER Macroeconomics Annual*, 31, 283–357.

Canova, Fabio and Gianni De Nicolo (2002), “Monetary disturbances matter for business fluctuations in the g-7.” *Journal of Monetary Economics*, 49, 1131–1159.

Canova, Fabio and Mehdi Hamidi Sahneh (2018), “Are small-scale svars useful for business cycle analysis? revisiting nonfundamentalness.” *Journal of the European Economic Association*, 16, 1069–1093.

Castelnuovo, Efrem, Giovanni Pellegrino, Giacomo Ranzato, et al. (2022), “Delayed overshooting puzzle: Does systematic monetary policy matter?” Technical report, Dipartimento di Scienze Economiche” Marco Fanno”.

Chiu, Yi-Bin, Chien-Chiang Lee, and Chia-Hung Sun (2010), “The us trade imbalance and real exchange rate: an application of the heterogeneous panel cointegration method.” *Economic Modelling*, 27, 705–716.

Clarida, Richard and Jordi Gali (1994), “Sources of real exchange-rate fluctuations: How important are nominal shocks?” In *Carnegie-Rochester conference series on public policy*, volume 41, 1–56, Elsevier.

Cook, David and Michael B Devereux (2016), "Exchange rate flexibility under the zero lower bound." *Journal of International Economics*, 101, 52–69.

Cumby, Robert E and Maurice Obstfeld (2007), *3. International Interest Rate and Price Level Linkages under Flexible Exchange Rates: A Review of Recent Evidence*. University of Chicago Press.

Curcuru, Stephanie E, Michiel De Pooter, and George Eckerd (2018a), "Measuring monetary policy spillovers between us and german bond yields." *FRB International Finance Discussion Paper*.

Curcuru, Stephanie E, Steven B Kamin, Canlin Li, and Marius Rodriguez (2018b), "International spillovers of monetary policy: Conventional policy vs. quantitative easing." *Quantitative Easing (August, 2018)*.

D'Amico, Stefania and Thomas B King (2015), "What does anticipated monetary policy do?"

Dedola, Luca, Giulia Rivolta, and Livio Stracca (2015), "If the fed sneezes, who gets a cold?" *Unpublished manuscript*.

Del Negro, Marco, Marc P Giannoni, and Christina Patterson (2012), "The forward guidance puzzle." *FRB of New York Staff Report*.

Dornbusch, Rudiger (1976), "Expectations and exchange rate dynamics." *Journal of political Economy*, 84, 1161–1176.

D'Amico, Stefania and Thomas B King (2017), "What does anticipated monetary policy do?"

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

Engel, Charles (2016), "Exchange rates, interest rates, and the risk premium." *American Economic Review*, 106, 436–74.

Fatum, Rasmus and Barry Scholnick (2006), "Do exchange rates respond to day-to-day changes in monetary policy expectations when no monetary policy changes occur?" *Journal of Money, Credit and Banking*, 1641–1657.

Faust, Jon (1998), "The robustness of identified var conclusions about money." In *Carnegie-Rochester conference series on public policy*, volume 49, 207–244, Elsevier.

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

Fernández-Villaverde, Jesús, Juan F Rubio-Ramírez, Thomas J Sargent, and Mark W Watson (2007), "Abcs (and ds) of understanding vars." *American economic review*, 97, 1021–1026.

Ferrari, Massimo, Jonathan Kearns, and Andreas Schrimpf (2017), "Monetary policy's rising fx impact in the era of ultra-low rates."

Forni, Mario and Luca Gambetti (2014), "Sufficient information in structural vars." *Journal of Monetary Economics*, 66, 124–136.

Forni, Mario, Domenico Giannone, Marco Lippi, and Lucrezia Reichlin (2009), "Opening the black box: Structural factor models with large cross sections." *Econometric Theory*, 25, 1319–1347.

Friedman, Milton et al. (1953), "The case for flexible exchange rates." *Essays in positive economics*, 157, 33.

Fry, Renee and Adrian Pagan (2011), "Sign restrictions in structural vector autoregressions: A critical review." *Journal of Economic Literature*, 49, 938–60.

Fry, Renee, Adrian Pagan, et al. (2007), "Some issues in using sign restrictions for identifying structural vars." *National Centre for Econometric Research Working Paper*, 14, 2007.

Gabaix, Xavier (2020), "A behavioral new keynesian model." *American Economic Review*, 110, 2271–2327.

Galí, Jordi (2020), "Uncovered interest parity, forward guidance and the exchange rate." *Journal of Money, Credit and Banking*, 52, 465–496.

Gali, Jordi and Tommaso Monacelli (2005), "Monetary policy and exchange rate volatility in a small open economy." *The Review of Economic Studies*, 72, 707–734.

Gelper, Sarah and Christophe Croux (2007), "Multivariate out-of-sample tests for granger causality." *Computational statistics & data analysis*, 51, 3319–3329.

Gomes, Sandra, Nikolay Iskrev, and Caterina Mendicino (2017), "Monetary policy shocks: We got news!" *Journal of Economic Dynamics and Control*, 74, 108–128.

Granger, Clive WJ and Paul Newbold (1974), "Spurious regressions in econometrics." *Journal of econometrics*, 2, 111–120.

Grilli, Vittorio, Nouriel Roubini, et al. (1995), "Liquidity and exchange rates: puzzling evidence from the g-7 countries." Technical report.

Gürkaynak, Refet S (2005), "Using federal funds futures contracts for monetary policy analysis."

Hausman, Joshua and Jon Wongswan (2011), "Global asset prices and fomc announcements." *Journal of International Money and Finance*, 30, 547–571.

Ilzetzki, Ethan and Keyu Jin (2013), “The puzzling change in the international transmission of us macroeconomic policy shocks.” *unpublished, London School of Economics.–2013*.

Inoue, Atsushi and Lutz Kilian (2013), “Inference on impulse response functions in structural var models.” *Journal of Econometrics*, 177, 1–13.

Inoue, Atsushi and Barbara Rossi (2019), “The effects of conventional and unconventional monetary policy on exchange rates.” *Journal of International Economics*, 118, 419–447.

Jones, Callum, Mariano Kulish, and Daniel M Rees (2018), *International spillovers of forward guidance shocks*. International Monetary Fund.

Kaplan, Greg, Benjamin Moll, and Giovanni L Violante (2018), “Monetary policy according to hank.” *American Economic Review*, 108, 697–743.

Kilian, Lutz and Helmut Ltkepohl (2017), *Structural Vector Autoregressive Analysis*. Themes in Modern Econometrics, Cambridge University Press.

Kim, Seong-Hoon, Seongman Moon, and Carlos Velasco (2017), “Delayed overshooting: is it an’80s puzzle?” *Journal of Political Economy*, 125, 1570–1598.

Kim, Soyoung and Nouriel Roubini (2000), “Exchange rate anomalies in the industrial countries: A solution with a structural var approach.” *Journal of Monetary economics*, 45, 561–586.

Krippner, Leo (2013), “Measuring the stance of monetary policy in zero lower bound environments.” *Economics Letters*, 118, 135–138.

Krippner, Leo (2020), “A note of caution on shadow rate estimates.” *Journal of Money, Credit and Banking*, 52, 951–962.

Kuttner, Kenneth N (2001), “Monetary policy surprises and interest rates: Evidence from the fed funds futures market.” *Journal of monetary economics*, 47, 523–544.

Leeper, Eric M, Todd B Walker, and Shu-Chun Susan Yang (2013), “Fiscal foresight and information flows.” *Econometrica*, 81, 1115–1145.

Magee, Stephen P (1973), “Currency contracts, pass-through, and devaluation.” *Brookings Papers on Economic Activity*, 1973, 303–325.

McKay, Alisdair, Emi Nakamura, and Jón Steinsson (2016), “The power of forward guidance revisited.” *American Economic Review*, 106, 3133–58.

McKinnon, Ronald I (2007), “The transfer problem in reducing the us current account deficit.” *Journal of Policy Modeling*, 29, 669–675.

Mishkin, Frederic S (1995), "Symposium on the monetary transmission mechanism." *Journal of Economic perspectives*, 9, 3–10.

Moffett, Michael H (1989), "The j-curve revisited: an empirical examination for the united states." *Journal of International Money and Finance*, 8, 425–444.

Paustian, Matthias (2007), "Assessing sign restrictions." *The BE Journal of Macroeconomics*, 7.

Rajan, Raghuram (2015), "Competitive monetary easing: is it yesterday once more?" *Macroeconomics and Finance in Emerging Market Economies*, 8, 5–16.

Rogers, John H, Chiara Scotti, and Jonathan H Wright (2018), "Unconventional monetary policy and international risk premia." *Journal of Money, Credit and Banking*, 50, 1827–1850.

Rogoff, Kenneth S and Maurice Obstfeld (2000), "The six major puzzles in international macroeconomics: Is there a common cause?"

Rose, Andrew K and Janet L Yellen (1989), "Is there a j-curve?" *Journal of Monetary economics*, 24, 53–68.

Rudel, Paul and Peter Tillmann (2018), "News shocks spillovers: How the euro area responds to expected fed policy." Technical report, MAGKS Joint Discussion Paper Series in Economics.

Scholl, Almuth and Harald Uhlig (2005), *New Evidence on the Puzzles*. Humboldt-Universität zu Berlin, Wirtschaftswissenschaftliche Fakultät.

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

Sims, Christopher A (1992), "Interpreting the macroeconomic time series facts: The effects of monetary policy." *European economic review*, 36, 975–1000.

Sims, Eric R (2012), *News, non-invertibility, and structural VARs*. Emerald Group Publishing Limited.

Steinsson, Jón (2008), "The dynamic behavior of the real exchange rate in sticky price models." *American Economic Review*, 98, 519–33.

Sutherland, Christopher S (2020), "Forward guidance and expectation formation: A narrative approach." Technical report, Bank of Canada Staff Working Paper.

Swanson, Eric T (2021), "Measuring the effects of federal reserve forward guidance and asset purchases on financial markets." *Journal of Monetary Economics*, 118, 32–53.

Taylor, John B (1995), "The monetary transmission mechanism: an empirical framework." *journal of Economic Perspectives*, 9, 11–26.

Uhlig, Harald (1994), "What macroeconomists should know about unit roots: a bayesian perspective." *Econometric Theory*, 10, 645–671.

Uhlig, Harald (2005), "What are the effects of monetary policy on output? results from an agnostic identification procedure." *Journal of Monetary Economics*, 52, 381–419.

Wheatley, Jonathan and Peter Garnham (2010), "Brazil in 'currency war'alert." *Financial Times*, 27.

Wu, Jing Cynthia and Fan Dora Xia (2016), "Measuring the macroeconomic impact of monetary policy at the zero lower bound." *Journal of Money, Credit and Banking*, 48, 253–291.

Appendices

A The two-country New Keynesian model

A.1 The model

A.1.1 Households

The representative households in the two-country economy seek to maximize their utility gained from consumption and leisure:

$$\mathcal{U} \equiv \mathrm{E}_0 \left(\sum_{t=0}^{\infty} \beta^t U_t \right) \text{ and } \mathcal{U}^* \equiv \mathrm{E}_0 \left(\sum_{t=0}^{\infty} \beta^t U_t^* \right) \tag{A.1}$$

where variables in country Foreign country are denoted by asterisks. $\beta \in (0,1)$ is the discount factor, $U_t \equiv \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}$ and $U_t^* \equiv \frac{(C_t^*)^{1-\sigma}}{1-\sigma} - \frac{(N_t^*)^{1+\varphi}}{1+\varphi}$ denote period t utility levels in Home (H) and Foreign (F) countries respectively. σ is the inverse elasticity of inter-temporal substitution, φ is the inverse elasticity of labour supply. The infinitely-lived representative household in the two country enjoy consumption of a constant elasticity of consumption (CES) composite index of domestically produced goods and imported goods given by C_t and C_t^*. $N_t \equiv \int_0^1 N_t(h)dh$ and $N_t^* \equiv \int_1^2 N_t^*(f)df$ denote hours worked H and F respectively. The consumption CES composite are defined as:

$$C_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{1-\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{1-\frac{1}{\eta}} \right]^{\frac{\eta}{\eta-1}}; \tag{A.2}$$

$$C_t^* \equiv \left[(1-\alpha)^{\frac{1}{\eta}} \left(C_{F,t}^*\right)^{1-\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}} \left(C_{H,t}^*\right)^{1-\frac{1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{A.3}$$

where where $\alpha \in (0,1)$ measures the degree of openness of the two economy economy and $\eta > 0$ is the elasticity of substitution between H and F goods. The aggregate consumption index of H and F produced goods are given by the CES function:

$$C_{H,t} \equiv \left[\int_0^1 C_t(h)^{\frac{\varepsilon-1}{\varepsilon}} dh \right]^{\frac{\varepsilon}{\varepsilon-1}} \text{ and } C_{F,t} \equiv \left[\int_1^2 C_t(f)^{\frac{\varepsilon-1}{\varepsilon}} df \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{A.4}$$

$h \in [0,1]$ and $f \in [0,1]$ denotes the good variety in each country. $\varepsilon > 1$ is the elasticity of substitution between the differentiated goods produced in each country. Assuming complete market for assets traded internationally, the representative household in each country seeks to maximize

(A.1) subject to the following sequence of budget constraints:

$$\int_0^1 P_t(h)C_t(h)dh + \int_0^1 P_t(f)C_t(f)df + \mathrm{E}_t\Big\{Q_{t,t+1}D_{t+1}\Big\} + \mathrm{E}_t\Big\{Q^*_{t,t+1}\mathcal{E}_{t+1}D^*_{t+1}\Big\} \le D_t + \mathcal{E}_t D^*_t + W_t N_t + T_t$$

$$\int_1^2 P^*_t(h)C^*_t(h)dh + \int_1^2 P^*_t(f)C^*_t(f)df + \mathrm{E}_t\Big\{Q^*_{t,t+1}D^*_{t+1}\Big\} + \mathrm{E}_t\Big\{Q_{t,t+1}\mathcal{E}_{t+1}D_{t+1}\Big\} \le D^*_t + \mathcal{E}_t D_t + W^*_t N^*_t + T^*_t$$

where $P_t(h)$ and $P_t(f)$ are the prices of H and F produced goods in terms of country H's currency, respectively. D_{t+1} and D^*_{t+1} are the nominal payoff in period $t+1$ of the portfolio held at the end of period t in terms of country H's currency. $Q_{t,t+1}$ and $Q^*_{t,t+1}$ are the stochastic discount factor for one period ahead nominal payoffs on H and F bonds. $\mathcal{E}_t$ is the nominal bilateral exchange rate expressed as the price of F country currency in terms of H currency. Thus, $\mathcal{E}_t$ measures how many H currency units one F country currency unit is worth. An increase in $\mathcal{E}_t$ corresponds to a depreciation. W_t and T_t are the nominal wage and lump-sum transfers (taxes), respectively. The optimal allocation of expenditure between H and F goods across varieties in each country is thus given by the following demand functions:

$$C_t(h) = \left(\frac{P_t(h)}{P_{H,t}}\right)^{-\varepsilon} C_{H,t}, \text{ and } C_t(f) = \left(\frac{P_t(f)}{P_{F,t}}\right)^{-\varepsilon} C_{F,t} \tag{A.5}$$

$$C^*_t(h) = \left(\frac{P^*_t(h)}{P^*_{H,t}}\right)^{-\varepsilon} C^*_{H,t}, \text{ and } C^*_t(f) = \left(\frac{P^*_t(f)}{P^*_{F,t}}\right)^{-\varepsilon} C^*_{F,t} \tag{A.6}$$

where $P_{H,t} \equiv \left(\int_0^1 P_t(h)^{1-\varepsilon}dh\right)^{\frac{1}{1-\varepsilon}}$ and $P^*_{F,t} \equiv \left(\int_1^2 P_t(f)^{1-\varepsilon}df\right)^{\frac{1}{1-\varepsilon}}$ are the producers price indices (PPIs) in H and F country respectively. $P^*_{H,t}$ and $P_{F,t}$, the price of imported goods, are defined analogously to $P_{H,t}$ and $P^*_{F,t}$. The optimal allocations of expenditures between domestic and imported goods are given by:

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \text{ and } C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \tag{A.7}$$

$$C^*_{H,t} = \alpha\left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\eta} C^*_t \text{ and } C^*_{F,t} = (1-\alpha)\left(\frac{P^*_{F,t}}{P^*_t}\right)^{-\eta} C^*_t \tag{A.8}$$

where $P_t \equiv \left[(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}$ and $P^*_t \equiv \left[(1-\alpha)^*\left(P^*_{F,t}\right)^{1-\eta} + (\alpha)^*\left(P^*_{H,t}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}$ are the aggregate Consumption Price Indices (CPIs) in the H and F country respectively. Combining (A.5) with the definition of PPIs, prices of imported goods and the definition of CPIs implies that the total consumption expenditures by domestic households is $P_{H,t}C_{H,t} + P_{F,t}C_{F,t} = P_tC_t$ and the total consumption expenditures by foreign households is $P^*_{H,t}C^*_{H,t} + P^*_{F,t}C^*_{F,t} = P^*_tC^*_t$. Thus, the household's problem in each country comes down to maximize (A.1) subject to:

$$P_tC_t + \mathrm{E}_t\left(Q_{t,t+1}D_{t+1}\right) + \mathrm{E}_t\left(Q^*_{t,t+1}\mathcal{E}_{t+1}D^*_{t+1}\right) \leq D_t + D^*_t + W_tN_t + T_t$$
$$P^*_tC^*_t + \mathrm{E}_t\left(Q^*_{t,t+1}D^*_{t+1}\right) + \mathrm{E}_t\left(Q_{t,t+1}\mathcal{E}_{t+1}D_{t+1}\right) \leq D^*_t + D_t + W^*_tN^*_t + T^*_t$$

The households optimizing behavior with respect to the two assets in country H yields the following symmetric consumption Euler equations (inter temporal optimality conditions) with the same equations holding for country F:

$$1 = E_t\bigg(M_{t+1}R_t\bigg) \tag{A.9}$$

$$1 = E_t\bigg(M_{t+1}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}R^*_t\bigg) \tag{A.10}$$

where $M_{t+1} = \beta E_t\bigg\{\frac{P_t}{P_{t+1}}\bigg(\frac{C_{t+1}}{C_t}\bigg)^{-\sigma}\bigg\}$, $R_t = E_t\bigg\{\frac{1}{Q_{t,t+1}}\bigg\}$ and $R^*_t = E_t\bigg\{\frac{1}{Q^*_{t,t+1}}\bigg\}$ are the gross nominal return of on a one-period riskless domestic and foreign bonds in $t+1$. The intratemporal optimality conditions for hours are given by:

$$C^\sigma_t N^\varphi_t = \frac{W_t}{P_t} \quad \text{and} \quad (C^*_t)^\sigma (N^*_t)^\varphi = \frac{W^*_t}{P^*_t} \tag{A.11}$$

The log-linearized version of the symmetric equation (A.9) are given by:

$$c_t = \mathrm{E}_t\left(c_{t+1}\right) - \frac{1}{\sigma}\left\{i_t - \mathrm{E}_t\left(\pi_{t+1}\right)\right\} \tag{A.12}$$

$$c^*_t = \mathrm{E}_t\left(c^*_{t+1}\right) - \frac{1}{\sigma}\left\{i^*_t - \mathrm{E}_t\left(\pi^*_{t+1}\right)\right\} \tag{A.13}$$

where $\pi_t = p_t - p_{t-1}$ and $\pi^*_t = p^*_t - p^*_{t-1}$ are the CPIs inflation rate. i_t and i^*_t are the nominal interest rate.

The log-linearized version of the symmetric equations (A.11) are given by:

$$w_t - p_t = \sigma c_t + \varphi n_t \tag{A.14}$$

$$w^*_t - p^*_t = \sigma c^*_t + \varphi n^*_t \tag{A.15}$$

A.1.2 Terms of trade, inflation

I assume that the law of one price (LOP) holds for individual goods so that $P_t(f) = \mathcal{E}_t P_t^*(f)$ and $P_t(h) = \mathcal{E}_t P_t^*(h)$. This means that the price indices for each country is given by $P_{F,t} = \mathcal{E}_t P_{F,t}^*$ and $P_{H,t} = \mathcal{E}_t P_{H,t}^*$[21]. Define the terms of trade as $\mathcal{S}_t \equiv \frac{P_{F,t}}{P_{H,t}}$. Replace $log(P_{F,t})$ in $s_t \equiv log(\mathcal{S}_t)$ yield an expression of the terms of trade as a linear function of the effective nominal exchange rate and the gap between the F price and the price on H produced goods:

$$s_t = p_{F,t}^* + e_t - p_{H,t} \tag{A.16}$$

Similarly, log-linearizing the CPIs equations around the steady state where $P_H = P_F = P$ gives

$$p_t = p_{H,t} + \alpha s_t \tag{A.17}$$

$$p_t^* = p_{F,t} + \alpha s_t \tag{A.18}$$

which in first difference gives the following approximate relation between CPIs, domestic prices and the terms of trade:

$$\pi_t = \pi_{H,t} + \alpha \Delta s_t \tag{A.19}$$

$$\pi_t^* = \pi_{F,t}^* - \alpha \Delta s_t \tag{A.20}$$

where $\pi_{H,t} \equiv p_{H,t} - p_{H,t-1}$ and $\pi_{F,t}^* \equiv p_{F,t}^* - p_{F,t-1}^*$ denote country H and F domestic inflation respectively. The gap between domestic inflations and CPIs inflation are proportional to the percentage change in terms of trade, with the coefficient of proportionality given by the openness index α.

A.1.3 Real exchange rate

The real exchange is defined as the ratio of the the two countries CPI's expressed in term of country H currency: $\mathcal{Q}_t \equiv \frac{\mathcal{E}_t P_t^*}{P_t}$. Combining $q_t \equiv log(Q_t$ with the previous definition of $log(P_{H,t})$, $log(P_{F,t})$ and equation (A.16) gives:

$$q_t = (1 - 2\alpha) s_t, \tag{A.21}$$

[21]Note that however, purchasing power parity only holds for intermediate degrees of trade openness: $P_t \neq \mathcal{E}_t P_t^*$.

A.1.4 International risk sharing and Uncovered Interest Rate parity (UIP)

The complete market assumption for internationally traded securities means that a condition analogous to (A.9) must also hold for the representative household in the F country:

$$1 = E_t\left(M^*_{t+1}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}R^*_t\right) \tag{A.22}$$

Divide (A.9) by (A.22) and solve for C_t gives:

$$C_t = \vartheta C^*_t \mathcal{Q}_t^{\frac{1}{\sigma}} \tag{A.23}$$

where $\vartheta \equiv E_t\left\{\frac{C_{t+1}}{C^*_{t+1}(Q^*_{t,t+1})^{\frac{1}{\sigma}}}\right\}$ is a constant that depends on initial conditions. Taking the log of the previous equality gives the international risk-sharing condition:

$$c_t = c^*_t + \frac{1}{\sigma}(1-2\alpha)s_t \tag{A.24}$$

Furthermore, from (A.9) and (A.10), the following arbitrage condition must holds:

$$\frac{Q^*_{t,t+1}}{Q_{t,t+1}} = E_t\left\{\frac{\varepsilon_{t+1}}{\varepsilon_t}\right\}$$

Log-linearizing gives the uncovered interest rate parity (UIP) condition:

$$i_t - i^*_t = \mathrm{E}_t\left(e_{t+1}\right) - e_t \tag{A.25}$$

A.1.5 Firms

There is a continuum of monopolistic firms in the H and F country that produce differentiated goods with a linear technology given by:

$$Y_t(h) = A_t N_t(h) \text{ and } Y^*_t(f) = A^*_t N^*_t(f) \tag{A.26}$$

where $Y_t(h)$ and $Y^*_t(f)$ are the output; A_t and A^*_t are technology shifter for all firms in countries respectively; N_t and N^*_t are the labor input used in the production process for both countries. The CES production functions for both economies are defined as $Y_t \equiv \left[\int_0^1 Y_t(h)^{\frac{\varepsilon-1}{\varepsilon}}dh\right]^{\frac{\varepsilon}{\varepsilon-1}}$ and $Y^*_t \equiv \left[\int_1^2 Y^*_t(f)^{\frac{\varepsilon-1}{\varepsilon}}df\right]^{\frac{\varepsilon}{\varepsilon-1}}$. Each firms in each country face a demand function given by (A.5) and (A.6) and set their prices in a staggered way à la Calvo (1983): in each period, only a fraction

$1-\theta_H$, ($\theta_H \in [0,1]$) and $1-\theta_F$, ($\theta_F \in [0,1]$) of firms in each country are able to change their prices and fix a new price $\bar{P}_{H,t}$ and $\bar{P}^*_{F,t}$. The remaining fraction θ_H and θ_F adjust their prices by indexing to the last period's inflation. Firms charging new prices seek to maximize the discounted expected value of profits subject to a sequence of demand constraint

$$Y_t(h) = \left(\frac{P_t(h)}{P_{H,t}}\right)^{-\varepsilon} Y_t \text{ and } Y_t^*(f) = \left(\frac{P_t^*(f)}{P^*_{F,t}}\right)^{-\varepsilon} Y_t^* \tag{A.27}$$

Solving this optimization problem gives the following first order conditions (FOCs):

$$\bar{P}_{H,t} = \mathrm{E}_t \left(\frac{\sum_{k=0}^{\infty} \theta_H^k Q_{t,t+k} Y_{t+k} \frac{\varepsilon}{\varepsilon-1} P_{H,t+k} MC_{H,t+k}}{\sum_{k=0}^{\infty} \theta_H^k Q_{t,t+k} Y_{t+k}} \right)$$
$$\bar{P}^*_{F,t} = \mathrm{E}_t \left(\frac{\sum_{k=0}^{\infty} \theta_F^k Q^*_{t,t+k} Y_{F,t+k} \frac{\varepsilon}{\varepsilon-1} P^*_{F,t+k} MC^*_{F,t+k}}{\sum_{k=0}^{\infty} \theta_F^k Q^*_{t,t+k} Y_{F,t+k}} \right)$$

where $MC_{H,t}$ and $MC^*_{F,t}$ are the H and F countries real marginal costs respectively. Log-linearizing the FOCs gives:

$$\bar{p}_{H,t} = \mu + (1-\beta\theta_H)\mathrm{E}_t \sum_{k=0}^{\infty} (\beta\theta_H)^k \left[p_{H,t+k} + mc_{t+k}\right] \tag{A.28}$$

$$\bar{p}^*_{F,t} = \mu + (1-\beta\theta_F)\mathrm{E}_t \sum_{k=0}^{\infty} (\beta\theta_F)^k \left[p^*_{F,t+k} + mc^*_{t+k}\right] \tag{A.29}$$

where $\mu = \ln \frac{\varepsilon}{\varepsilon-1}$ is the log of the gross markup, or equivalently, the equilibrium markup in the flexible price economy.

A.1.6 Equilibrium - Aggregate demand

The market-clearing conditions are given by:

$$Y_t(h) = C_t(h) + C_t^*(h)$$
$$Y_t^*(f) = C_t(f) + C_t^*(f).$$

Substituting Equations (A.5) - (A.8), (A.23) and (A.27) into the above equalities yields:

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \left[(1-\alpha) + \alpha \mathcal{Q}_t^{\eta-\frac{1}{\sigma}}\right];$$
$$Y_t^* = \left(\frac{P^*_{F,t}}{P_t^*}\right)^{-\eta} C_t^* \left[(1-\alpha) + \alpha \mathcal{Q}_t^{-(\eta-\frac{1}{\sigma})}\right],$$

which give in log-lineared form around a symmetric steady state:

$$y_t = c_t + \frac{\alpha\omega}{\sigma} s_t \tag{A.30}$$

$$y_t^* = c_t^* - \frac{\alpha\omega}{\sigma} s_t \tag{A.31}$$

where $\omega \equiv \alpha[2(1-\alpha)(\sigma\eta - 1) + 1] > 0$. If each country behaves like a closed economy ($\alpha \to 0$), $y_t = c_t$ and $y_t^* = c_t^*$. This means that each country's output equals its domestic consumption. Inserting (A.30), (A.31) into (A.24), gives the following expression:

$$s_t = \frac{\sigma}{\omega_4 + 1} \left(y_t - y_t^* \right), \tag{A.32}$$

where $\omega_4 \equiv 4\alpha(1-\alpha)(\sigma\eta - 1)$. The terms of trade depend on the difference in the output of countries H and F. Finally, replace for c_t from (A.30) and (A.31) into the Euler equations (A.12) - (A.13) and insert (A.41) and (A.42) to get[22]:

$$y_t = \mathrm{E}_t y_{t+1} - \frac{1}{\sigma} \left\{ i_t - \mathrm{E}_t \pi_{H,t+1} \right\} - \frac{\omega_2}{\sigma} \mathrm{E}_t \Delta s_{t+1} \tag{A.33}$$

$$y_t^* = \mathrm{E}_t y_{t+1}^* - \frac{1}{\sigma} \left\{ i_t^* - \mathrm{E}_t \pi_{F,t+1}^* \right\} + \frac{\omega_2}{\sigma} \mathrm{E}_t \Delta s_{t+1} \tag{A.34}$$

with $\omega_2 \equiv 2\alpha(1-\alpha)(\sigma\eta - 1)$. The IS equations are similar to the one in a closed economy except that now there is an additional term linking domestic output to the international environment due to the presence of international trade. When each country is closed, or when both the coefficient of relative risk aversion and the elasticity of substitution between goods produced in countries H and F are unity ($\sigma = \eta = 1$), we get the closed economy New Keynesian IS curve. Another representation is found by inserting for s_t into equations (A.33) and (A.34) :

$$y_t = \mathrm{E}_t y_{t+1} - \frac{1}{\sigma_\omega} \left\{ i_t - \mathrm{E}_t \pi_{H,t+1} \right\} + \frac{\omega_2}{\omega_2 + 1} \mathrm{E}_t \Delta y_{t+1}^* \tag{A.35}$$

$$y_t^* = \mathrm{E}_t y_{t+1}^* - \frac{1}{\sigma_\omega} \left\{ i_t^* - \mathrm{E}_t \pi_{F,t+1}^* \right\} + \frac{\omega_2}{\omega_2 + 1} \mathrm{E}_t \Delta y_{t+1} \tag{A.36}$$

where $\sigma_\omega \equiv \frac{(\omega_2+1)\sigma}{\omega_4+1}$. Note that the degree of α influences the sensitivity of output to the domestic real interest rate.

[22]Note that replacing for c_t from (A.30) and (A.31) into the Euler equations (A.12) - (A.13) only gives a version of the IS equation the function of the CPIs.

A.1.7 Equilibrium - Trade balance

The Home country net exports are define as the difference between the total Home production and the total Home consumption relative to Home steady state output :

$$NX_t \equiv \frac{Y_t - \frac{P_t}{P_{H,t}} C_t}{Y} \tag{A.37}$$

The first-order approximation around the symmetric steady state where $P_t = P_{H,t} = P$ and $Y_t = C_t = Y$ and zero net export, yields:

$$\begin{aligned} nx_t &\approx \frac{Y - \frac{P}{P} Y}{Y} + \frac{1}{Y}\left[(Y_t - Y) - \frac{P}{P}(C_t - C) - \frac{1}{P} C (P_t - P) + \frac{1}{P^2} PC (P_{Ht} - P)\right] \\ &= \frac{Y_t - Y}{Y} - \frac{C_t - C}{C} - \frac{P_t - P}{P} + \frac{P_{Ht} - P}{P} \\ &= (y_t - y) - (c_t - c) - (p_t - p) + (p_{Ht} - p) = y_t - c_t - p_t + p_{Ht} \end{aligned}$$

substitute for s_t from (A.18):

$$nx_t = y_t - c_t - \alpha s_t$$

Finally, insert for $y_t - c_t$ from (A.30) to get:

$$nx_t = \alpha \left(\frac{\omega}{\sigma} - 1\right) s_t \tag{A.38}$$

In the special case with $\sigma = \varepsilon = 1, nx_t = 0 \forall t$, though the latter property will also hold for any configuration satisfying $\omega - \sigma \equiv \sigma\varepsilon + (1 - \alpha)(\sigma\varepsilon - 1) - \sigma = 0$. More generally, the sign of the relationship between the terms of trade and net export is ambiguous, depending on the relative size of σ, ε.

A.1.8 Equilibrium - Aggregate supply

Market clearing in the labor market:

$$N_t = \int_0^1 N_t(h) dh \quad \text{and} \quad N_t^* = \int_1^2 N_t^*(f) df$$

From (A.26), $N_t(h) = \left(\frac{Y_t(h)}{A_t}\right)$ and $N_t^*(f) = \left(\frac{Y_t^*(f)}{A_t}\right)$. Replace these into the above equations with the market clearing conditions (A.30), (A.31) and the consumption demands (A.5), (A.6) to get:

$$N_t = \frac{Y_t \mathcal{V}_t}{A_t} \quad \text{and} \quad N_t^* = \frac{Y_t \mathcal{V}_t^*}{A_t^*} \tag{A.39}$$

where $\mathcal{V}_t \equiv \int_0^1 \left(\frac{P_t(h)}{P_{H,t}}\right)^{-\varepsilon} dh$ and $\mathcal{V}_t^* \equiv \int_1^2 \left(\frac{P_t^*(f)}{P_{F,t}^*}\right)^{-\varepsilon} df$ denote the levels of price dispersion in countries H and F, respectively. A first-order approximation around the deterministic steady state of $\mathcal{V}_t \approx \mathcal{V}_t^* \approx 1$. Hence, log-linearizing (A.39) yields:

$$y_t = a_t + n_t \quad \text{and} \quad y_t^* = a_t^* + n_t^*. \tag{A.40}$$

Using equations (A.28) and (A.29), one can solve for the respective domestic inflation as:

$$\pi_{H,t} = \beta \mathrm{E}_t \left(\pi_{H,t+1}\right) + \lambda_H mc_{H,t} \tag{A.41}$$

$$\pi_{F,t}^* = \beta \mathrm{E}_t \left(\pi_{F,t+1}^*\right) + \lambda_F mc_{F,t}^* \tag{A.42}$$

where β is the discount factor, $\lambda_H = \big((1-\beta\theta_H)(1-\theta_H)\big)/\theta_H$, $\lambda_F = \big((1-\beta\theta_F)(1-\theta_F)\big)/\theta_F$ and $mc_{H,t}$, $mc_{F,t}$ are the real marginal cost.

The real marginal cost in countries H and F are given by $MC_{H,t} \equiv \frac{W_{H,t}R_t}{P_{H,t}A_{H,t}}$ and $MC_{F,t}^* \equiv \frac{W_{F,t}^* R_t^*}{P_{F,t}^* A_{F,t}}$ respectively. Taking these in and adding and subtracting p_t log yield:

$$mc_{H,t} = (w_{H,t} - p_t) + i_t + (p_t - p_{H,t}) - a_t$$
$$mc_{F,t} = (w_{F,t} - p_t) + i_t + (p_t - p_{F,t}) - a_t^*$$

Insert in these equations (A.14), (A.15), the log-linear version of the CPIs, (A.24), (A.40) and (A.32) to get:

$$mc_{H,t} = \frac{\varsigma}{\omega_4 + 1} y_t + \frac{\omega_2 \sigma}{\omega_4 + 1} y_t^* + i_t - (1+\varphi) a_t \tag{A.43}$$

$$mc_{F,t} = \frac{\varsigma}{\omega_4 + 1} y_t^* + \frac{\omega_2 \sigma}{\omega_4 + 1} y_t + i_t^* - (1+\varphi) a_t^* \tag{A.44}$$

where $a_t = \rho_a a_{t-1} + v_a$ and $a_t^* = \rho_a^* a_{t-1}^* + v_{a^*}$ are the log deviation of the exogenous AR(1) productivity from their steady-state values. $\varsigma \equiv (\omega_2 + 1)\,\sigma + (\omega_4 + 1)\,\varphi, \omega_2 \equiv 2\alpha(1-\alpha)(\sigma\eta - 1)$ and $\omega_4 \equiv 4\alpha(1-\alpha)(\sigma\eta - 1)$.

Finally the natural levels of outputs y_t^n and $(y_t^n)^*$ are obtained by taking the flexible version of (A.43) and (A.44)

$$mc_{H,t} = \frac{\varsigma}{\omega_4 + 1} y_t^n + \frac{\omega_2 \sigma}{\omega_4 + 1} y_t^* + i_t - (1+\varphi) a_t$$
$$mc_{F,t} = \frac{\varsigma}{\omega_4 + 1} (y_t^n)^* + \frac{\omega_2 \sigma}{\omega_4 + 1} y_t + i_t^* - (1+\varphi) a_t^*$$

Solve for the respective natural output to get:

$$y_t^n = \frac{\varsigma\psi}{\delta}a_t - \frac{\omega_2\sigma\psi}{\delta}a_t^* \quad \text{and} \quad (y_t^n)^* = \frac{\varsigma\psi}{\delta}a_t^* - \frac{\omega_2\sigma\psi}{\delta}a_t \tag{A.45}$$

with $\psi \equiv (\omega_4 + 1)(1 + \varphi)$ and $\delta \equiv \sigma^2(2\omega_2 + 1) + 2\sigma\varphi(\omega_2 + 1)(\omega_4 + 1) + \varphi^2(\omega_4 + 1)^2$.

A.1.9 The two-country New Keynesian Phillips curve and the Dynamic IS equations

Define country H output gap as $\tilde{y}_t \equiv y_t - y_t^n$ and country F output gap as $\tilde{y}_t^* \equiv y_t^* - (y_t^n)^*$. The respective domestic real interest rate implies that $i_t \equiv r_t + \mathrm{E}_t\pi_{H,t+1}$ and $i_t^* \equiv r_t^* + \mathrm{E}_t\pi_{F,t+1}^*$. Using these, (A.35) and (A.36) becomes:

$$y_t = \mathrm{E}_t y_{t+1} - \frac{1}{\sigma_\omega}\{r_t - \rho\} + \frac{\omega_2}{\omega_2 + 1}\mathrm{E}_t\Delta y_{t+1}^* \tag{A.46}$$

$$y_t^* = \mathrm{E}_t y_{t+1}^* - \frac{1}{\sigma_\omega}\{r_t^* - \rho\} + \frac{\omega_2}{\omega_2 + 1}\mathrm{E}_t\Delta y_{t+1} \tag{A.47}$$

So, the respective natural output can be define in the same way as:

$$y_t^n = \mathrm{E}_t y_{t+1}^n - \frac{1}{\sigma_\omega}\{r_t^n - \rho\} + \frac{\omega_2}{\omega_2 + 1}\mathrm{E}_t\Delta y_{t+1}^* \tag{A.48}$$

$$(y_t^n)^* = \mathrm{E}_t(y_{t+1}^n)^* - \frac{1}{\sigma_\omega}\{(r_t^n)^* - \rho\} + \frac{\omega_2}{\omega_2 + 1}\mathrm{E}_t\Delta y_{t+1} \tag{A.49}$$

By taking the difference between (A.46) and (A.48) and between (A.47) and (A.49), we get the New Keynesian IS curves for the open economies:

$$\tilde{y}_t = \mathrm{E}_t\tilde{y}_{t+1} - \frac{1}{\sigma_\omega}\{i_t - \mathrm{E}_t\pi_{H,t+1}\} + \frac{\omega_2}{\omega_2 + 1}\left\{\mathrm{E}_t\Delta\tilde{y}_{t+1}^*\right\} + \frac{1}{\sigma_\omega}r_t^n \tag{A.50}$$

$$\tilde{y}_t^* = \mathrm{E}_t\tilde{y}_{t+1}^* - \frac{1}{\sigma_\omega}\left\{i_t^* - \mathrm{E}_t\pi_{F,t+1}^*\right\} + \frac{\omega_2}{\omega_2 + 1}\{\mathrm{E}_t\Delta\tilde{y}_{t+1}\} + \frac{1}{\sigma_\omega}(r_t^n)^* \tag{A.51}$$

where $r_t^n \equiv -\Theta a_t - \Omega_1 a_t^*$ and $(r_t^n)^* \equiv -\Theta a_t^* - \Omega_1 a_t$ are the real natural interest rates. $\Theta \equiv \frac{\sigma(1-\rho_a)\psi\left[(\omega_2+1)\varsigma - \omega_2^2\sigma\right]}{(\omega_4+1)\delta}$ and $\Omega_1 \equiv \frac{\sigma(1-\rho_a^*)\omega_2\psi[s - \sigma(\omega_2+1)]}{(\omega_4+1)\delta}$.

Finally, combine the output gaps definition and the condition on real marginal costs under the flexible-price equilibrium where the real marginal cost is constant, and then By insert this into (A.43) and (A.44) to get:

$$mc_{H,t} = \frac{\varsigma}{\omega_4 + 1}\tilde{y}_t + \frac{\omega_2\sigma}{\omega_4 + 1}\tilde{y}_t^* + r_t \quad \text{and} \quad mc_{F,t}^* = \frac{\varsigma}{\omega_4 + 1}\tilde{y}_t^* + \frac{\omega_2\sigma}{\omega_4 + 1}\tilde{y}_t + r_t^*$$

The fluctuations in the real marginal costs depend on the output gap and the cost channel.

Substituting these equations into (A.41) and (A.42) yields the New Keynesian Philips curve for the open economies:

$$\pi_{H,t} = \beta \mathrm{E}_t \left(\pi_{H,t+1}\right) + \kappa_\omega \left(\tilde{y}_t + \tilde{y}_t^*\right) + i_t \tag{A.52}$$

$$\pi_{F,t}^* = \beta \mathrm{E}_t \left(\pi_{F,t+1}\right) + \kappa_\omega \left(\tilde{y}_t^* + \tilde{y}_t\right) + i_t^*, \tag{A.53}$$

with $\kappa_\omega \equiv \frac{\kappa\varsigma}{\omega_4+1}$.

A link between CPIs inflation and domestic inflations, are obtained by replacing (A.32), the definition of the output gap and (A.45) into equations (A.19) and (A.19):

$$\pi_t = \pi_{H,t} + \frac{\alpha\sigma}{\omega_4+1}\Delta\tilde{y}_t - \frac{\alpha\sigma}{\omega_4+1}\Delta\tilde{y}_t^* + i_t + \Omega_2\Delta a_t - \Omega_2\Delta a_t^* \tag{A.54}$$

$$\pi_t^* = \pi_{F,t}^* + \frac{\alpha\sigma}{\omega_4+1}\Delta\tilde{y}_t^* - \frac{\alpha\sigma}{\omega_4+1}\Delta\tilde{y}_t + i_t^* + \Omega_2\Delta a_t^* - \Omega_2\Delta a_t \tag{A.55}$$

with $\Omega_2 \equiv \frac{\alpha\sigma(1+\varphi)(\varsigma+\omega_2\sigma)}{\delta}$.

A.1.10 Monetary policy and equilibrium dynamics

I assume that the central bank in each country follow a Taylor rule:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left(\phi_\pi \pi_t + \phi_{\tilde{y}}\tilde{y}_t\right) + v_{m,t} \tag{A.56}$$

$$i_t^* = \rho_i^* i_{t-1}^* + (1-\rho_i^*)\left(\phi_\pi^* \pi_t^* + \phi_{\tilde{y}^*}^*\tilde{y}_t^*\right) + v_{m,t}^* \tag{A.57}$$

where $\phi_{\tilde{y}}$ and ϕ_π are the central bank's reaction coefficients to the output gap and CPI inflation in country H. Similarly, $\phi_{\tilde{y}^*}^*$ and ϕ_π^* are the country F central bank's reaction coefficients to the output gap and CPI inflation. Monetary policy shocks are represented by $v_{m,t} = \epsilon_m$ and $v_{m,t}^* = \epsilon_m^*$, which are independent and identically distributed in both economies.

A.2 Model calibration

Parameters	Home: U.S.	Foreign: Eu. area	Source
β, discount factor	0.99	0.99	
σ, risk aversion	2	2	
η, substitution H/F	1.01	1.01	Cacciatore and Traum (2018)
θ, Calvo parameter	0.86	0.58	Cacciatore and Traum (2018)
φ, Inverse Frisch elasticity	1.69	2.25	Cacciatore and Traum (2018)
α, Openness	0.3	0.3	
ρ_r, smoothness monetary policy	0.75	0.81	Cacciatore and Traum (2018)
ϕ_π, Feedback Taylor rule inflation	2.17	1.90	Cacciatore and Traum (2018)
ϕ_y, output feedback Taylor Rule	0.05	0.18	Cacciatore and Traum (2018)
ρ_{rnat},	0.90	0.90	

B Extension of the zero lower bound (ZLB)

In the ZLB simulation, the Home central bank follows a monetary policy rule with the ZLB constraints on nominal interest rates:

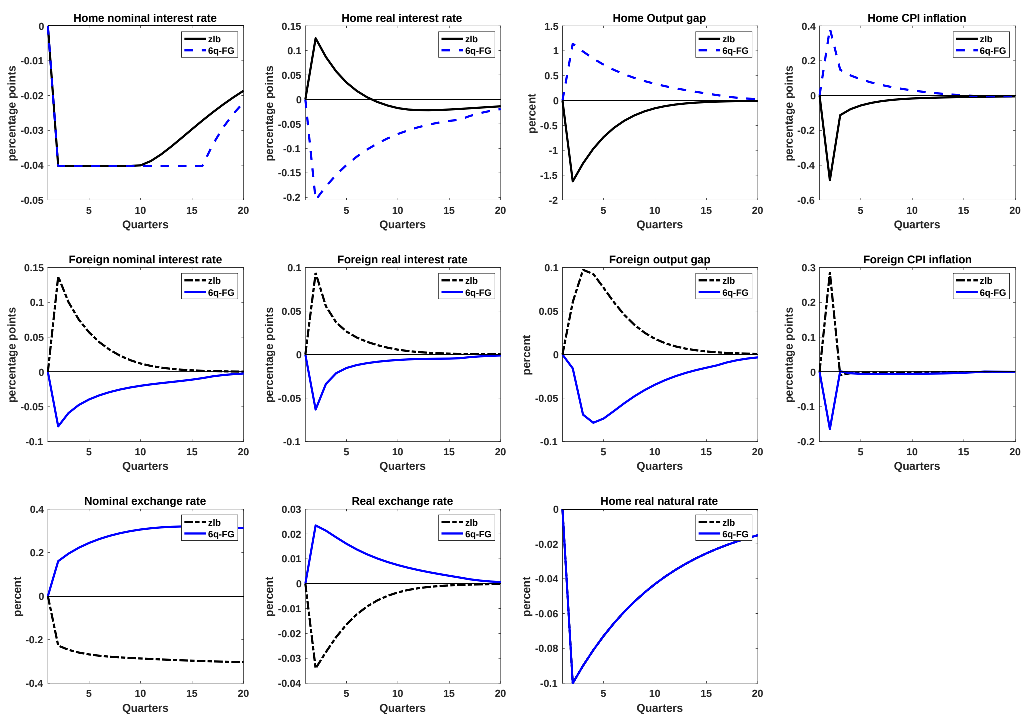
$$i_t = max\left(0, \rho_i i_{t-1} + (1-\rho_i)\left(\phi_\pi \pi_{H,t} + \phi_{\tilde{y}} \tilde{y}_t\right) + v_t\right) \quad \text{(B.1)}$$

ϕ_π denotes the Taylor rule sensitivity to inflation, $\phi_{\tilde{y}}$ denotes the Taylor rule sensitivity to output gap, and ρ_i is the interest rate smoothing parameter. v_t is the exogenous monetary policy shock. In this specification, initially, a negative shock to the natural interest rate takes the Home economy into a recession and the ZLB (liquidity trap) for a certain period of time. The initial shock is expressed as a first order auto regressive process ($AR(1)$):

$$r_t^n = \rho_{rnat} r_{t-1}^n + \varepsilon^n \quad \text{(B.2)}$$

where ρ_{rnat} is the AR processes coefficient, ε^n is the natural interest rate independent shock.

Figure 9: SOE-NK model response to a four quarters ahead credible forward guidance shock.



Following the shock, the Home central bank announce its commitment to extend the ZLB for longer periods than suggested by the Taylor rule. This froward guidance policy adopted by the Home country can be thought of as the "calendar-based" forward guidance of the Federal reserve in 2011. Panel (b) of figure **??** illustrates the responses and the subsequent economic dynamics of the model. The solid black line shows the impulse response to a negative shock to natural interest rate in the Home country and the dotted red line, extension of the ZLB. After the negative real interest rate shock, the economy enter in recession and a liquidity trap for nine quarters. However, an extension of the ZLB for more than what is suggested help to stimulate the economy. As mentioned by Cook and Devereux (2016) at the ZLB, the nominal exchange rate appreciates and looses its stabilizing role. With stronger forward guidance policy, the benefits of the flexible exchange rate is restored: nominal exchange rate immediately depreciates and both inflation and the output gap rise.

If a country faces a negative demand shock with the monetary policy constrained by the zero lower bound, inflation expectations fall pushing up relative real interest rate which causes nominal and real exchange rate appreciation. The exchange rate moves in the wrong direction and exacerbates the effects of the negative shocks. However, an optimal credible forward guidance, that is, a credible commitment of accommodative monetary policy in the future after the shock can ensure an immediate contemporaneous depreciation of the exchange rate. The optimal credible forward guidance can then be a useful instrument to activate the exchange rate channel of monetary policy, yet, there is no conclusive evidence on whether this mechanism is actually present in the data. exchange rate regime is thus a shock absorber that allows nominal and real depreciation in response to negative shocks, delivering efficient macroeconomic stabilization. However, since 2008, most central banks lost their conventionnal tools, the nomimal interest rate, stucks at the zero lower bound. Cook and Devereux (2016) using a New-Keynesian framework argue that if a country faces a negative demand shock with the monetary policy constrained by the zero lower bound, inflation expectations fall pushing up relative real interest rate which cause nominal and real exchange rate appreciaton as the policy rate cannot be lowered. Thus, the exchange rate moving in the wrong direction exacerbates the effects of the shocks. However, an optimal credible forward guidance, that is, a credible commitment of accomodative monetary policy in the future after the shock can ensure an immediate contemporaneous depreciation of the exchange rate. The optimal credible forward guidance can then be a useful instrument to activate the exchange rate channel of monetary policy, yet, there is no conclusive evidence on whether this mechanism is actually present in the data.

C Data description

Data for U.S. and foreign countries are from the St. Louis Federal Reserve Bank database (FRED). The different bilateral exchange rate are from the Bank for International Settlements (BIS). The data span from 1986 I to 2019 II for U.S. - U.K., U.S. - Canada, and 1994 I to 2019 II for U.S. - Euro and U.S. - Japan.

Variable	Definition
U.S. GDP deflator	FRED: USAGDPDEFQISMEI
Inflation rate	$\left(\frac{GDP\ deflator_t}{GDP\ deflator_{t-1}} - 1\right) \times 100$
U.S. nominal GDP	FRED: Seasonnally Adjusted nominal GDP
U.S. real GDP	$\frac{U.S.\ nominal\ GDP_t}{GDP\ deflator_t}$
3 months T-bill	FRED: monthly to quaterly TB3MS
U.S. nominal money supply	FRED: monthly to quaterly M2SL
U.S. real money supply	$\frac{U.S.\ real\ money\ supply_t}{GDP\ deflator_t}$
SPF 3 months T-bill	Phildelphia fed bank: Mean quaterly forecasts
SPF U.S. real GDP	Author calculation using Mean quaterly forecasts
SPF U.S. inflation rate	Author calculation using Mean quaterly forecasts
U.K. Pound Sterling to One U.S. Dollars	FRED: monthly to quaterly EXUSUK $= \frac{1}{EXUSUK}$
U.K. real GDP	Author calculation from FRED: UKNGD and GBRGDPDEFQISMEI
U.K. Interbank rate	FRED: IRSTCI01GBQ156N
Canadian Dollars to One U.S. Dollar	FRED: monthly to quaterly EXCAUS
Canada real GDP	Author calculation from FRED: Canada nominal GDP and GDP deflator
Central Bank Rates for Canada	FRED: IRSTCB01CAQ156N
Euro Community Unit to one U.S. Dollars	FRED: monthly to quaterly EXUSEC $= \frac{1}{EXUSEC}$
Euro real GDP	Author calculation from FRED: EUNNGDP and NAGIGP01EZQ661S
Interbank Rate for the Euro Area	FRED: IRSTCI01EZQ156N
Japanese Yen to One U.S. Dollar	FRED: monthly to quaterly EXJPUS
Japan real GDP	Author calculation from IFS: Japan GDP components
Central Bank Rates for Japan	FRED: monthly to quaterly IRSTCB01JPM156N

D Sufficient information test

Following Gelper and Croux (2007) and 16, the full model to be tested is given by

$$z_t = \phi_0 + \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} + \psi_1 x_{t-1} + \cdots + \psi_p x_{t-p} + \varepsilon_{\mathrm{z},t}.$$

Here z_t and y_t are the first difference stationary time series, $\varepsilon_{\mathrm{f},t}$ is an iid sequence with mean zero and covariance matrix Σ_{z}. The null hypothesis (H_0) of the test is that x_t does not Granger cause y_t:

$$\mathrm{H}_0 : \psi_1 = \psi_2 = \cdots = \psi_p = 0.$$

Under H_0, the restricted model is given by:

$$z_t = y_t = \phi_0 + \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} + \varepsilon_{\mathrm{y},t},$$

where $\varepsilon_{\mathrm{y},t}$ is an iid sequence with mean zero and covariance matrix Σ_{y}.

Consider a sample of size T. The out-of-sample test is conducted in the following three steps:

1. Divides the series z_t in two parts: one containing observations 1 to N and a second the remaining $N+1$ to T observations. The first N observations are always included for parameter estimation. Here by convention with Gelper and Croux (2007) I took $N = T/2$.

2. Estimate the full and the restricted model by ordinary least squares using only observations 1 to N, and compute recursively the associated forecasts of observation $N+1$, $\hat{z}_{N+1}$ and $\hat{y}_{N+1}$. Then $\hat{z}_{N+2}$ and $\hat{y}_{N+2}$ are forecasted based on the first $(N+1)$ observations. This procedure continues recursively up to the end of the series, yielding the series of one-step-ahead forecasts $\hat{z}_t$ and $\hat{y}_t$ for t ranging from $N+1$ up to T. Note that the last forecasts, $\hat{z}_T$ and $\hat{y}_T$ are based on model estimated using the first $T-1$ observations.

3. Compute the corresponding one-step-ahead forecast errors for $t = N+1, \ldots, T$ as $u_{z,t} = z_t - \hat{z}_t$ and $u_{y,t} = y_t - \hat{y}_t$. These vectors are collected into a matrix of dimension $((N+1toT) \times k)$, where the s th row contains the vector of one step ahead forecast errors for observation $N+s$. The matrix containing the one-step-ahead forecast errors from the full model will be referred to by u_z and from the restricted model by u_y.

4. Compares the forecasting performance of the full and the restricted model using u_z and u_y. This is done with two methods:

   - Compute the following test statistic to compare the mean squared forecast errors (MSFE) of the full and the restricted model

$$\text{MSFE} = \log\left(\frac{|u_{\text{r}}'u_{\text{r}}|}{|u_{\text{f}}'u_{\text{f}}|}\right)$$

where $|.|$ stands for the determinant of a matrix.

- Compute the likelihood ratio test

$$\text{Reg} = P\left(\log\left(\left|u_{\text{r}}'u_{\text{r}}\right|\right) - \log\left(\left|\hat{\varepsilon}'\hat{\varepsilon}\right|\right)\right),$$

where $\hat{\varepsilon}$ is the residual from the regression $u_{\text{r},t} = \lambda\left(u_{\text{r},t} - u_{\text{f},t}\right) + e_t$.

5. The comparison is made by computing the approximate critical values and p-values by a residual based bootstrap method:

   - Estimate the model under the null hypothesis (restricted model y) using the series $y_1, y_2, \ldots, y_T$. Compute the sequence of residuals $r_1, r_2, \ldots, r_T$.
   - Compute the value of one of the test statistic to be called s_0 (step 1 to 4).
   - Generate $Nb = n$ new time series $y_1^*, y_2^*, \ldots, y_T^*$ according to the restricted model y, with the unknown parameters replaced by their estimates, and the error terms replaced by a bootstrap sample (so resampling with replacement) from $r_1, r_2, \ldots, r_T$.
   - Compute for each of the Nb series the value of one of the test statistic, resulting in $s_1^*, \ldots, s_{Nb}^*$. (step 1 to 4). For computing the test statistics one also uses the values of x_t, which are kept fix.
   - The percentage of bootstrap replicates $s_1^*, \ldots, s_{Nb}^*$ exceeding s_0 is an approximation of the p-value. The α-quantile of the bootstrap replicates serves a critical value of the test at level α.

E The Normal inverse Wishart Prior

The normal inverse Wishart prior assumes a normal prior for the VAR coefficients and a inverse Wishart prior for the covariance matrix. This is a conjugate prior for the VAR model. This prior for the VAR parameters can be specified as follows:

$$p(\alpha|\Sigma_u) \sim N(\alpha^*, V \bigotimes \Sigma_U), \text{ with } \alpha = Vec(\Phi(L))$$

and

$$p(\Sigma_u) \sim IW_K(S_*, n)$$

The V matrix is a diagonal matrix where the diagonal elements are defined as:

$$\left(\frac{\lambda_0\lambda_1}{l^{\lambda_3}\sigma_i}\right)^2 \text{ for the coefficient on the lags}$$

$$\left(\lambda_0\lambda_4\right)^2 \text{ for the constant}$$

S_* is an $n \times n$ diagonal matrix were the diagonal element s are given by:

$$\frac{\sigma_i^2}{\lambda_0}$$

The parameters of the diagonal elements the following interpretation:

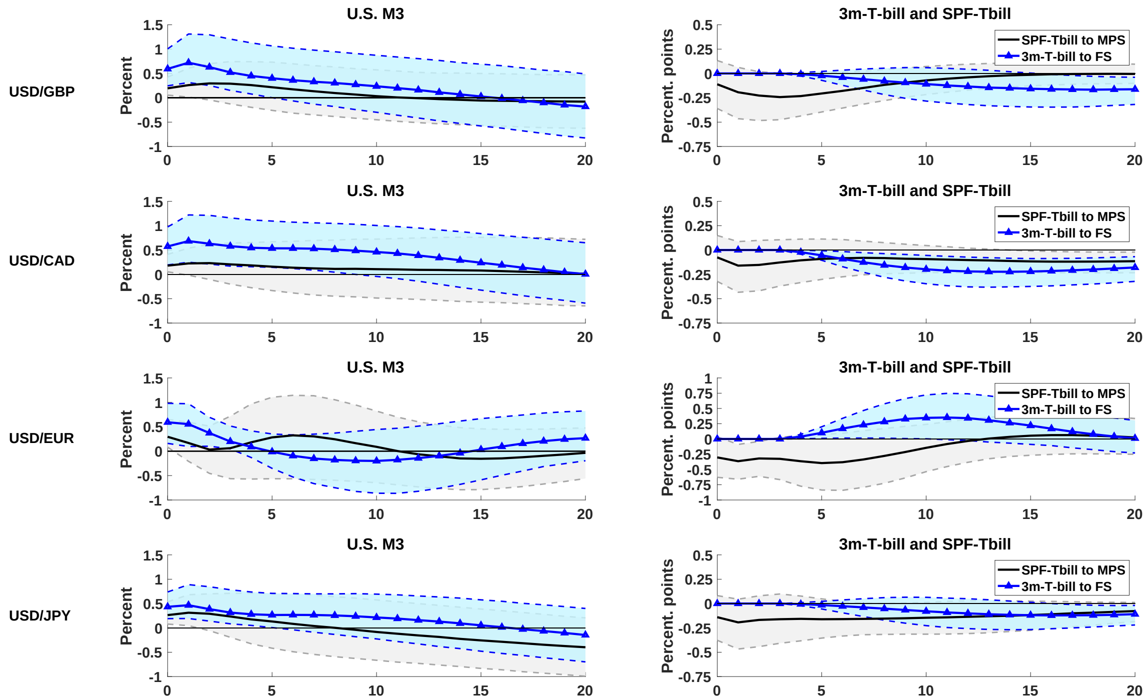
λ_0: controls the overall tightness of the prior on the covariance matrix.

λ_1: controls the tightness of the prior on the coefficients on the first lag. As $\lambda_1 \to 0$ the prior is imposed more tightly.

λ_3: controls the degree to which coefficients on lags higher than 1 are likely to be zero. As λ_3 increases coefficients on higher lags are shrunk to zero more tightly.

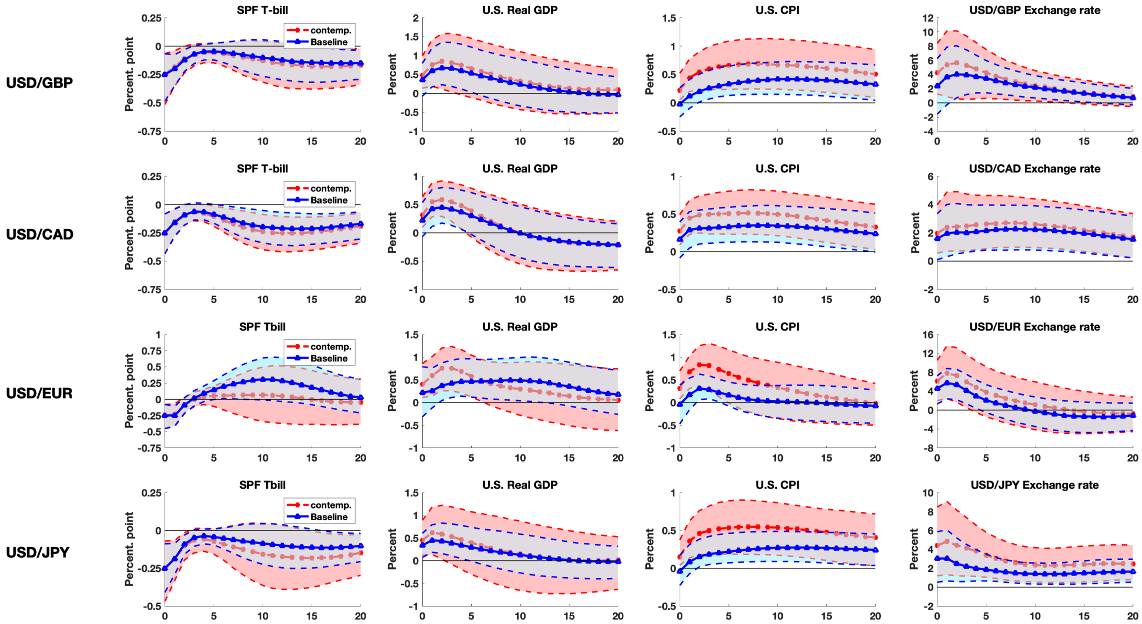
λ_3: controls the prior variance on the constant. As $\lambda_4 \to 0$ the constant is shrunk to zero.

F Baseline model IRFs of M3, SPF-Tbill and 3m-Tbill to the unanticipated monetary and forward guidance easing



Note:The solid black line is the median estimated impulse response (in percent) to a 25 basis point unanticipated monetary easing. The solid blue triangle line is the median estimated impulse response (in percent) to a 25 basis point forward guidance easing. Shaded areas indicate the 16% and 84% credible sets.

G Baseline model IRFs with contemporaneous sign restrictions



Note:

H Forward guidance dates for narrative sign restrictions

Starting from the 1990q3 survey, the Federal Reserve Bank of Philadelphia have set the deadlines for forecasters responses at late in the second to third week of the middle month of each quarter. Since Sutherland (2020) forward guidance data are monthly, I needed to find good date matching to impose the narrative restrictions on the quarterly data. Since forecasters deadline is in the middle month of the quarter, I pick the date conditional on a forward guidance shock being listed in the first month of the corresponding quarter and followed by forward guidance of the same sign within the quarter.

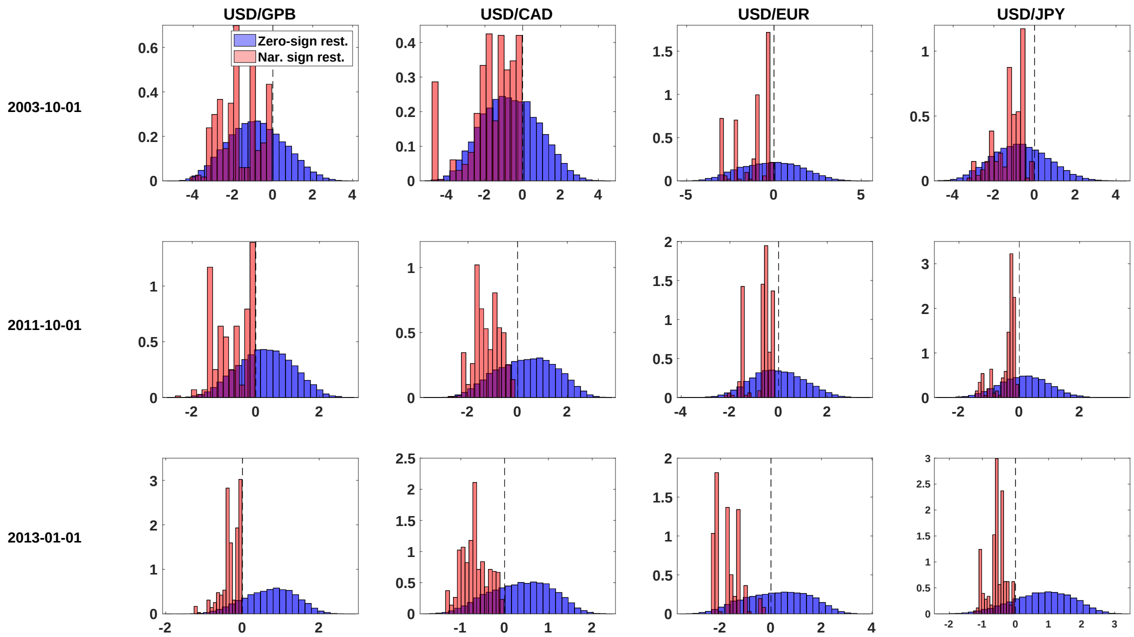
2003q4: *"Qualitative forward guidance"*
Forecasters deadline: 2003-11-14.
FOMC communication: 2003-10-13, 2003-11-10, 2003-12-08.
Statement: *"The Committee perceives that the upside and downside risks to the attainment of sustainable growth for the next few quarters are roughly equal. In contrast, the probability, though minor, of an unwelcome fall in inflation exceeds that of a rise in inflation from its already low level. The Committee judges that, on balance, the risk of inflation becoming undesirably low remains the predominant concern for the foreseeable future. In these circumstances, the Committee believes that policy accommodation can be maintained for a considerable period."*

2011q4: *"Time-contingent forward guidance"*
Forecasters deadline: 2011-11-08
FOMC communication: 2011-10-10, 2011-11-14, 2011-12-12.
Statement: *"The Committee also decided to keep the target range for the federal funds rate at 0 to 1/4 percent and currently anticipates that economic conditions–including low rates of resource utilization and a subdued outlook for inflation over the medium run–are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013."*

2013q1: *"State-contingent forward guidance"*
Forecasters deadline: 2013-02-11
FOMC communication: 2013-01-14, 2013-02-11, 2013-03-11.
Statement: *"To support continued progress toward maximum employment and price stability, the Committee expects that a highly accommodative stance of monetary policy will remain appropriate for a considerable time after the asset purchase program ends and the economic recovery strengthens. In particular, the Committee decided to keep the target range for the federal funds rate at 0 to 1/4 percent and currently anticipates that this exceptionally low range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6-1/2 percent, inflation between one and two years ahead is projected to be no more than a half percentage point*

above the Committee's 2 percent longer-run goal, and longer-term inflation expectations continue to be well anchored. The Committee views these thresholds as consistent with its earlier date-based guidance. In determining how long to maintain a highly accommodative stance of monetary policy, the Committee will also consider other information, including additional measures of labor market conditions, indicators of inflation pressures and inflation expectations, and readings on financial developments. When the Committee decides to begin to remove policy accommodation, it will take a balanced approach consistent with its longer-run goals of maximum employment and inflation of 2 percent."

I Narrative sign restriction: shock distribution at the specific narrative dates



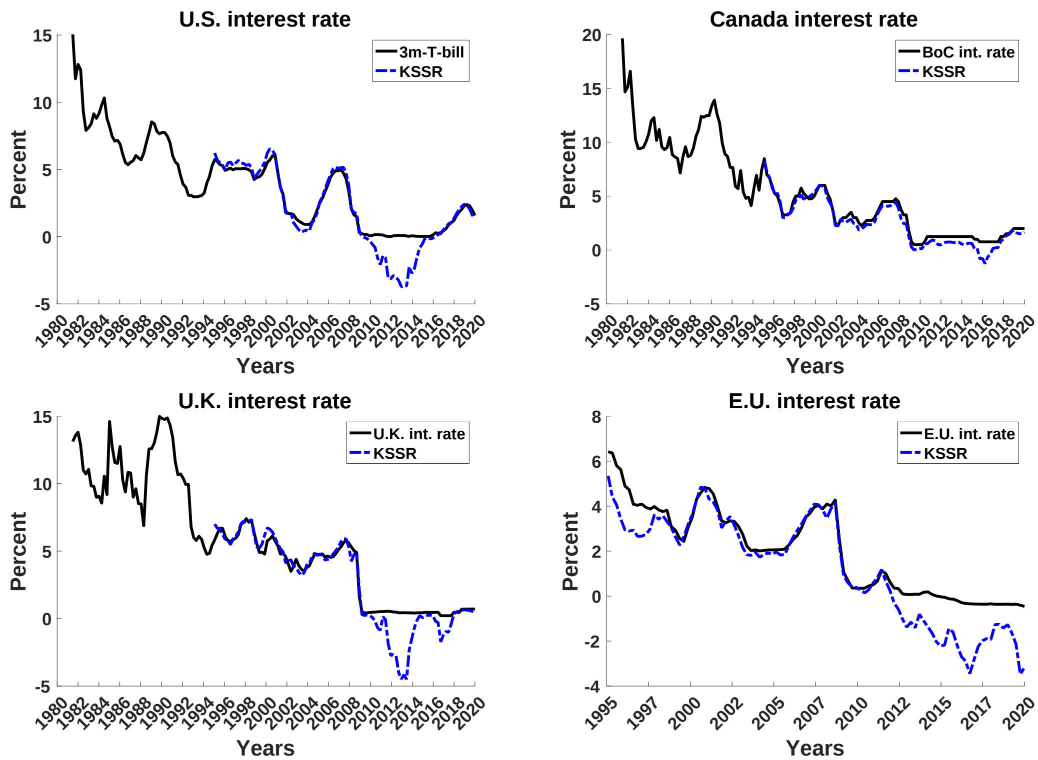
Note:Each row of the figure correspond to the dates of forward guidance announcements used in the narrative restrictions. The column reports the corresponding specification. The pink bars represent the posterior distribution of the forward guidance shocks with the narrative sign restrictions on the corresponding dates. The blue bars are the posterior distribution of the shocks without the narrative sign restrictions. We can see that the narrative sign restrictions completely squeezes the shocks posterior distribution to negative part as expected with the applied sign of a negative shocks during these dates.

J Shadow rate

The *"shadow rate" ssr* concept was initially developed by Black (1995). propose another approach to solve for the ZLB. According to him, so long as investors can hold currency, the nominal short rate cannot be negative. The existence of currency as a store value may prevent investors to holds instruments bearing negative interest rate. However, Defining currency as an option, he introduced the concept of *"shadow interest rate"* which can be positive or negative. This interest rate can be resumed as the interest rate in a world without currency: when the short term interest rate is stuck at zero for a time, one can follow the *"shadow short rate"* which can be negative, and whenever it becomes positive, it just reflect the short term interest rate. The instantaneous risk-free rate i_t is then given by the maximum between the shadow rate or zero:

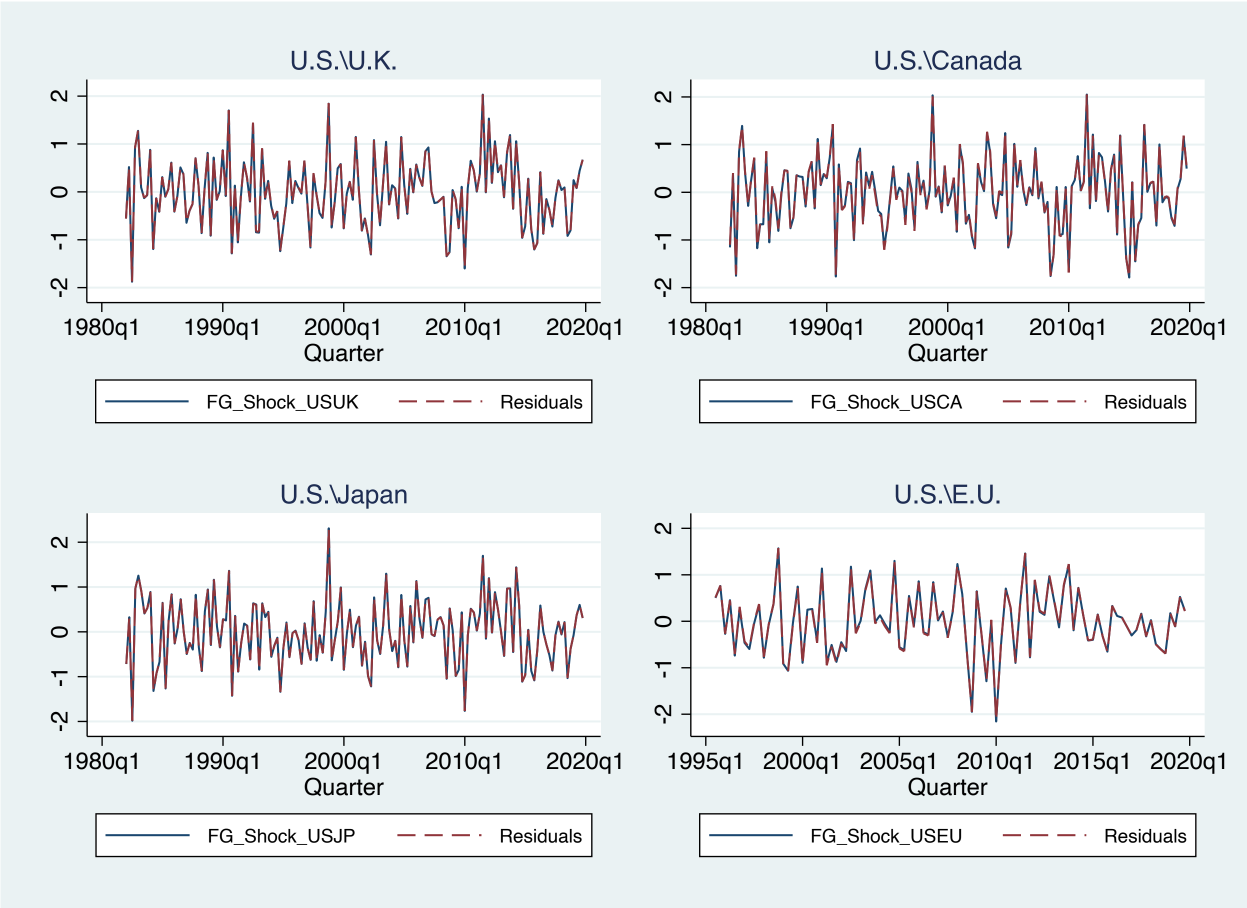
$$i_t = max\{0, s_t\} \tag{B.1}$$

Figure 10: Shadow rate plot



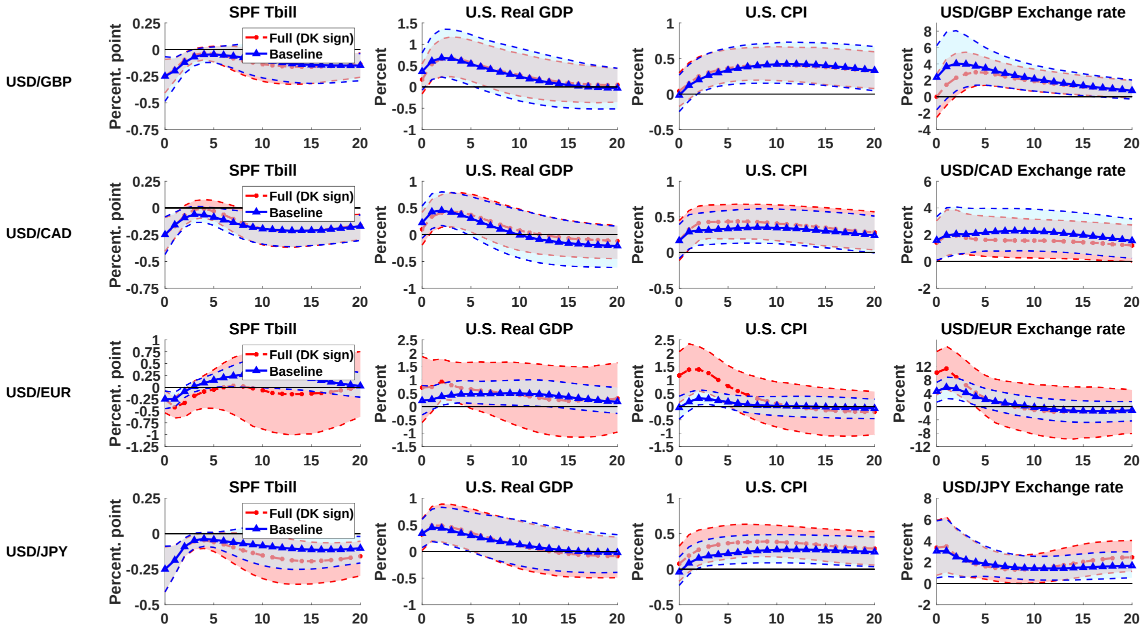
Note:The solid black line is the median estimated impulse response (in percent) to a 25 basis point unanticipated monetary easing. The solid blue triangle line is the median estimated impulse response (in percent) to a 25 basis point forward guidance easing. Shaded areas indicate the 16% and 84% credible sets.

K Identified shocks vs purged shocks



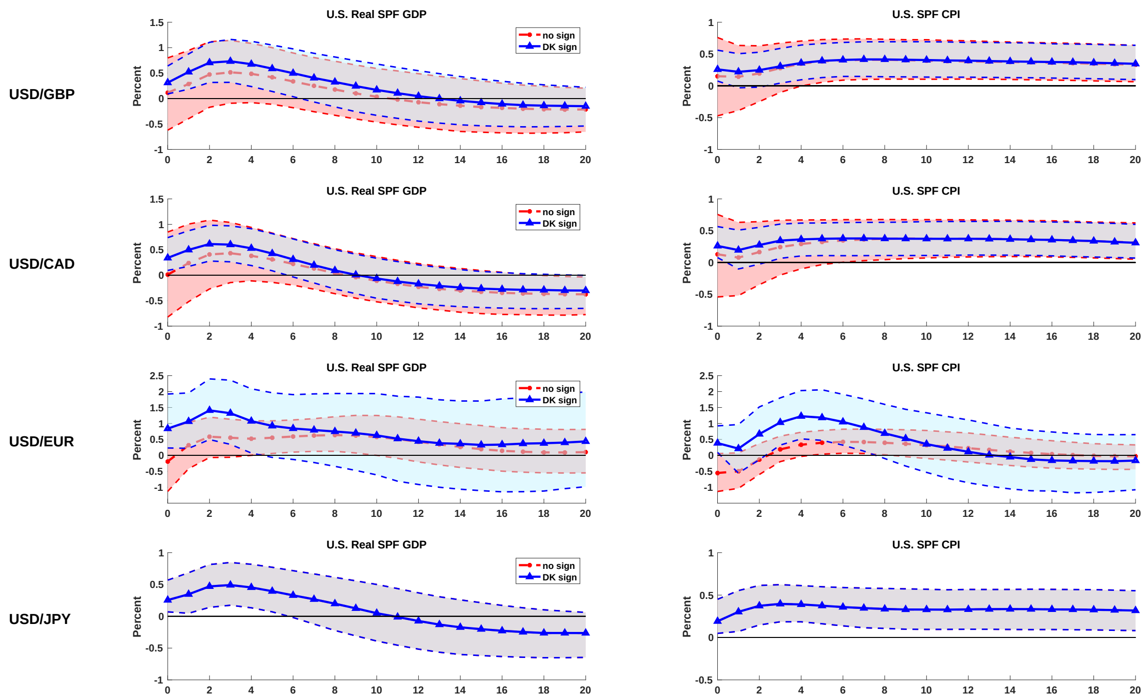
Note:The solid blue lines are the identified shocks with the baseline VAR model. the dotted red line are the residuals (*"purged shocks"*) of the regression of the identified shocks on the first difference of the SPF real GDP and CPI. As we can see there is no significant differences between the *"purged shocks"* cleaned from possible information on GDP and CPI forecasts.

L Full model IRFs with DK sign restrictions on the SPF GDP and CPI VS baseline model IRFs



Note:The solid black line is the median estimated impulse response (in percent) to a 25 basis point unanticipated monetary easing. The solid blue triangle line is the median estimated impulse response (in percent) to a 25 basis point forward guidance easing. Shaded areas indicate the 16% and 84% credible sets.

M IRFs of the SPF GDP and CPI in the full model with and without DK sign restrictions



Note:The solid black line is the median estimated impulse response (in percent) to a 25 basis point unanticipated monetary easing. The solid blue triangle line is the median estimated impulse response (in percent) to a 25 basis point forward guidance easing. Shaded areas indicate the 16% and 84% credible sets.