WP/16/125

IMF Working Paper

U.S. Dollar Dynamics: How Important Are Policy Divergence and FX Risk Premiums?

By Ravi Balakrishnan, Stefan Laseen, and Andrea Pescatori

INTERNATIONAL MONETARY FUND

 WP/16/125

IMF Working Paper

Western Hemisphere Department

U.S. Dollar Dynamics: How Important Are Policy Divergence and FX Risk Premiums?

Prepared by Ravi Balakrishnan, Stefan Laseen, and Andrea Pescatori[1]

Authorized for distribution by Stephan Danninger

July 2016

Abstract

We investigate the drivers of dynamics of major U.S. FX bilaterals. We first construct a novel measure of FX risk premiums using Consensus exchange rate forecasts. We then use VAR analysis to show that (i) risk premium shocks play a key role in driving dynamics of the major U.S. FX bilaterals; (ii) longer-term interest differentials also matter, especially for the Canadian $ and the Euro; (iii) oil price shocks play a particularly important role for the Canadian $ (an oil exporter); and (iv) risk appetite shocks (e.g., VIX shocks) generally lead to U.S. dollar appreciation. The importance of risk premium and longer-term interest differential shocks fit well with a simple theoretical model and are supported by recent event studies.

JEL Classification Numbers: E43, F31, G15

Keywords: Foreign exchange, monetary policy shocks, FX risk premium, SVAR

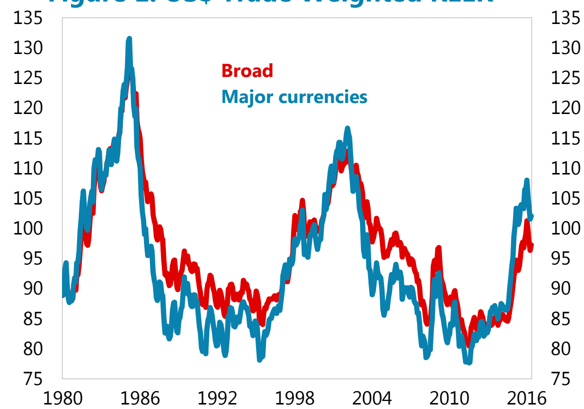
Author's E-Mail Address: rbalakrishnan@imf.org, slaseen@imf.org, apescatori@imf.org

[1] The authors are grateful to Nigel Chalk, Stephan Danninger, Jaewoo Lee, and other IMF colleagues for their helpful comments; as well as to Udi Rosenhand for excellent research assistance.

I. Introduction and Summary

Between April 2014 and December 2015, the U.S. real effective exchange rate (REER) appreciated by 16 percent, the sharpest swing since the Plaza accord in 1985 (Figure 1). Yet over the same period, policy rate and inflation differentials barely moved, seemingly at odds with such a sizeable exchange rate movement. While macroeconomists often seem to see exchange rates as having "lives on their own" (Obstfeld 2004), in this paper, we try to uncover macroeconomic factors that are typically behind substantial dollar movements.

Figure 1. US$ Trade Weighted REER



Sources: FRB; and Haver Analytics

There is a vast empirical literature on exchange rates (see Engel 2013 for a survey). And while theory provides some guidance, real and nominal exchange rates (among major currencies) have often moved in a way *not* closely connected to current (or past) macroeconomic variables.[2] This makes both understanding and forecasting exchange rate movements hard. For example, some argue that since Fama (1984) the systematic rejection of the uncovered interest parity has cast doubts on the explanatory role of interest rates. Similarly, since Meese and Rogoff (1983) empirical tests have repeatedly shown the difficulty of fundamental-based exchange rate forecasts in outperforming a random walk model. These seeming empirical failures of theoretical models have often translated into a push towards momentum-based explanations.

Part of the failure of traditional macroeconomic models to explain exchange rate movements is because they have rarely figured out how to appropriately price risk in financial markets—a crucial element in understanding FX markets. More recently, however, theory has made progress in the modeling of time-varying risk, and confirmed its importance for understanding financial markets, including FX markets (Colacito and Croce 2011, 2013, Gourio et al. 2013, Gabaix and Maggiori 2015).

In addition to pricing risk, *news shocks* are a thorny obstacle to traditional empirical analysis based on small scale SVARs (a la Eichenbaum and Evans 1995)—the ones typically used in macro-econometrics. Here the difficulty lies in reconciling the information set of the econometrician with the one of the typical FX investor. In particular, investors' views about future monetary policy divergence are rarely fully captured by policy rate movements or monetary policy surprises series (such as the ones of Coibion 2011 or Gertler and Karadi 2015).

[2] Baxter and Stockman (1989) and Flood and Rose (1995) are two papers that first systematically documented the limited feedback of exchange rate movements to macro variables and prices.

To address these issues, and analyze the importance of monetary policy divergence and FX risk premiums in driving U.S. dollar movements, this paper does the following:

- *Theory*. We develop a small general equilibrium macro model to illustrate the importance of longer-term interest rate and FX risk premium shocks relative to monetary policy and other cyclical shocks in driving exchange rate dynamics. The model is calibrated to derive benchmark hypotheses for the VAR analysis.

- *FX Risk Premium Measure*. We construct a measure for the exchange rate premium at 3-month, 1-year, and 2-year horizons for four major U.S. dollar bilaterals (against the Euro, Yen, Loonie, and the British Pound) using Consensus exchange rate forecasts.

- *SVARs*. We use SVARs to econometrically study the drivers of four major U.S. FX bilaterals. We focus on the impact of policy divergence, FX risk premium, cyclical, oil price, and global sentiment shocks. Including longer-term interest rates, VIX, Consensus Forecasts on inflation and GDP differentials, and a measure of FX risk premium is a novel feature of this analysis.[3]

- *Event Studies*. To complement the econometric analysis and provide more granularity on the impact of news shocks, we study the relation between dynamics of the four major U.S. bilateral exchange rates and 10-year interest differentials and FX risk premiums around some major recent events. These include the taper tantrum, ECB forward guidance and QE announcements, and the Bank of Canada's surprise policy rate cut in January 2015.

We find strong support for the importance of monetary policy divergence and changes in FX risk premiums in driving dollar dynamics.[4] Our detailed findings include:

- A simple two-country GE model illustrates the importance of policy divergence (proxied by persistent deviations in neutral rates) and risk premium shocks in accounting for exchange rate movements. Cyclical and monetary policy shocks do not explain much.

- Our measure of the FX risk premium is quite volatile (especially at short horizons) but low frequency movements do still explain a substantial part of its variance. On average, the FX risk premiums show a preference for U.S. assets—boosted during periods of global uncertainty and especially at the turn of the century—with the exception of the Yen.

---

[3] Eichenbaum and Evans (1995) have a small scale two-country VAR with industrial production, the price level, non-borrowed reserves, short-term interest rates, and the bilateral exchange rate; while Scholl and Uhlig (2008) adds the forward discount premium to that. Faust and Rogers (2003) includes the 10-year yield but does not control for global sentiment and FX risk premium shocks, which tend to reduce US long-term rates relative to trading partners.

[4] Monetary policy divergence refers to when monetary policy in two countries is expected to differ over a long period of time because of potential persistent deviations in real and nominal fundamentals or in policy preferences. Arising policy divergence is usually reflected in movements in long-term interest rate differentials.

- The SVARs suggest that long-term interest rate differential shocks have a significant hump-shaped impact on exchange rates and the share of the variance decomposition increases with the horizon. On average, a 10 bps increase in long-term bond differentials due to policy divergence induces an appreciation of the currency by about 0.5 percent at peak after one year.[5] This shock is especially important for the Canadian dollar and the Euro. U.S. monetary policy shocks have a short-lived, negative impact on Euro and Yen risk premiums, are imprecisely estimated, and do not explain much of the variance of exchange rate movements.

- The SVARs also point to the importance of FX risk premium shocks, which explain about 50 percent of the exchange rate forecast error variance at short horizons.[6] A shock to global uncertainty is captured by movements in the VIX. It usually appreciates the U.S. dollar and increases the FX risk premium (flight to safety) with the exception of the Yen.

- Oil shocks are more relevant for the commodity-currencies such as the Loonie, and to a smaller extent the British Pound, appreciating both currencies and reducing the FX risk premium (preference for Loonie and UK assets).[7] For all countries inflation differential shocks explain between 10 and 20 percent of the long-term forecast error variances, but not much at shorter horizons. And most of the cyclical shocks, such as monetary policy shocks and output growth differential shocks, do not explain much of the exchange rate movements.[8]

- Event studies broadly confirm the SVAR results. Shocks that move long-term interest rate differentials usually also move the dollar. While changes in FX risk premiums can reinforce or offset this depending on how the shock affects investors' perceptions of the risks associated with dollar relative to other currency assets.

Looking ahead, our results suggest that if monetary policy divergence persists, as seems likely, it will continue to drive dollar movements. But this effect could be offset or reinforced by FX risk premium movements. Moreover, depending on the dollar bilateral, oil price

[5] We identify policy divergence shock with innovations to the long-term interest rate differentials that do not affect global market risk (the VIX). In this way, we try to purge the long-term rates from the term premium such that they reflect only the sum of expected short-term interest rates. Policy divergence should mainly capture market views on medium term neutral rate differentials, although this argument is, in principle, complicated if the monetary authority and markets form different views on the neutral rate.

[6] We order the SVAR in such a way that the FX risk premium does not change global uncertainty contemporaneously.

[7] This is in line with findings of Chen and Rogoff (2003), among others, on commodity currencies. As shown in Appendix 2 (Figures A3-4), these results appear to be even stronger before the Great Recession, likely related to the importance of shale oil production in the US since 2010 and the secular downtrend in North Sea oil production in the UK.

[8] This result is in line with Juvenal (2011) which finds little role for monetary policy shocks in explaining exchange rate movements, but in contrast with other studies that find a disproportionate role for monetary policy shock, such as Bergin (2006) and Lubik and Schorfeide (2006).

dynamics could play an important role, while positive global uncertainty shocks will generally lead to dollar appreciation.

The rest of the paper is structured as follows. Section II explains theoretically why we must take account of FX risk premiums and uses a small GE model to show that they matter greatly along with policy divergence for explaining exchange rate dynamics. Section III explains the measurement of the FX risk premium and discusses some of its empirical characteristics, along with those of the underlying Consensus forecasts. Section IV performs the SVAR analysis, while section V looks at some recent event studies. Section VI concludes.

II. Theory: Why Risk Premiums And Long-Term Interest Rates Matter

A. Why is there an FX Risk Premium?

In absence of default risk, capital controls, and transaction costs the following relation between domestic and foreign interest rates with the foreign currency must hold at all horizons (see Appendix A for more details)

$$E_t\left[m_{t,t+j}\left(1-\exp^{i^*_{t,t+j}-i_{t,t+j}}\frac{S_{t+j}}{S_t}\right)\right]=0 \tag{1.1}$$

where S_t is the spot exchange rate expressed in terms of the home currency, $m_{t,t+j}$ is the pricing kernel (or SDF) between time-t and $t+j$ for the home investor and $i_{t,t+j}$ is a risk-free rate for a deposit denominated in foreign currency maturing in j periods.[9] Throughout this paper we will take the U.S. as the home country such that an increase in the exchange rate represents a depreciation of the U.S. dollar. We denote the foreign country with a '*' and define country differentials as the foreign minus the home variable.

Equation (1.1) simply states that, in equilibrium, investors should be indifferent between the return from a domestic deposit and the return from a foreign currency deposit plus the expected foreign currency appreciation—adjusted for the compensation for currency risk. After some manipulations and under log-normality assumptions, equation (1.1) can be written in the familiar uncovered-interest-parity (UIP) form[10]

$$i_{t,t+j}=i^*_{t,t+j}+E_t\Delta s_{t+j}-rp_{t,t+j} \tag{1.2}$$

where $rp_{t,t+j}$ represents the foreign exchange (FX) risk premium for horizon j and $s_t = \log(S_t)$. An increase in rp_t can be interpreted as an increase in the preferences for holding U.S. dollar-denominated assets vis a vis foreign-currency assets. For given expected depreciation, a higher FX risk premium allows a lower US interest rate.
Formally, for the domestic investor, the risk premium is determined by changes in the covariance between the pricing kernel (which describes the way investors price risk) and the

[9] An analog equation holds for foreign investors.

[10] It is common in the empirical literature to refer to UIP condition without a FX risk premium term. In this paper, we will refer to the UIP condition as the one including a risk premium.

home currency depreciation (see Appendix A). Higher domestic uncertainty should also lead to a decline in the risk premium. Alternatively, higher global uncertainty typically induces a relative increase in foreign investor perception of risk, which induces a "flight to safety" (i.e. an increase in preferences for US assets―see Burnstein et al. 2004). Also, as we will see, other factors such as monetary policy shocks, policy uncertainty, and oil price movements can affect the FX risk premium by altering, possibly only temporarily, the stochastic properties of the exchange rate or the SDF.

B. Small Illustrative Macroeconomic Model

Model Equations

A small macro model can bring equation (1.1) into a general equilibrium setup and illustrates some theoretical implications that will guide our empirical analysis (equation block 1.3). The model captures the salient features of a standard two-country sticky-price model under perfect capital mobility and flexible exchange rate regimes (Benigno and Benigno 2008 among others).[11] At the heart of the model there is the UIP condition (equation 1.2) that relates home and foreign interest rates. A monetary policy rule and backward looking IS and Phillips curves for each country close the model. The monetary policy rule reacts to inflation and output gaps while its intercept captures the neutral rate. We introduce a small feedback from the exchange rate to the real economy by allowing exchange rate appreciation to reduce both inflation and output, ceteris paribus.[12] There are 3 cyclical shocks that affect the IS curve, the Phillips curve, and the monetary policy rule, respectively. A 1-year ahead news shock has also been added to the monetary policy rules to illustrate the potential effects of central bank's announcements (such as forward guidance). Finally, the neutral rate is modelled as an exogenous process.[13]

While it is possible to link the pricing kernel (through the SDF) to an economy's fundamentals, the literature has not yet found a broad consensus on how to micro found the FX risk premium (Engel 2013 and 2015).[14] Moreover, most of the analysis presented in the literature adopts solution methods that—relying on low-order approximations of the equilibrium conditions—rule out, by construction, movements in the risk premium. We will, thus, follow a more flexible approach, constructing the FX risk premium directly from survey data rather than pinning it to macroeconomic variables. We then estimate a $AR(n)$ process for the observed FX risk premium.

---

[11] In the calibration we use U.S. for the home country and UK for the foreign country.

[12] There is a vast literature that has documented the disconnect between the real economy and the (real) exchange rate (Devereux and Engel 2002 and Obstfeld and Rogoff 2001). As it is in our case, the higher the disconnect, the lower the speed of mean reversion of the exchange rate and the higher is the bound to exchange rate volatility.

[13] The neutral rate is in general a function of preferences and technology which are often introduced as exogenous in the business cycle literature. Our simplified approach is aimed at capturing the neutral rate as a driver of low frequency movements in policy rates, as highlighted in the recent empirical literature (see for example Pescatori Turunen 2015).

[14] This issue reflects the more general problem of current macroeconomic models in successfully modeling the behavior of price of risk (e.g., equity premium, term premium, and FX risk premium).

The model can be described by the following system of equations (where $\tilde{x} \equiv x^* - x$ represents variables expressed in country differentials while L is the lag operator)

$$
\begin{aligned}
&E_t \Delta s_{t+1} = \tilde{i}_t + rp_t \\
&\tilde{i}_t = \rho_i \tilde{i}_{t-1} + (1-\rho_i)[\tilde{\imath}_t + \phi_p(\tilde{\pi}_t + \tilde{\pi}_{t-1})/2 + \phi_y(\tilde{y}_t + \tilde{y}_{t-1})/2] - \tilde{\varepsilon}_{m,t} - \tilde{\upsilon}_t \\
&\tilde{\pi}_t = \alpha_1 \tilde{\pi}_{t-1} + \alpha_2 \tilde{\pi}_{t-2} + \kappa \tilde{y}_{t-1} - \tau_p(L)s_t - \tilde{\varepsilon}_{\mathrm{p},t} \\
&\tilde{y}_t = \gamma(L)\tilde{y}_{t-1} - \sigma(\tilde{i}_t - \tilde{\imath}_t) - \tau_y(L)s_t - \tilde{\varepsilon}_{\mathrm{y},t}
\end{aligned}
\tag{1.3}
$$

where π, and y, represent inflation and output gaps while the vector ε represents shocks to the monetary policy rule, inflation, and output. Forward guidance, ν_t, reflects information on future (1-year head) policy rate deviations from systematic policy, $\nu_{t+12} = 0.5\nu_{t+11} + \xi_t$. These deviations are driven by current and past monetary policy announcements, ξ_{t-j}—with the past ones discounted geometrically. The neutral rate differential, $\tilde{\imath}_t$, and the risk premium, rp_t, follow exogenous processes.

Model Calibration

The model is calibrated at monthly frequencies using U.S. and UK data from 1990 to 2015. The standard deviations of the IS and Phillips' curve and the parameter κ are set to match the second moments of GDP and inflation differentials between U.S. and UK.[15] The exogenous risk premium process is estimated based on the constructed 1-year U.S. dollar-UKP risk premium measure (see Section III). The neutral rate differential process has been calibrated to roughly match the evolution of U.S. and UK short-term rates.[16] In line with recent empirical estimates, the standard deviations of monetary policy and forward guidance shocks are both set at 12.5 bps (Gertler and Karadi 2015). In the monetary policy rule, the long-term policy rate responses to inflation and output are $\phi_p = 1.5$ and $\phi_y = 0.5$, while the persistence is 0.9. Finally, the output sensitivity to the interest rate gap is unitary and we assume $\tau_p = 0.25/3$ and $\tau_y = 1/3$ with $L = 3$ in both cases. Though stylized, such a simple model goes a long way in generating FX volatility which is governed by the exchange rate feedback to the real economy—for given standard deviations of the shocks. The model also replicates the ratios between FX actual and expected changes that are found in the data.

Model Results

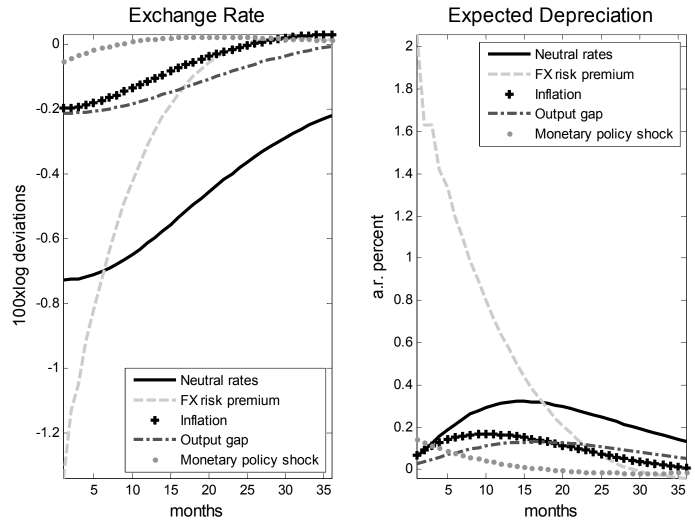
Idiosyncratic shocks that increase inflation and output of the home country (relatively to the foreign country) appreciate the home exchange rate by little and without much persistence (Figure 2). Similarly, a monetary policy tightening shock induces only a brief appreciation of

[15] GDP data have been converted to monthly data by spline interpolation.

[16] Since the empirical literature on the neutral rate has highlighted substantial estimation uncertainty (Pescatori and Turunen 2015, Hamilton et al.2015) and estimates are not available for all countries in our sample we have simply used HP-filtered interest rate differentials.

the home currency, which is unwound as soon as the systematic component of monetary policy reacts to a more subdued inflation and output outlook.

Figure 2. Model Impulse Responses to Various Shocks



Model-based responses of the exchange rate (left) and expected depreciation (right) to Neutral rate, risk premium, inflation, output gap, and monetary policy shock (1 standard deviation).

A shock to the risk premium has a strong direct impact, not surprisingly, even though it is not long lasting. The neutral rate shock is meant to capture monetary policy divergence. Its effect is both substantial and persistent, working mainly through future expected short-term rates.[17] Indeed, by solving equation (1.2) (setting $j = 1$ without loss of generality) forward we can see how the exchange rate is determined by the cumulated sum of expected future short-term rates and FX risk premiums.

$$s_t = E_t \sum_{i=0}^{\infty} (i^*_{t+i} - i_{t+i}) + E_t \sum_{i=0}^{\infty} rp_{t+i} + s_\infty \tag{1.4}$$

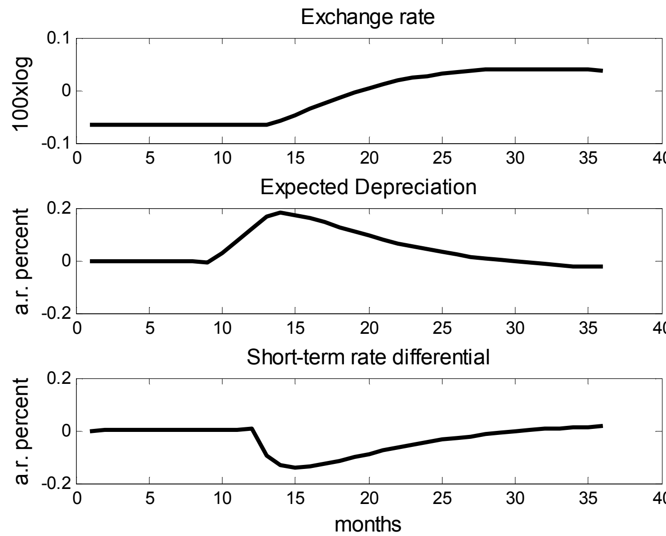
This implies that the exchange rate should respond to changes in long-term interest rate differentials—once long-term rates are adjusted for the term premium.

A US forward guidance shock announcing a period of tighter than usual policy 1 year from now generates an appreciation of the U.S. dollar today even though the short-term interest rate differential barely moves (Figure 3).[18] Moreover, it leads to a period of negative covariance between the exchange rate and the short-term interest rate differential when the policy is actually implemented (i.e., the U.S. dollar depreciates while US interest rates are rising).

[17] Interestingly, by inducing low frequency movements the neutral rate shock introduces also longer-term predictability.

[18] The degree of reaction of the interest rate differential depends on the feedback effect of the exchange rate on output and inflation differentials via monetary policy rules. Given backward looking IS and Phillips' curves, in the presence of a full exchange rate disconnect, interest rates differentials do not move at all.

Figure 3. Model Impulse Responses to a Forward Guidance Shock



Model-based responses of the exchange rate (top) and expected depreciation (middle), and short-term interest rate differential (bottom) to a 12-month-ahead domestic monetary policy tightening (forward guidance).

Cyclical and monetary policy shocks do not explain much of the exchange rate forecast error variance neither at short nor at long horizons (Table 1). Neutral rate shocks (i.e., policy divergence), can explain more than 2/3 of the low frequency movements of the exchange rate (i.e. in the level of the exchange rate). Risk premiums shocks, instead, explain most of the short-term fluctuations (i.e., in the exchange rate change).

Forward guidance is just one of various potential news shocks. Another example is a shock that affects views on the neutral rate path. It has been shown, however, that news shocks pose an important limit to VAR analyses by making the autoregressive representation *non-invertible* and fazing the ability of the VAR to recover the true impulse responses (Blanchard et al. 2013, Leeper et al. 2013, Sims 2012). For example, in the case of the forward guidance shock, the exchange rate actually starts depreciating when U.S. interest rates rise because there is a jump appreciation when the announcement of the future interest rate hikes is made. Announcements and data releases, however, are in general not captured by small-scale VARs. [19] Thus, the non-invertibility problem is essentially a problem of missing information where the information set of the econometrician (i.e., the VAR) is smaller relative to the one of FX traders/investors. In this context, long-term yields—by capturing information about expected movements in future short term rates—are a good candidate to alleviate the non-invertibility problem by bringing the information set of the VAR more in line with the ones of market participants. Also, the event studies of Section V bypass the invertibility problem and are useful complement to the VAR analysis.

[19] Andersen et al. (2003) and Faust et al. (2007) using high frequency data around have shown that macroeconomic releases generates movements in exchange rates.

Table 1. Relative Importance of the Shocks in Model Calibrations

	Variance decomposition						STD
	Risk Premium	Inflation	Output	Neutral Rate	MP Shock	F.G.	All
FX	40.2	2.1	3.5	53.6	0.1	0.5	4.4
FX actual change	70.2	2.0	2.3	25.0	0.1	0.4	12.0
FX actual change	85.7	2.0	1.5	9.5	0.4	1.0	4.9

Note: Forecast error variance decomposition at infinite horizon. F.G. stands for forward guidance.

III. The FX Risk Premium: Measurement and Properties

A. Measurement Approach

To construct FX risk premiums, we use the framework laid out in the previous section. For each bilateral exchange rate, the FX risk premium over a given horizon is defined as:

$$rp_{t,t+j} = i^*_{t,t+j} - i_{t,t+j} + E_t \Delta s_{t+j}$$

We focus on four major dollar bilaterals: \$/euro, \$/sterling, \$/yen, and \$/can.[20] To actually measure risk premiums we need data on interest rate differentials and forecasts of future spot exchange rates over the same horizon. We follow Balakrishnan and Tulin (2006). For interest rates, we use Eurocurrency deposit rates where possible and generic government bond rates from Bloomberg otherwise. For exchange rate forecasts, we use survey data from Consensus Economics—which constrains our sample to start in 1989.[21] Since exchange rate expectations are surveyed on a specific day of the month, we match the consensus forecast data with the exchange rates and interest rates prevailing over that specific day.

Although there are important caveats to the use of survey data on exchange rates, the consensus forecasts, by including a long list of forecasters, appear good proxies of investor sentiment, as we will show in the next subsection.

More generally, there are studies suggesting that survey data can deliver biased forecasts of exchange rates and thus appear to be incompatible with rational expectations (see Chinn and Frankel 1994 and Bofinger and Schmidt 2004). However, as noted by Lewis (1989), unbiasedness is implied by rational expectations only if there is agreement on the true model. Given that most well-known models of exchange rates forecast poorly, it seems clear that this

[20] Although we do perform some robustness checks for the VAR analysis using non-dollar bilaterals, and hence calculate FX risk premium measures for these bilaterals.

[21] Since 1989, Consensus Economics have produced monthly exchange rate forecasts across a range of currencies at 3 month and 12 month horizons. In the mid-1990s, they started producing 2-year ahead exchange rate forecasts. Currently, they survey more than 250 financial and economic forecasters and cover 90 currencies. Thus, the sample is extremely rich and allows us to construct risk premium estimates across a slew of dollar bilaterals at three month, one year, and 2 year horizons for both industrialized and emerging market countries.

does not hold. Thus, survey data expectations could be rational despite delivering biased forecasts—especially when peso problems and learning behavior are taken into account. Also, Engel and West (2005) has shown that the inability to forecast exchange rates can be a natural implication of some exchange rate models. In particular, when fundamentals are close to be integrated then it may not be surprising that present-value models cannot forecast better than a random walk model of exchange rates.

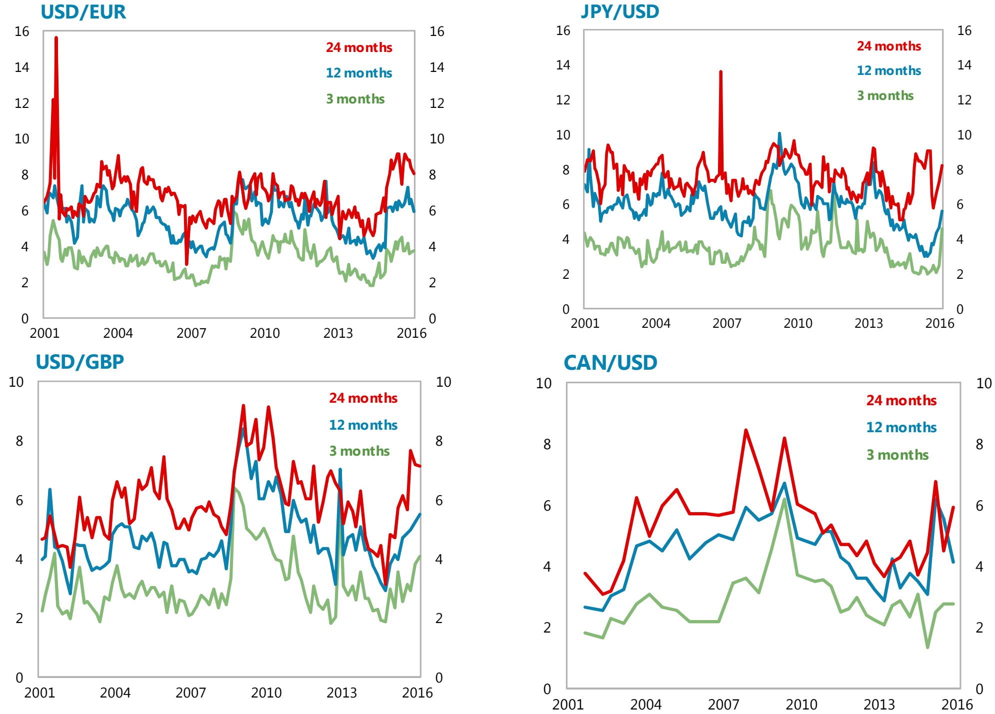
In terms of measuring risk premiums using UIP—an ex ante condition—all that matters are whether the consensus forecasts are good proxies for investor sentiment, and to the extent that the consensus forecast is the mean of the forecast of numerous professional forecasters this should be the case— regardless of how forecasters form their exchange rate expectations and their accuracy.[22] In the next subsection, we look more closely at the statistical features of the Consensus Forecasts.

B. Features of Consensus Forecasts

Consensus forecasts are characterized by significant differences in beliefs as shown by the standard deviation across forecasts (Figure 4). This likely reflects different beliefs of various forecasters on the drivers of exchange rate dynamics, including regarding the underlying model. However, as far as the mean forecast reflects the expectations of the marginal investor, the constructed risk premium will reflect it too.

[22] For example, Hauner et al.(2010) finds that exchange rate expectations from surveys are correlated with inflation differentials and productivity differentials suggesting that the relative PPP and Balassa-Samuelson effect are common inputs into expectation formation of market forecasters. See also Cheung and Chinn (2001) for a view on currency traders' expectations.

Figure 4. Bilateral Forecast Uncertainties
(Standard deviations as a percent of Consensus forecast)



Sources: Consensus Economics; and IMF staff calculations

What about the Consensus forecast errors and how they compare to those using a random walk model? Focusing on dollar bilaterals, forecast changes (i.e., expected changes in the exchange rate) are less volatile than actual changes and do not have a significant bias over the whole sample period, especially at longer horizons (Tables 2 and 3). Indeed, the mean forecast error converges towards zero as the horizon increases, suggesting that forecasters do a much better job forecasting exchange rates at longer horizons and that there is simply too much noise driving shorter-term exchange rate movements. Near-term Consensus forecasts do worse than the random walk forecast when comparing root-mean-squared forecast-errors (RMSFEs) at the 3-month horizon. However, the RMSFEs are very close at the one year horizon and Consensus forecasts have lower RMSFEs at the 2-year horizon (at the 1 percent significance level for both all and dollar-only bilaterals).[23]

[23] Since the seminal contribution of Meese and Rogoff (1983), the random walk model has been a benchmark used to test alternative exchange rate model.

Table 2: Exchange Rate Changes
(standard deviation 1/)

	Expected	Actual
3-month	9.42	21.71
1-year	4.31	10.32
2-year	2.86	7.31

1/ Average across all four bilaterals in sample. The sample period is 1990-2016 monthly data.

Table 3: Bilateral Forecast Errors

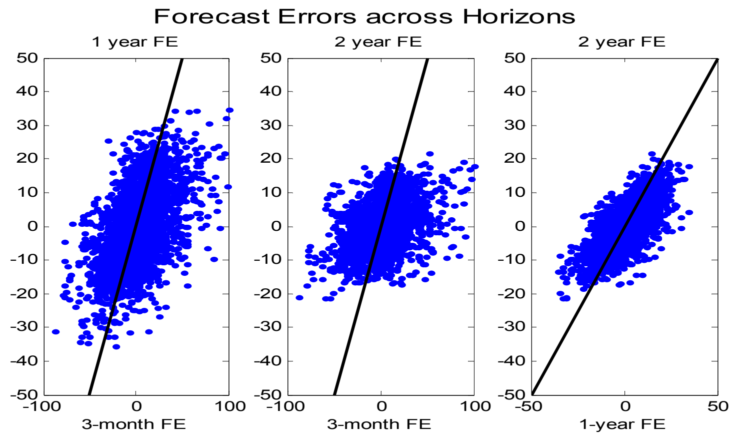
		Mean	RMSFE	Kurtosis
Dollar	3-Month	-2.10	22.05	1.49
	1-Year	-0.46	9.83	-0.28
	2-Year	-0.19	6.49	-0.55
Comparison with R.W.				
All	3-Month	-0.01	1.10	-0.70
	1-Year	-0.13	1.05	-0.31
	2-Year	0.03	0.95	-0.24
Dollar	3-Month	-0.32	1.09	-0.74
	1-Year	-0.30	1.01	-0.45
	2-Year	-0.08	0.93	-0.19

Note: The sample period is 1990-2016, with monthly data for all bilaterals of actual and expected exchange rate changes (for dollar bilaterals, an increase represents a US$ appreciation). The comparison is done against the random walk model (R.W.). For the mean and kurtosis, the comparison is the bilateral average differences CF-R.W., while the RMSFE is a ratio CF/R.W.

At all horizons, the distribution of consensus forecasts has smaller tails (lower kurtosis) than the ones associated with a random walk forecasting model. This suggests that, relative to a random walk, it is the many smaller misses that explain most of the variance of the forecast errors rather than fewer but bigger misses. This is also consistent with forecasters being able to anticipate big changes but not noise or market momentum.

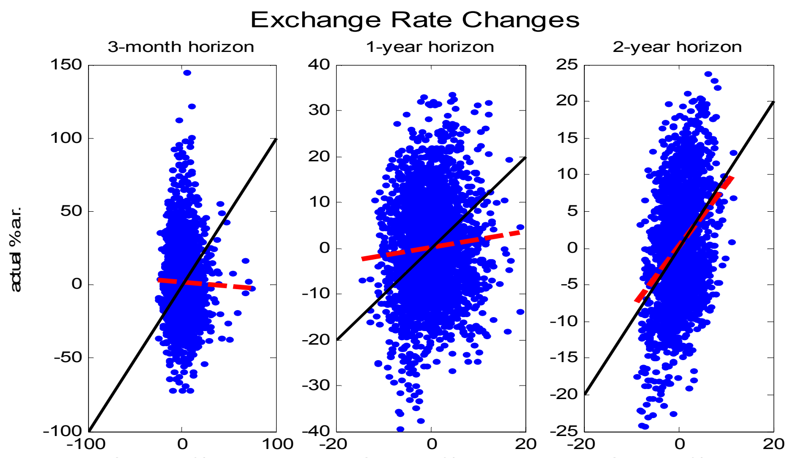
Another way of slicing the data is to look at scatter plots of the forecasted and actual exchange rate changes at various horizons and the forecast errors (Figures 5 and 6). They confirm the much closer relationship between the forecast and actual change as the horizon increases. Indeed, the regression line is close to the 45-degree line at the 2-year horizon. There is also a clear positive relation between short-term and long-term forecast errors, suggesting that forecasters may rely more on fundamental-based rather than momentum-based models in the way they form expectations.

Figure 5. Scatter plot of Forecast Errors at Different Horizons



Pooled Consensus forecast errors across all bilaterals: 1-year against 3-month forecast error (left Panel), 2-year against 3-month forecast error (middle panel), 2-year against 1-year forecast error (left Panel).

Figure 6. Scatter Plot of Actual Exchange Rate Changes Against Forecast Ones at Different Horizons



Actual exchange rate changes against pooled Consensus forecast errors across all bilaterals at 3-month, 1-year, and 2-year horizon. Black line is the 45 degree line, red dashed is the regression line.

C. Risk Premium Estimates and their Historical Evolutions

Figure 7 shows the risk premiums for the four major U.S. bilaterals. They have persistent dynamics and have been both positive and negative at various times. Table 4 has the means and standard deviations for the four FX risk premiums. For the UK and euro, the mean of the risk premium over the sample is not statistically different to zero at the 5 percent level, while it is for the Loonie (positive) and the Yen (negative). The latter probably reflects the Yen's safe haven status and a prolonged period of exceptionally low nominal interest rates.

Figure 7: Major U.S. Dollar Bilateral Risk Premiums

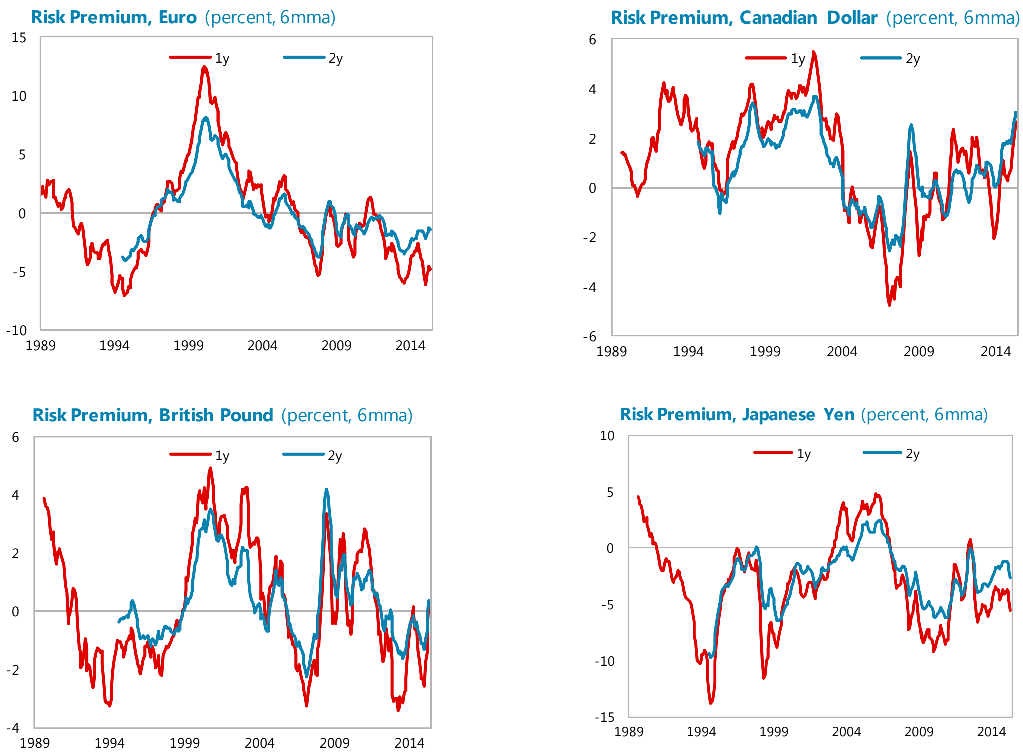


Table 4. Risk Premium Statistics
(by bilateral exchange rate)

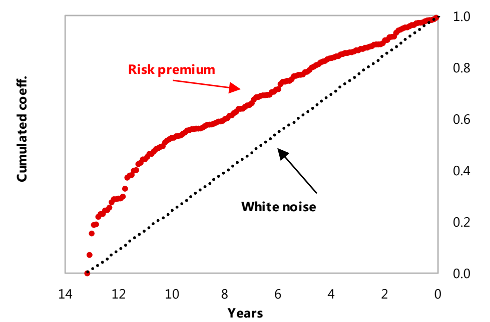
	GBP	EUR	CAD	JPY	Weighted
Standard dev.	2.5*	4.5	2.43***	4.47***	2.59**
Mean	.23*	-.16	1.13***	-3.13***	-.28**

Note: FX risk premiums constructed using Consensus forecast from 1990 to 2016 at 1-year horizon.

The risk premium is moved by factors operating at both high and low frequencies. Indeed, though stationary, a spectral decomposition shows that a substantial part of the variance of the risk premium can be explained by movements in cycles longer than 5 years—which account for most of the differences relative to the spectrogram of a white noise process (Figure 8).

In terms of historical evolution, the risk premiums for the euro, Sterling and Loonie were particularly high at the turn of the century (preference for U.S. assets). This coincided with a strong U.S. economy and the IT revolution, as well as the start of the eurozone. In contrast, however, following the Asian crisis through the mid-2000s the Yen enjoyed negative risk premiums, likely reflecting its safe haven status relative to other parts of Asia. The average FX premium across the major dollar bilaterals declined in the period before the GFC, while preferences for US-denominated assets relative to other currencies increased in the midst of the crisis—with the exception of Yen-denominated assets.

Figure 8. Spectral Analysis - Risk premium 1 year



Sources: Authors' estimates. Cumulated normalized sprectogram coefficients based on 1 year USD-UKP risk premium compared to a white noise process.

IV. VAR Analysis

As discussed in section II, expected cumulative short term interest rates and foreign exchange risk premiums should be important drivers of exchange rate movements. In this section, to quantify and disentangle their effects, along with those of other factors (e.g., oil price and VIX dynamics), we perform an SVAR analysis for each of our 4 dollar bilaterals using monthly data from 1993 to 2016.

A. Variables and Identification

A large strand of the literature addresses the question on what factors, especially monetary policy, affect the exchange rate. Typically, they use a vector autoregression (VAR) in interest rates (domestic and foreign) and exchange rates (Eichembaum and Evans 1995). The identification of the shocks is, however, contentious.[24] Our identification strategy builds on timing assumptions (i.e., recursive ordering) and a selection of variables that are supposed to help isolate the most relevant factors behind exchange rate and risk premium movements (as outlined in Section II). In particular, we aim to capture shocks to discount factors (risk shocks), to the cyclical outlook for output and inflation, to the monetary policy reaction function, to the neutral rate (expected policy divergence), and FX-specific risk shocks.

We estimate a VAR for our 4 dollar-bilateral exchange rates. In particular, the VAR includes the CBOE Volatility Index (VIX), the Crude Oil Price for West Texas Intermediate (WTI), the Consensus one-year ahead GDP growth forecast differential (dY), the Consensus one-year ahead inflation forecast differential (dπ), the one-year interest rate differential (di1), the

[24] There is for example considerable evidence from the event-study literature showing that global interest rates and exchange rates respond immediately and substantively to U.S. monetary policy shocks (Andersen et al. 2003, 2007; Faust et al. 2007; Ehrmann and Fratzscher, 2003, 2005; Bredin et al. 2010; Hausman and Wongswan, 2011; Rogers et al. 2014; Wright, 2012; Kiley, 2013; Gilchrist et al. 2014).

risk-premium (RP), the 10-year interest rate differential (di10) and the nominal exchange rate (S).[25]

The constructed risk premiums and the output and inflation forecast differentials are observable only in one day (a Monday) of a given month.[26] Consistent with this timing, we use the same exchange rate as reported by Consensus Forecast and for the remaining variables we take the average of the 5 days (the previous week) prior to the date of the survey.

The first structural shock (associated with the VIX equation) represents a *global risk sentiment* shock which is allowed to affect all variables.[27] Oil price innovations represent a risk-preserving shock to oil prices which can move expected GDP and interest rate differentials but not the VIX. It is useful to capture significant changes in the medium-term oil market outlook.[28] The FX risk premium shock by not moving contemporaneously the VIX can be interpreted as a FX-specific risk shock. The policy divergence shock is captured by innovations in the long-term interest rate differentials that do not contemporaneously affect, among other variables, equity market risk (the VIX), expected inflation differentials, and the FX risk premium. In this way, and to the extent that the term premium co-moves with market risk, we purge the long-term rates of the term premium such that it reflects only the sum of expected short-term interest rates.[29]

B. Results

Figure 9A-9D show the impulse responses of the exchange rates and risk premiums to the shocks described above and forecast error variance decompositions of the exchange rate. The impulse responses suggest that a global risk sentiment shock generates a persistent appreciation of the dollar against the Loonie, the Euro, and the British Pound but a

[25] All variables are in logarithms except interest rate differentials and risk premiums. Results were generated using monthly data covering the sample period 1993:1-2016:3. Dynamic responses were calculated using the following ordering: VIX, WTI, expected GDP growth differential, expected inflation differential, short-rate differential, risk premium, long-rate differential, exchange rate. The ordering of oil prices is in line with Killian and Vega (2011) who finds that oil prices generally do not respond to U.S.macroeconomic news, at daily or monthly frequency.

[26] To estimate a rolling 12-month-forward forecast, we weigh the current year forecast and the next year forecast according to how many months each forecast captures within the relevant 12-month-ahead window.

[27] Various alternative series have been tried to capture risk shocks such as measures of policy and stock market uncertainty (Baker, Bloom, and Davis 2015) in the U.S. and relatively to the foreign country, and a measure of financial market risk (the excess bond premium—see Gilchrist and Zacraijcek 2012). In all cases, the VAR specification with the VIX, however, proved to be superior.

[28] WTI oil price series is particularly useful for oil-exporter countries (such as UK and Canada).

[29] The main results are robust to different orderings of the variables, using different measures of risk, looking at non-dollar bilaterals, and different sample periods (see Appendix B). When we replace the long-term interest rate differential with the U.S. term premium (Adrian et al. 2013) the surprise increase in the term premium has no significant effect on any U.S. exchange rate bilateral, consistent with equation 1.4 that the expected sum of short-term interest rates is what really matters.

depreciation of the dollar against the Yen in line with the often-mentioned flight-to-safety phenomenon which entails a U.S. dollar appreciation in periods of uncertainty and crises. After an oil price shock, there is a depreciation of the dollar against all currencies. The persistence of the impulse responses differs between countries, with the Canadian dollar and the Yen responses demonstrating greater persistence than the ones for the Euro and the British Pound. An 8 percent increase in the price of oil leads to a depreciation of the U.S. dollar exchange rate by between 0.25 percent and 0.8 percent on impact. These results are in line with Fratzscher, Schneider and Van Robays (2013) who find very similar effects.[30]

Shocks to the cyclical outlook for inflation and output have transitory effects on the exchange rate. Moreover, in line with theory (Section II), shocks to short-term rate differentials have minor or insignificant effects on both the exchange rate and the FX risk premium. Policy divergence (shocks to neutral rate differentials), instead, plays a larger role in explaining exchange rate movements for the Loonie and the Euro but less so for the Pound and the Yen, where risk premium shocks appears to be relatively more important.

FX-specific risk premium shocks explain almost half of exchange rate variations at short horizons and a significant part of longer-term exchange rate movements. Global risk shocks are also relevant, both through their direct effect on the exchange rate and, indirectly, by affecting the FX risk premium. They tend to appreciate the U.S. dollar against its major currencies and increase the FX risk premium (preference for U.S. assets). The exception is the Yen, which also appears to enjoy a safe haven status. For commodity-currencies such as the Loonie, and to a lower extent the British Pound, WTI plays a significant role in explaining exchange rate variations.[31] For the Loonie, shocks to WTI also explain a significant share of FX risk premium dynamics, which is perhaps not surprising given Canada has the highest value added from oil of the countries/economic zones being studied.

C. Risk Premiums and Monetary Policy Shocks

The identified shocks of the SVAR of the previous section can explain about 50 percent of the forecast error variance of the FX risk premium for most of the dollar bilaterals. An interesting question, however, is the extent to which monetary policy shocks move FX risk premiums, and in which direction. The empirical failure of the UIP induces a positive covariance between the UIP-based risk premium and the interest rate differentials.[32] The idea is that lower domestic interest rates (induced by monetary easing for example), imply a

---

[30] It is not possible to exclude some reverse causality since periods of strong U.S. dollar are associated with weakness in commodity prices (Frenkel and Rose 2010). To minimize this possibility, we have expressed the WTI in SDR.

[31] Appendix A3 has the exchange rate impulse responses using the excess bond premium rather than VIX as the global risk sentiment factor and compares how they change if we use the pre-Great Recession sample rather the than full sample. The differences in the responses of the exchange rate to WTI shocks in the different samples suggest that the impact has declined more recently. This is likely related to the importance of shale oil production in the US since 2010 and the secular downtrend in North Sea oil production in the UK.

[32] Our FX risk premium is calculated using expectation surveys. It is, however, possible to interpret the residual of a UIP regression as a risk premium whenever $E_t s_{t+1} = s_{t+1} + i.i.d.$ In UIP regressions it is often found that the coefficient in front of the interest rate differential is negative (rather than 1). This bias is possible only if the residual of the regression (interpreted as the risk premium) co-varies positively with the interest differential.

reduction in the relative risk of holding assets denominated in the home currency. Christiano, Trabandt and Walentin (2011), henceforth CTW, tries to capture this idea by assuming a functional form that generates a fall in the assessment of risk in the domestic economy when the domestic interest rate is reduced. More specifically, their risk adjustment term takes the following functional form:

$$rp_t = e^{(-\alpha(i_t^* - i_t) + \varepsilon_t)}$$

where $\alpha > 0$ and ε_t is an exogenous process. Our measure of the risk adjustment term, or the risk premium, allows us to directly test this specification and to investigate how risk is affected by monetary policy shocks.

The recent monetary policy literature offers various estimated series of monetary policy surprises designed to be orthogonal to output and inflation forecasts. Their orthogonality, in turn, can be exploited to estimate the causal effects of raising interest rates on economic activity and inflation (Cochrane 2004).[33] Here we choose to blend the traditional recursive identification strategy with the use of the monetary policy surprise data using a proxy VAR (Gertler and Karadi 2015). Hence, we add a measure of monetary policy shocks in the U.S. and a measure of shocks in the UK to the benchmark VAR specification above. The monetary policy shock measures are ordered first in the VAR. Otherwise the ordering is the same as in the benchmark specification.

U.S. monetary policy shocks – measured with the Gertler and Karadi (2015) estimated shocks – have a short-lived negative impact on Euro area and Japan risk premium but a positive effect on the Canadian risk premium (Figure 10A and 10B). The UK risk premium is less significantly affected but goes in the same direction as Euro and Japan. The UK monetary policy shocks have some impact on risk premiums and the Euro exchange rate but they are generally small and insignificant.

These results generally confirm the CTW specification. A positive monetary policy shock does seem to make the risk in the domestic economy to increase. This is however not the case for Canada where the opposite is true, with a positive U.S. monetary shock, causing the FX risk premium to rise (preference for U.S. assets) and the Loonie to depreciate. This different response may be caused by Canada's close trade links to the United States. Consistent with the theoretical results of section II, however, monetary policy shocks can explain little of the variance of exchange rate dynamics.

V. Event Studies

In this section, we use some event studies to complement the VAR analysis. They do this in two ways: (a) they allow us to zoom in on some recent major announcements and associated dollar movements; and (b) they also help overcome the invertibility problem (illustrated by

[33] Monetary policy surprise series have been constructed by Romer and Romer (2004), Coibion (2012), Gertler and Karadi (2015) for the U.S. and by Cloyne and Hürtgen (2016) for theUKThe most suited for our analysis are Gertler and Karadi (2015) and Cloyne and Hürtgen (2016) since they are market-based and the sample spans from 1990 till 2013 and 2015, respectively.

the reaction of the exchange rate and interest rates to a forward guidance shock in Section II.V) that can plague econometric methods, including VARs. We focus on two sets of event studies: (i) the taper tantrum (Figure 11); and (ii) recent QE/forward guidance/interest rate announcements/surprises by other major central banks, apart from the Fed, starting with Mario Draghi's Jackson Hole speech in the summer of 2014 (Figure 12).[34]

A. Taper Tantrum

As has been well documented, former Fed Chair Ben Bernanke's speech in May 2013 appeared to be the catalyst for a significant and persistent rally in the U.S.10-year treasury yield. But this did not lead to an appreciation of the dollar against all major bilaterals. This could be because much of the rally reflected an increase in the U.S. term premium rather than relatively higher future expected policy rates.[35] Moreover, what happened to the interest rates of the other currency needs to be taken into account, and FX risk premiums tended to decline (increasing preference for foreign assets). The latter may have been a result of the speech creating more uncertainty about the U.S. outlook and likely policy reaction of the Fed. The key trends for the major bilaterals were:

- ***Euro***. Despite a significant decrease in the 10-year interest differential which started well before the taper tantrum (of about 100 bps), the euro actually appreciated against the dollar. It appears that the impact of a declining 10-year interest differential was more than offset by a marked decline in the FX risk premium (an increasing preference for euro assets), especially in the year following Ben Bernanke's speech.

- ***Yen***. The dollar did appreciate somewhat against the yen in the months following the Bernanke speech but the appreciation was much sharper beforehand. This is because beforehand a declining 10-year interest differential combined with a rising risk premium (increasing preference for U.S. assets). The sharp moves before the start of the taper tantrum likely reflected the start of Abenomics, with quantitative and qualitative easing formally adopted in Japan in April 2013. After the Bernanke speech, as for the euro, there was a significant decline of the risk premium (an increasing preference for Yen assets). The dollar continued to appreciate against the yen, however, as the post-taper tantrum decline in the 10-year interest differential was more marked for the yen than for the euro (100 bps versus 60 bps).

- ***Loonie***. The loonie's depreciation against the dollar started well before the taper tantrum, as did the decline in the 10-year interest differential. Both trends continued after May 2013, and while the risk premium also declined, its dynamics were quite volatile, suggesting that most of the loonie dynamics were driven more by the declining 10-year interest differential.

---

[34] Of course, we are not denying the potential importance of other events, for example changes in risk sentiment related to troubles in the Eurozone and the OPEC meeting of November 2014. Although for the latter event, we did not find major movements in the exchange rates, risks premiums, or long-term interest differentials.

[35] In his May 2013 speech, Fed Chair Ben Bernanke stressed that the pace of the bond purchase program would slow down rather than provide forward guidance on policy rates " The Committee currently anticipates that it would be appropriate to moderate the monthly pace of purchases later this year."

- ***British Pound***. The British Pound appreciated considerably against the dollar following the Bernanke speech. This appears consistent with the dynamics of the 10-year interest differential: while it declined somewhat immediately after the Bernanke speech, it rose sharply in the months that followed, as the sterling 10-year UK gilt yield rose even more than the 10-year U.S. treasury rate.

B. Forward Guidance and Interest Rate Announcements/Surprises outside the U.S.

There have been various important announcement/surprises made by central banks apart from the Fed that have changed perceptions of forward guidance and/or monetary policy. We focus on two in this subsection. First, announcements by the ECB, starting with Mario Draghi's speech at Jackson Hole in August 2014 and followed by the formal announcement of QE in January 2015. Second, the surprise interest rate cut by the Bank of Canada, also in January 2015. These events had a major impact on the euro and loonie, as discussed below:

- ***Euro***. Before Mario Draghi's Jackson Hole speech, the 10-year interest differential was already on a declining trend, while the risk premium was rising. Both factors underpinned a depreciating euro, a trend which accelerated following Draghi's speech, and steepened again following the QE announcement in January 2015. The decline in the 10-year rate was particularly sharp following that announcement. The euro stabilized and started to appreciate in April 2015, which again seems consistent with the 10-year interest differential rebounding and the risk premium starting to decline around the same time.

- ***Loonie***. On January 21, 2015, the Bank of Canada surprised markets by cutting the policy rate by 25 basis points. In the immediate months that followed, the 10-year interest differential declined markedly, before briefly rebounding and then declining again. The depreciating loonie seemed to track these movements fairly closely, albeit with less monthly volatility. Initially the loonie seemed to depreciate less than would be suggested by the decline in the 10-year interest differential. This may reflect that the risk premium fell significantly in the quarter following the cut (a preference for Canadian assets), consistent with the results of section IV.C that lower domestic interest rates imply a reduction in the relative risk of holding home-currency assets (Christiano, et al. 2011).

Both sets of event studies support the earlier VAR results in that policy divergence (as proxied by l0-year interest differentials) seems to have played an important role in the recent dollar appreciation. But they also show that FX risk premium movements can offset or reinforce this depending on the source of the shock and the dollar bilateral.

VI. Conclusions

Real and nominal exchange rates (among major currencies) have often moved in a way *not* closely connected to current (or past) macroeconomic variables, making both understanding and forecasting exchange rate movements hard. In this paper we have focused our attention on exchange rate determinants that have usually been less scrutinized by the literature, such as risk premiums and the differential of the expected sum of short-term interest rates (i.e., *policy divergence*). We do this by using a three-pronged approach: simulations of a small macroeconomic model, event studies, and structural VAR analysis.

Using long-term interest rate differentials to capture shocks to policy divergence, our VAR analysis suggests that their effect is key, especially for the euro and the loonie. We also find that risk premiums play a major role in explaining dollar movements. We confirm and quantify the finding that global risk sentiment shocks increase the preference for the dollar (and the yen), while oil shocks are more relevant for the commodity-currencies such as the loonie, and to a smaller extent the British pound. Cyclical shocks, such as monetary policy shocks and output growth differential shocks, do not explain much of the exchange rate movements. Event studies confirm the role played by movements in long-term interest rate differentials in the recent dollar appreciation, with risk premium movements offsetting or reinforcing this depending on the source of the shock and the dollar bilateral. These findings are generally consistent with those from a small macroeconomic model.

Looking ahead, our results suggest that if monetary policy divergence persists it will continue to drive dollar movements. This effect, however, could be offset or reinforced by FX risk premium movements. Moreover, depending on the dollar bilateral, oil price dynamics could play an important role, while an increase in global uncertainty will generally lead to the appreciation of the U.S. dollar and Yen.

References

Adrian, Tobias, Richard K. Crump, and Emanuel Moench. "Pricing the term structure with linear regressions." *Journal of Financial Economics* 110.1 (2013): 110-138.

Andersen, Torben G., et al. "Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange." *American Economic Review* (2003): 38-62.

Balakrishnan, Ravi, and Volodymyr Tulin. “U.S. Dollar Risk Premiums and Capital Flows.” *IMF Working Paper 06/160.*

Baker, Scott R., Nicholas Bloom, and Steven J. Davis. *Measuring economic policy uncertainty*. No. w21633. National Bureau of Economic Research, 2015.

Baxter, Marianne, and Alan C. Stockman. "Business cycles and the exchange-rate regime: some international evidence." *Journal of monetary Economics* 23.3 (1989): 377-400.

Benigno, Gianluca, and Pierpaolo Benigno. "Designing targeting rules for international monetary policy cooperation." *Journal of Monetary Economics*53.3 (2006): 473-506.

Blanchard, Olivier J., Jean-Paul L'Huillier, and Guido Lorenzoni. *News, noise, and fluctuations: An empirical exploration*. No. w15015. *National Bureau of Economic Research*, 2009.

Bofinger, Peter, and Robert Schmidt. "Should One Rely on Professional Exchange Rate Forecasts? An Empirical Analysis of Professional Forecasts for the EUR/US-$ Rate." *SSRN Working Paper Series* (2004).

Burstein, Ariel, Martin Eichenbaum, and Sergio Rebelo, “Large devaluations and the real exchange rate.” No. w10986. *National Bureau of Economic Research,* 2004.

Chen, Yu-chin, and Kenneth Rogoff. "Commodity currencies." *Journal of international Economics*60.1 (2003): 133-160.

Cheung, Yin-Wong, and Menzie David Chinn. "Currency traders and exchange rate dynamics: a survey of the U.S.market." *Journal of international money and finance* 20.4 (2001): 439-471.

Chinn, Menzie, and Jeffrey Frankel. *Patterns in exchange rate forecasts for 25 currencies.* No. w3807. National Bureau of Economic Research, 1991.

Cloyne, James, and Patrick Hürtgen. "The macroeconomic effects of monetary policy: a new measure for the United Kingdom." *Bank of England working paper* 493 (2014).

Cochrane, J., (2004). “Comments on ‘A new measure of monetary shocks: Derivation and implications’ by Christina Romer and David Romer.” July 17 2004, presented at NBER EFG meeting.

Coibion, Olivier, “Are the effects of monetary policy shocks big or small?” No. w17034. *National Bureau of Economic Research*, 2011.

Colacito, Riccardo, and Mariano Massimiliano Croce. "Risks for the long-run and the real exchange rate." *Journal of Political Economy*119.1 (2011).

Colacito, Riccardo, and Mariano M. Croce. "International asset pricing with recursive preferences." *The Journal of Finance* 68.6 (2013): 2651-2686.

Devereux, Michael B., and Charles Engel. "Exchange rate pass-through, exchange rate volatility, and exchange rate disconnect." *Journal of Monetary economics* 49.5 (2002): 913-940.

Ehrmann, M., and Fratzscher M., (2005). “Equal Size, Equal Role? Interest Rate Interdependence between the Euro Area and the United States," *Economic Journal*, 115.

Eichenbaum, Martin, and Charles L. Evans. "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates." *The Quarterly Journal of Economics* 110.4 (1995): 975-1009.

Engel C, N C Mark and K D West (2008) “Exchange rate models are not as bad as you think”. In Acemoglu, D, K Rogoff and M Woodford (Eds), *NBER Macroeconomics Annual 2007*. Vol. 22 of NBER Chapters, National Bureau of Economic Research, Inc, pp. 381-441.

Fama, Eugene F. "Forward and spot exchange rates." *Journal of monetary economics* 14.3 (1984): 319-338.

Faust, Jon, et al. "The high-frequency response of exchange rates and interest rates to macroeconomic announcements." *Journal of Monetary Economics* 54.4 (2007): 1051-1068.

Flood, Robert P., and Andrew K. Rose. "Fixing exchange rates a virtual quest for fundamentals." *Journal of Monetary Economics* 36.1 (1995): 3-37.

Gabaix, Xavier and Matteo Maggiori, "International liquidity and exchange rate dynamics." *Quarterly Journal of Economics* 130.3 (2015).

Gertler, Mark, and Peter Karadi. *Monetary policy surprises, credit costs and economic activity.* No. w20224. National Bureau of Economic Research, 2014.

Gilchrist, Simon, and Egon Zakrajšek. "Credit Spreads and Business Cycle Fluctuations." *American Economic Review* 102.4 (2012): 1692-1720.

Gourio, Francois, Michael Siemer, and Adrien Verdelhan. "International risk cycles." *Journal of International Economics* 89.2 (2013): 471-484.

Hamilton, James D., et al. “The equilibrium real funds rate: Past, present and future.” No. w21476. *National Bureau of Economic Research,* 2015.

Hauner, David, Jaewoo Lee, and Hajime Takizawa. “In which exchange rate models do forecasters trust?” *International Monetary Fund working paper* 11/116.

Hausman J., and Wongswan J., (2011). “Global asset prices and FOMC announcements”, *Journal of International Money and Finance*, p. 547—571.

Kiley, M., T., (2013). "Exchange Rates, Monetary Policy Statements, and Uncovered Interest Parity: Before and After the Zero Lower Bound," *Finance and Economics Discussion Series 2013-17*. Board of Governors of the Federal Reserve System (U.S.).

Kilian, Lutz, and Clara Vega. "Do energy prices respond to U.S. macroeconomic news? A test of the hypothesis of predetermined energy prices." *Review of Economics and Statistics* 93.2 (2011): 660-671.

Laubach, Thomas, and John C. Williams. "Measuring the natural rate of interest." *Review of Economics and Statistics* 85.4 (2003): 1063-1070.

Leeper, Eric M., Todd B. Walker, and Shu-Chun Susan Yang. "Fiscal foresight and information flows." *Econometrica* 81.3 (2013): 1115-1145.

Lewis, Karen K. "Changing beliefs and systematic rational forecast errors with evidence from foreign exchange." *The American Economic Review* (1989): 621-636.

Meese, R A and K Rogoff (1983), “Empirical exchange rate models of the seventies: Do they fit out of sample?”, *Journal of International Economics* 14 (1-2), 933-48.

Obstfeld, Maurice, and Kenneth Rogoff. "The six major puzzles in international macroeconomics: is there a common cause?" *NBER Macroeconomics Annual 2000, Volume 15.* MIT press, 2001. 339-412.

Pescatori, Andreas, and Jarkko Turunen. "Lower for Longer: Neutral Rates in the United States." (2015), *International Monetary Fund,* WP No. 15/135.

Rogers, J., Scotti C., and Wright J., H., (2015). “Unconventional Monetary Policy and International Risk Premia”, paper presented at the Sixteenth Jacques Polak Annual Research Conference: "Unconventional Monetary and Exchange Rate Policies", November 5-6, 2015.

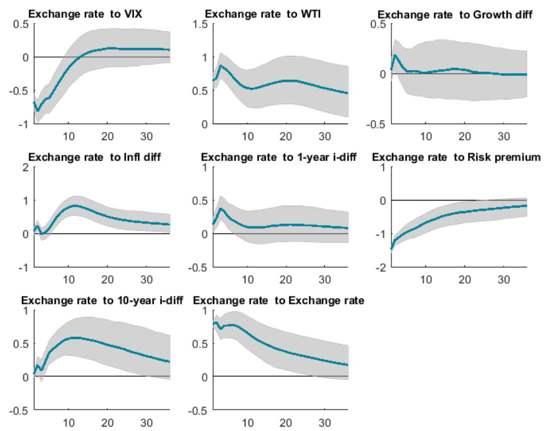
Romer, Christina D., and David H. Romer. "A new measure of monetary shocks: Derivation and implications." *The American Economic Review*94.4 (2004): 1055-1084.

Sims, Eric R. "News, non-invertibility, and structural VARs." *Advances in Econometrics* 28 (2012): 81.

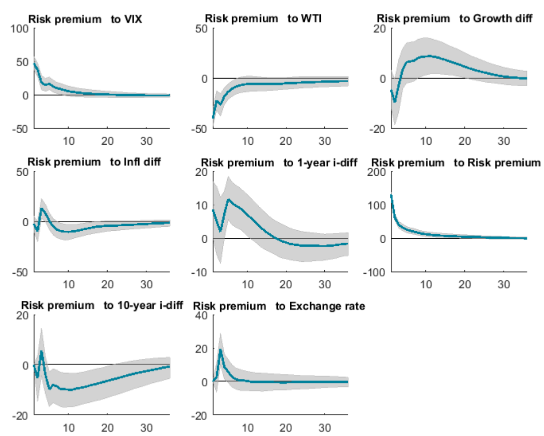
A. Figures and Tables

Figure 9A. Canada. Impulse Response Functions of the Exchange Rate and the risk Premium and Forecast Error Variance Decomposition of the Exchange Rate.

(a). Exchange Rate 1/



(b). Risk Premium 2/



(c). Exchange Rate – Forecast Error Variance Decomposition 3/

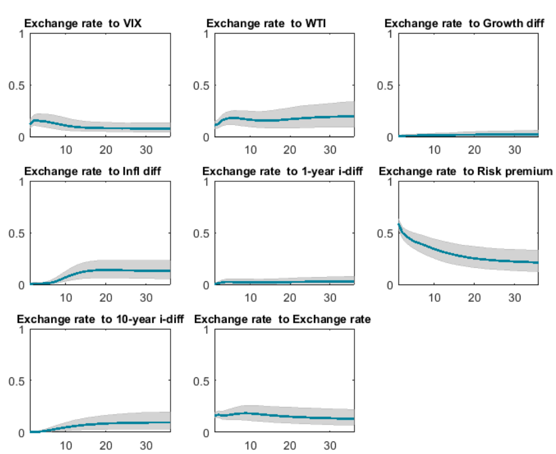
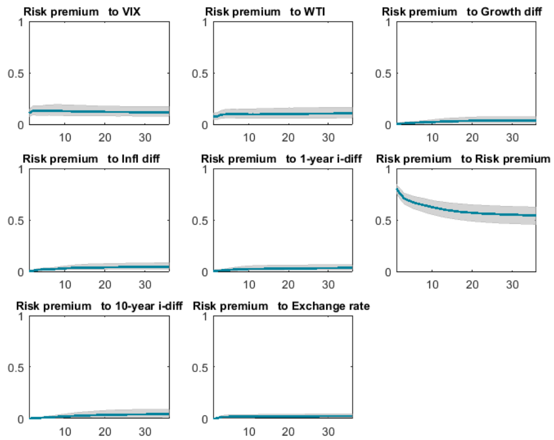


Figure 9A. Canada. Impulse Response Functions of the Exchange Rate and the risk Premium and Forecast Error Variance Decomposition of the Exchange Rate (Concluded)

(d). Risk Premium – Forecast Error Variance Decomposition 4/



Source: Authors' calculations

1/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. dollar against the Canadian Loonie.

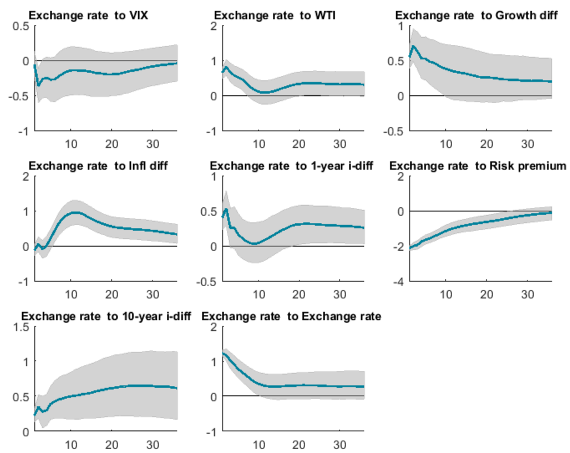
2/ Dynamic responses of the risk premium to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: 100 x risk premium. The shaded bands are 68 percent confidence intervals. An increase in the risk premium can be interpreted as an increase in the preferences for holding U.S. dollar-denominated assets vis a vis the Canadian Loonie.

3/ Forecast Error Variance Decomposition of the exchange rate. x-axis: months, y-axes: share of variance due to the innovations in the VAR. The shaded bands are 68 percent confidence intervals.

4/ Forecast Error Variance Decomposition of the risk premium. x-axis: months, y-axes: share of variance due to the innovations in the VAR. The shaded bands are 68 percent confidence intervals.

Figure 9B. Euro. Impulse Response Functions of the Exchange Rate and the risk Premium and Forecast Error Variance Decomposition of the Exchange Rate.

(a). Exchange Rate 1/



(b). Risk Premium 2/

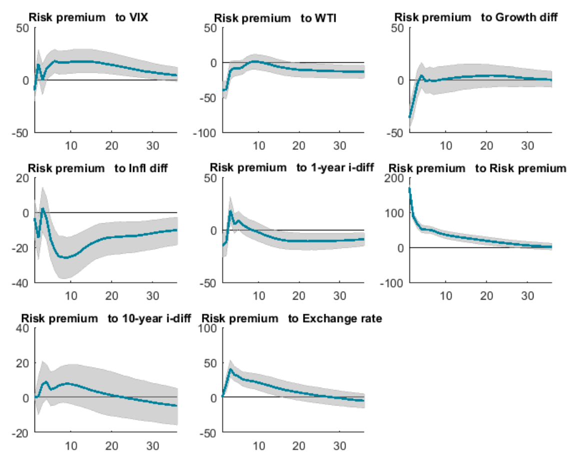
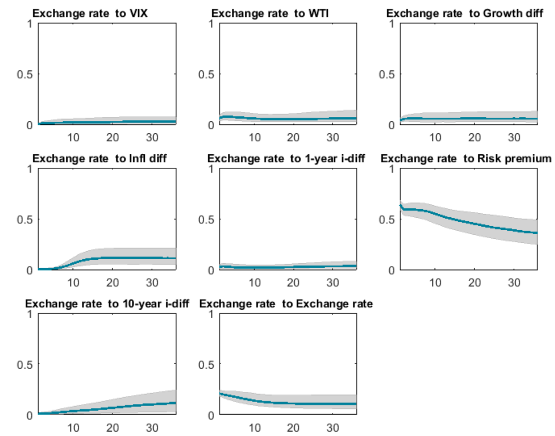
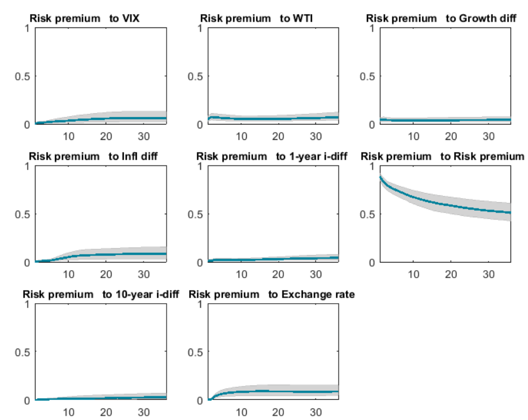


Figure 9B. Euro. Impulse Response Functions of the Exchange Rate and the risk Premium and Forecast Error Variance Decomposition of the Exchange Rate (Concluded)

(c). Exchange Rate – Forecast Error Variance Decomposition 3/



(d). Risk Premium– Forecast Error Variance Decomposition 4/



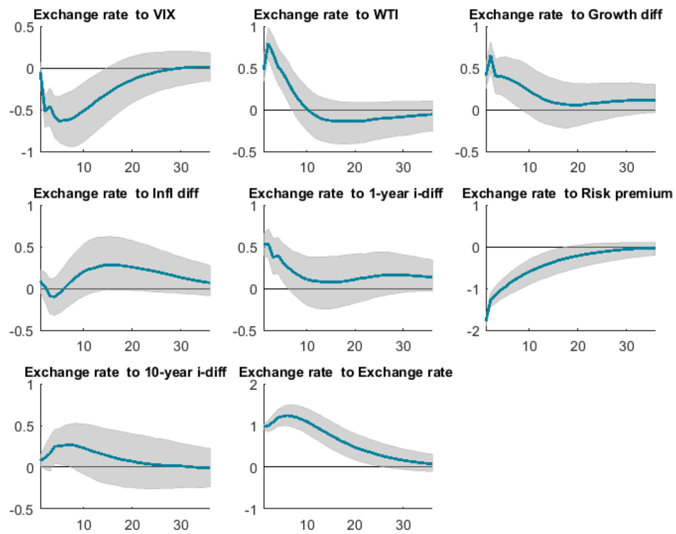
Source: Authors' calculations

1/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. dollar against the Euro.

2/ Dynamic responses of the risk premium to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the risk premium can be interpreted as an increase in the preferences for holding U.S. dollar-denominated assets vis a vis the Euro.

Figure 9C. United Kingdom. Impulse Response Functions of the Exchange Rate and the risk Premium and Forecast Error Variance Decomposition of the Exchange Rate.

(a). Exchange Rate 1/



(b). Risk Premium 2/

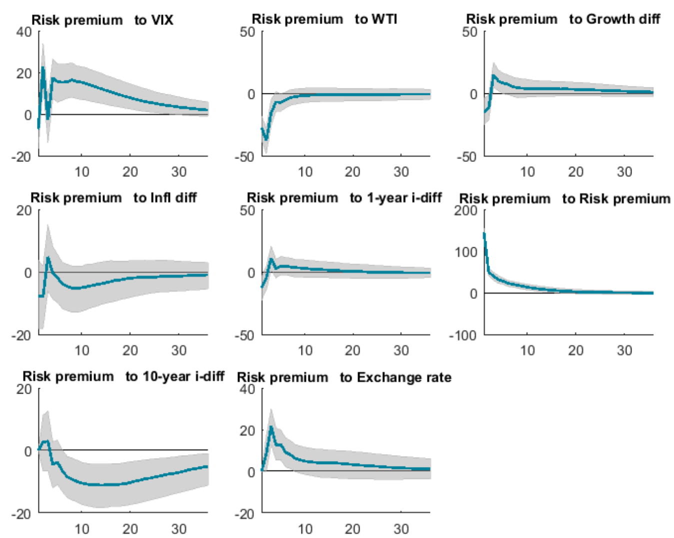
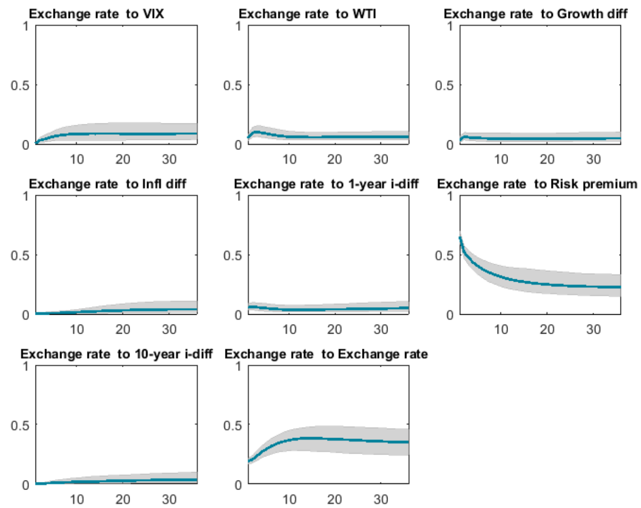
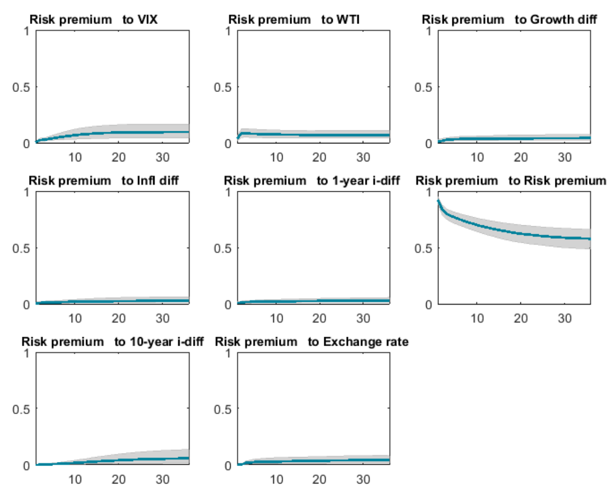


Figure 9C. United Kingdom. Impulse Response Functions of the Exchange Rate and the risk Premium and Forecast Error Variance Decomposition of the Exchange Rate (Concluded)

(c). Exchange Rate – Forecast Error Variance Decomposition 3/



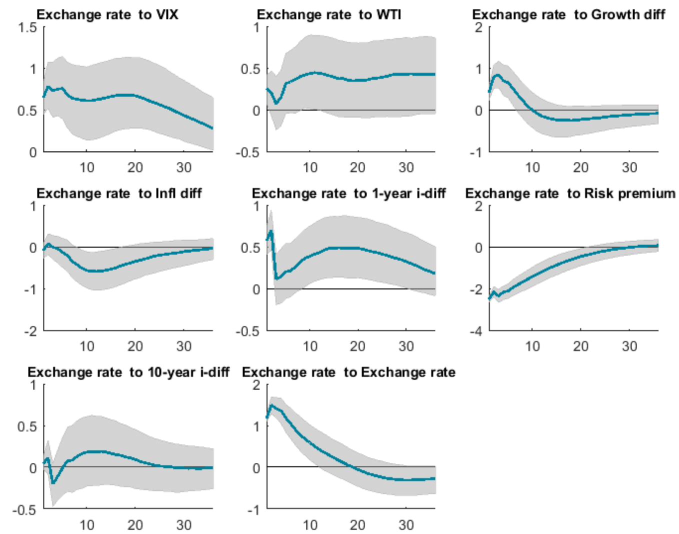
(d). Risk Premium– Forecast Error Variance Decomposition 4/



Source: Authors' calculations
1/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. dollar against the Pound.
2/ Dynamic responses of the risk premium to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the risk premium can be interpreted as an increase in the preferences for holding U.S. dollar-denominated assets vis a vis the the Pound.
3/ Forecast Error Variance Decomposition of the exchange rate. x-axis: months, y-axes: share of variance due to the innovations in the VAR. The shaded bands are 68 percent confidence intervals.
4/ Forecast Error Variance Decomposition of the risk premium. x-axis: months, y-axes: share of variance due to the innovations in the VAR. The shaded bands are 68 percent confidence intervals.

Figure 9D. Japan. Impulse Response Functions of the Exchange Rate and the risk Premium and Forecast Error Variance Decomposition of the Exchange Rate.

(a). Exchange Rate 1/



(b). Risk premium 2/

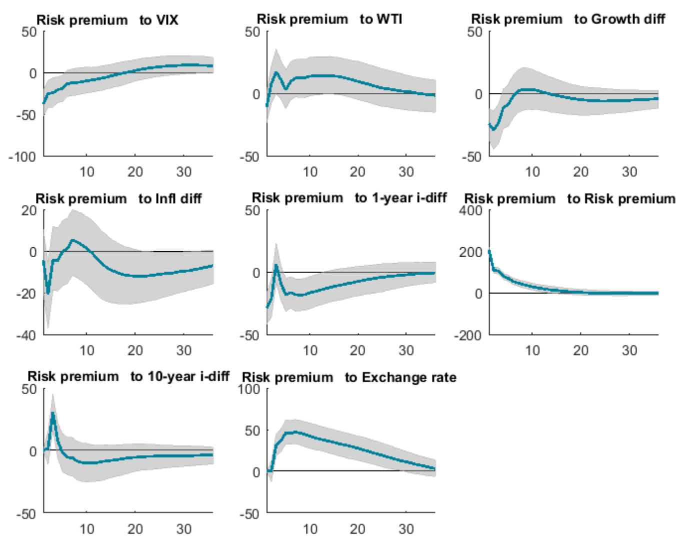
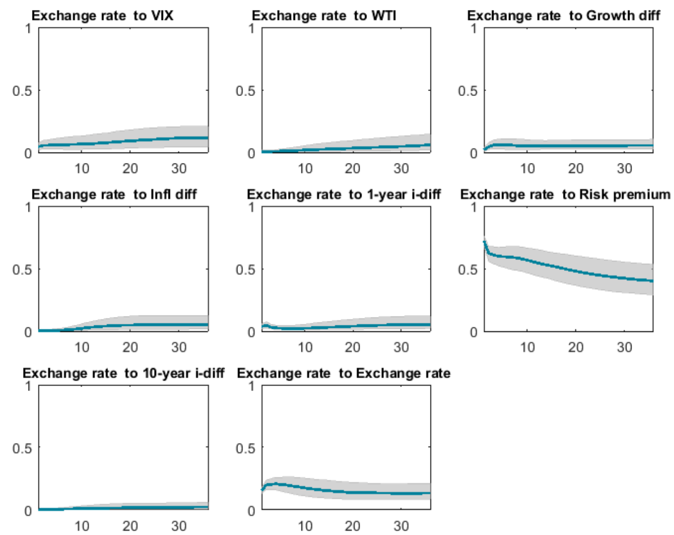
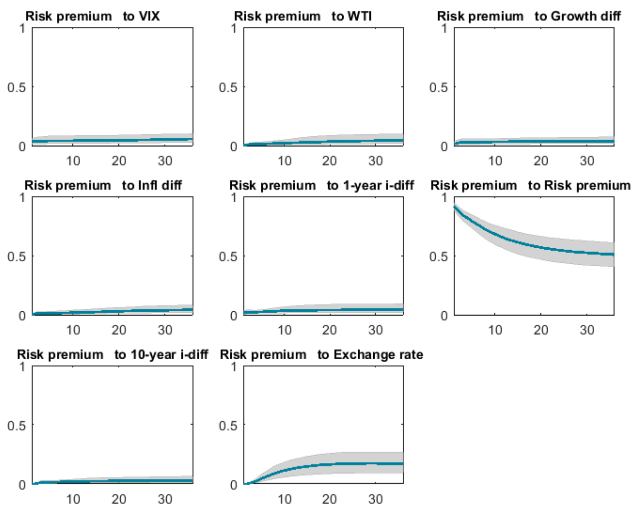


Figure 9D. Japan. Impulse Response Functions of the Exchange Rate and the risk Premium and Forecast Error Variance Decomposition of the Exchange Rate. (Concluded)

(c). Exchange Rate – Forecast Error Variance Decomposition 3/

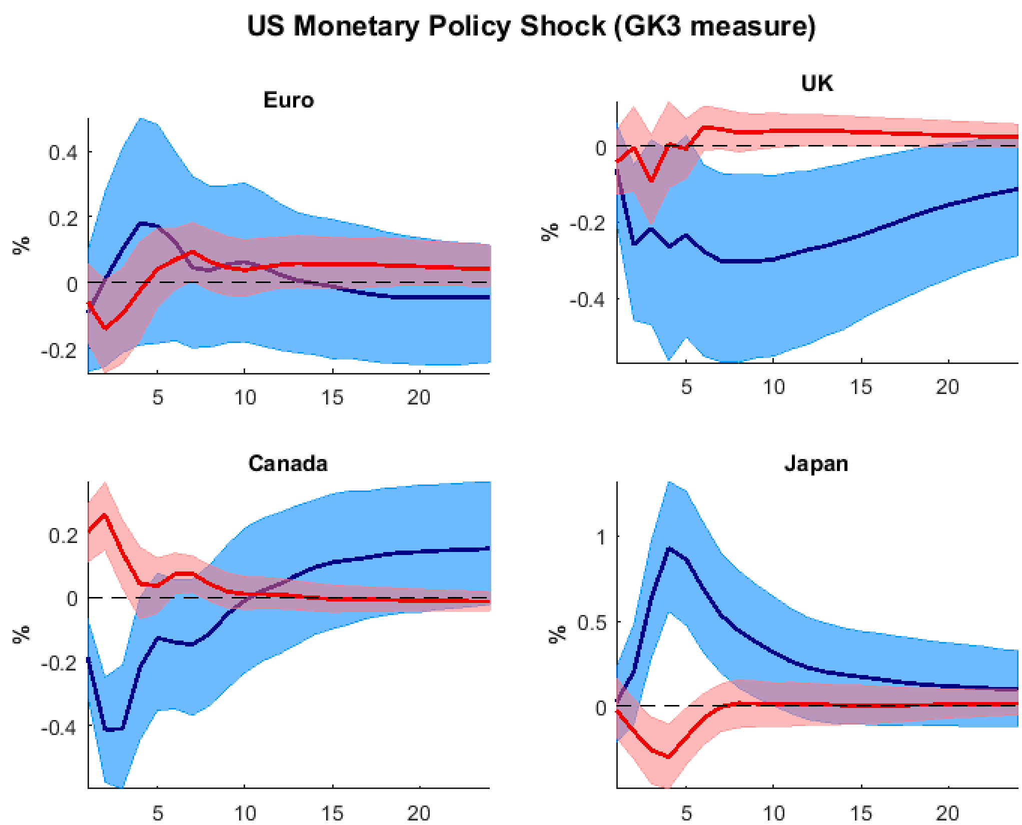


(d). Risk Premium– Forecast Error Variance Decomposition 4/



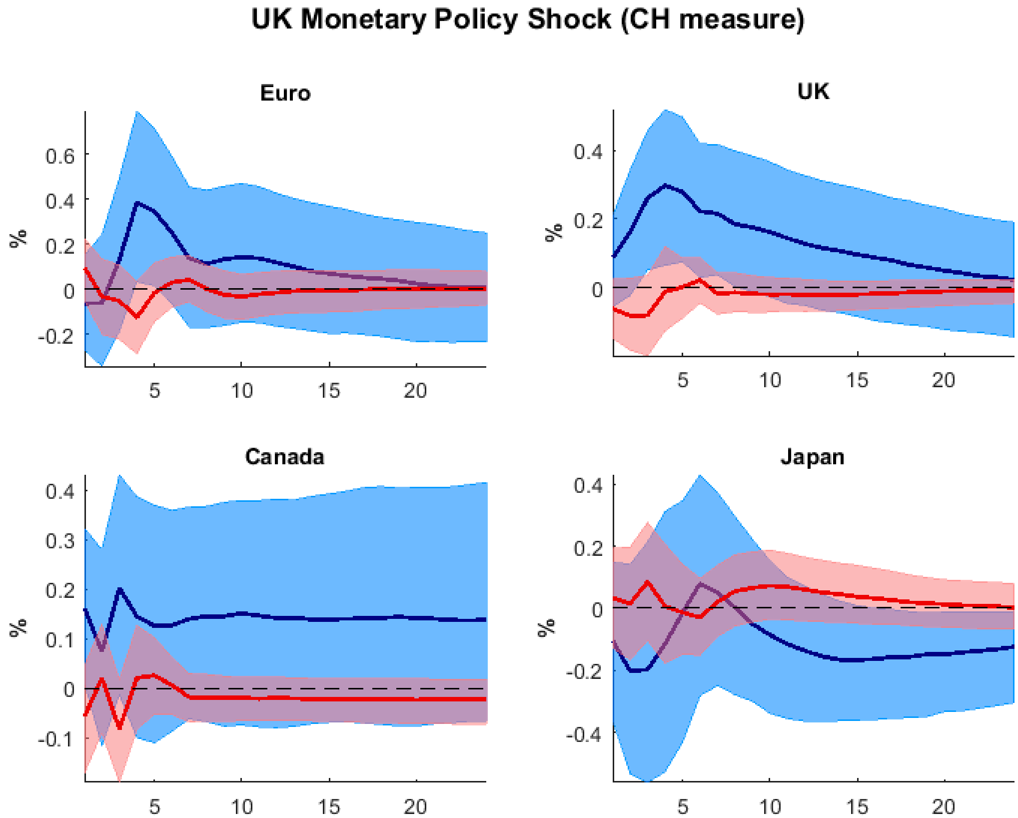
Source: Authors' calculations
1/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. dollar against the Yen.
2/ Dynamic responses of the risk premium to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the risk premium can be interpreted as an increase in the preferences for holding U.S. dollar-denominated assets vis a vis the Yen.
3/ Forecast Error Variance Decomposition of the exchange rate. x-axis: months, y-axes: share of variance due to the innovations in the VAR. The shaded bands are 68 percent confidence intervals.
4/ Forecast Error Variance Decomposition of the risk premium. x-axis: months, y-axes: share of variance due to the innovations in the VAR. The shaded bands are 68 percent confidence intervals.

Figure 10A. Impulse Response Functions of the Exchange Rate and the risk Premium to a U.S. Monetary Policy Shock.



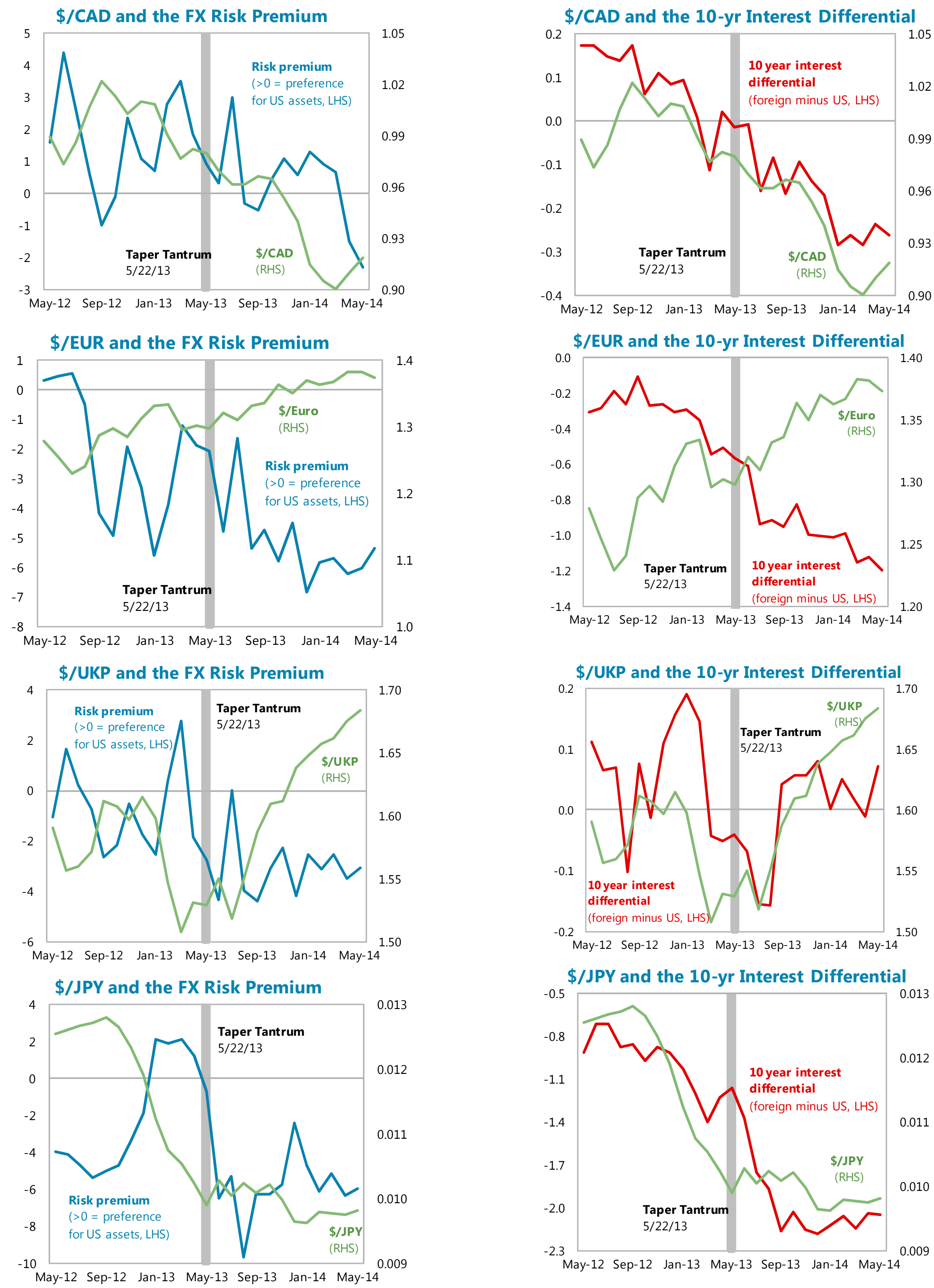
Sources: Authors' calculations
Note. Dynamic responses of the exchange rate and the risk premium to a standard deviation innovation to the monetary policy shock. Red lines show impulse responses to the risk premium while blue show impulse responses to the exchange rates. The shaded bands are 68 percent confidence intervals. x-axis: months, y-axes: percentage points. An increase in the exchange rate implies a depreciation of the U.S. dollar and an increase in the risk premium can be interpreted as an increase in the preferences for holding U.S. dollar-denominated assets.

Figure 10B. Impulse Response Functions of the Exchange Rate and the risk Premium to a U.K. Monetary Policy Shock.



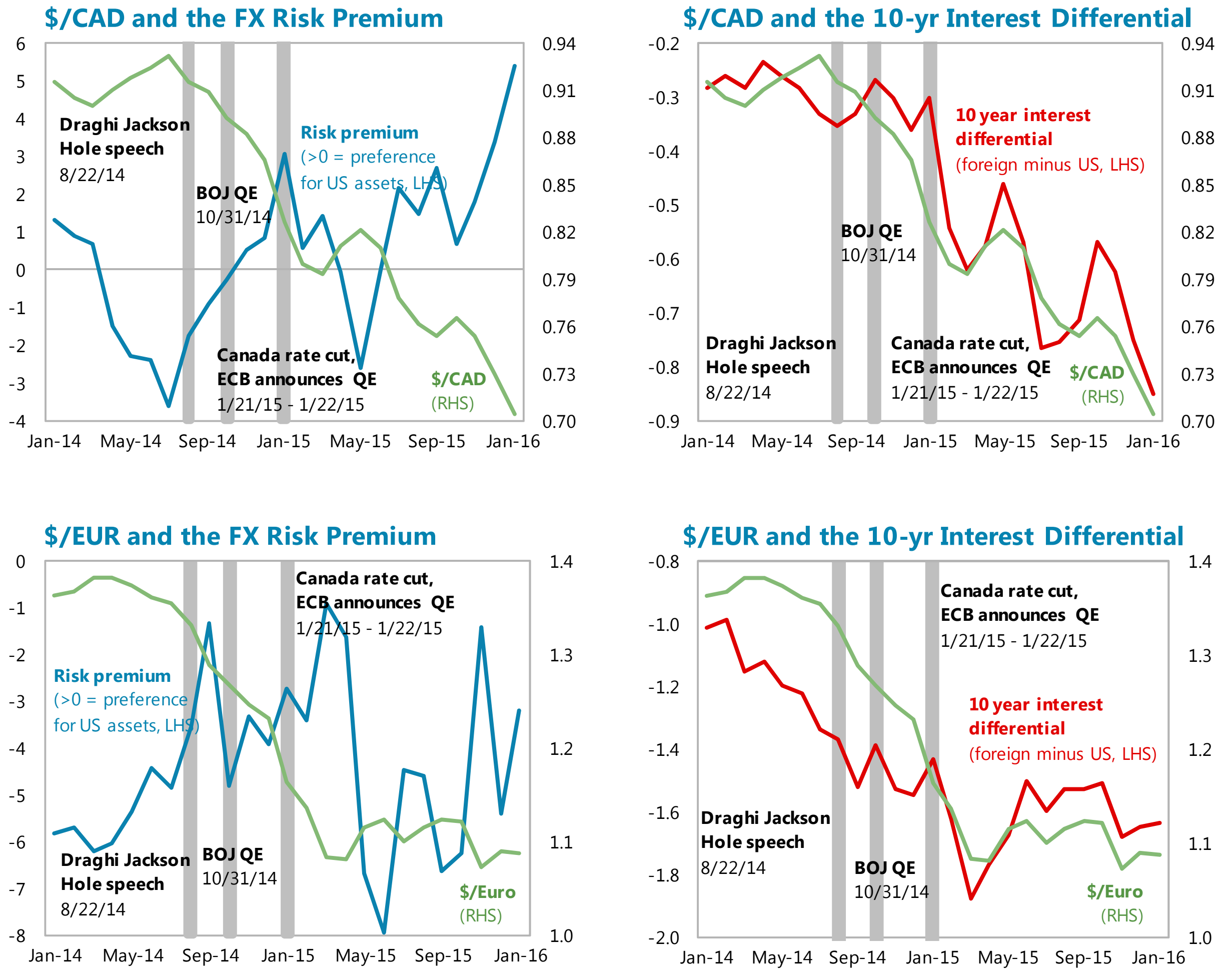
Source: Authors' calculations
Note. Dynamic responses of the exchange rate and the risk premium to a standard deviation innovation to the monetary policy shock. Red lines show impulse responses to the risk premium while blue show impulse responses to the exchange rates. The shaded bands are 68 percent confidence intervals. x-axis: months, y-axes: percentage points. An increase in the exchange rate implies a depreciation of the U.S. dollar and an increase in the risk premium can be interpreted as an increase in the preferences for holding U.S. dollar-denominated assets.

Figure 11 Event Study: Taper Tantrum



Sources: Bloomberg; Consensus Economics; and Authors' calculations

Figure 12 Event Study: Non-US Monetary Policy Announcements/Surprises



Sources: Bloomberg; Consensus Economics; and Authors' calculations

APPENDIX 1. ANALYTICAL DERIVATION OF THE FX RISK PREMIUM

In absence of default risk, capital controls, and transaction costs the following no-arbitrage relation between the spot and forward exchange rate (S and F) has to hold at all times and at various maturities

(1.5)
$$\exp^{i_t} = \exp^{i_t^*} \frac{F_t}{S_t}$$

where F_t is the time-t forward exchange rate at the maturity corresponding to the one of the deposit rates.[1] In absence of the forward contract the exchange rate risk is not hedged. We can replace the forward with the future spot rate in the above formula and—if a stochastic discount factor, $mt, t + j$, to price future (nominal) payoffs exists—in risk-adjusted expected terms we must have[2]

(1.6)
$$E_t\left[m_{t,t+j}\left(1-\exp^{i_t^*-i_t}\frac{S_{t+j}}{S_t}\right)\right]=0$$

Since $E_t[\mathrm{m}_{t,t+1}] = \exp^{i_t}$, we can write

(1.7)
$$\exp^{-i_t^*} = E_t\left[m_{t,t+j}\frac{S_{t+j}}{S_t}\right]$$

Under log-normality we have

(1.8)
$$i_t^* - i_t + E_t\Delta s_{t+j} + 0.5[\mathrm{var}_t(\mathrm{m}_{t+j}) + \mathrm{var}_t(\Delta s_{t+j})] + \mathrm{cov}(\mathrm{m}_{t+j}, \Delta s_{t+j});$$

hence, our FX risk premium of horizon j is

(1.9)
$$rp_{t,j} = -0.5[\mathrm{var}_t(\mathrm{m}_{t+j}) + \mathrm{var}_t(\Delta s_{t+j})] - \mathrm{cov}(\mathrm{m}_{t+j}, \Delta s_{t+j}).$$

A similar derivation can be done using the foreign stochastic discount factor.

---

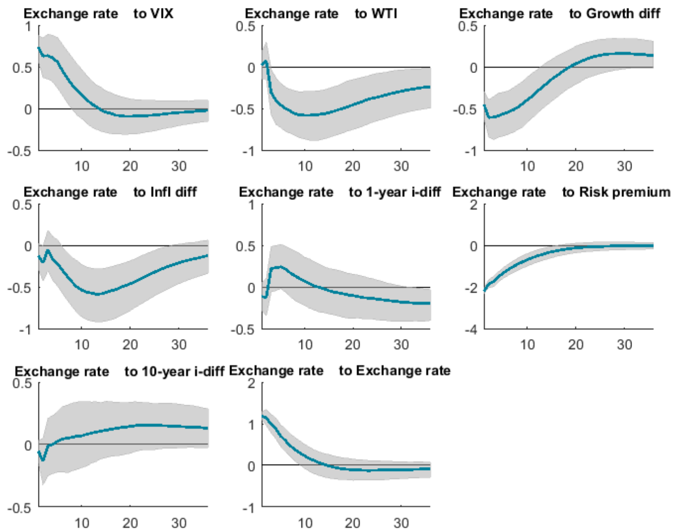
[1] If equation (1.5) does not hold, say $\exp^{i_t} < \exp^{i_t^*} F_t / S_t$, it is possible to follow a simple arbitrage strategy by borrowing in domestic currency, converting the funds in foreign currency and buying a foreign bond, and locking the future bond proceeds in domestic currency by entering into the forward contract today.

[2] The existence of a positive stochastic discount factor is equivalent to absence of arbitrage opportunities (see Cochrane 2005 for example).

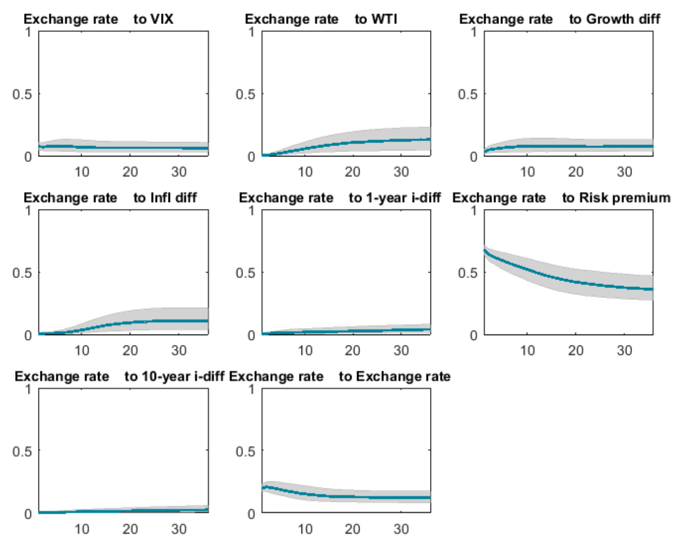
APPENDIX 2. VAR ROBUSTNESS CHECKS

Figure A1. Canada Dollar per Euro Bilateral Exchange Rate. Impulse Response Functions of the Exchange Rate and the Risk Premium and Forecast Error Variance Decomposition of the Exchange Rate.

(a) Exchange Rate – Impulse Response Functions 1/



(b) Exchange Rate – Forecast Error Variance Decomposition 2/



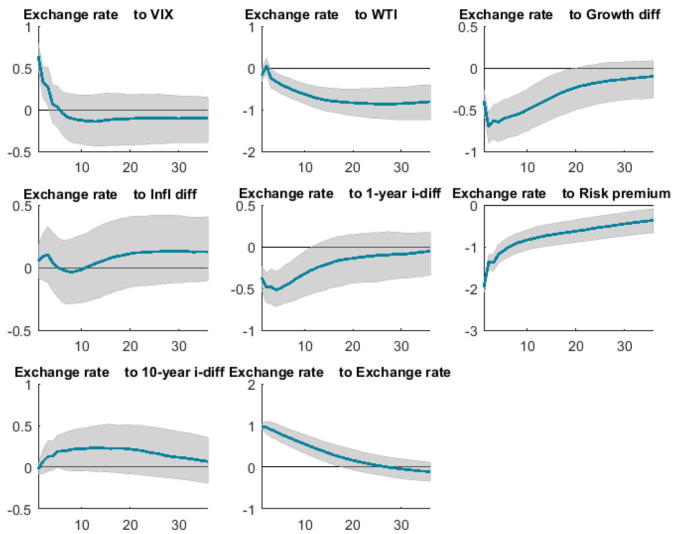
Source: Authors' calculations

1/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the Loonie against the Euro.

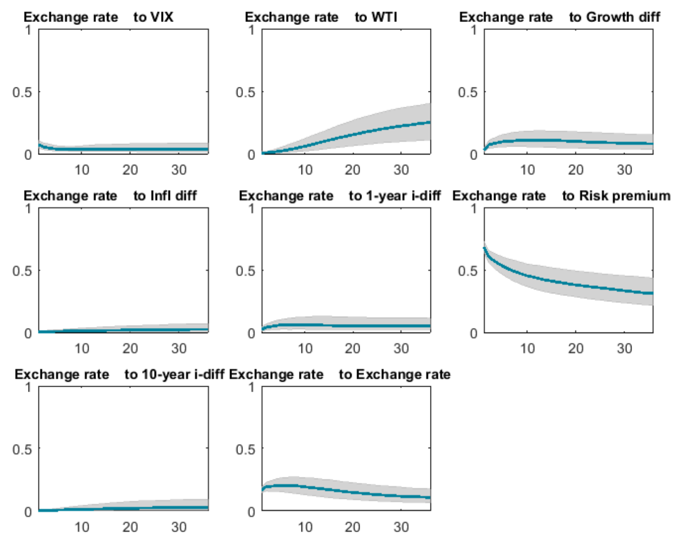
2/ Forecast Error Variance Decomposition of the exchange rate. x-axis: months, y-axes: share of variance due to the innovations in the VAR. The shaded bands are 68 percent confidence intervals.

Figure A2. Canadian Dollar per UK Pound Bilateral Exchange Rate. Impulse Response Functions of the Exchange Rate and the Risk Premium and Forecast Error Variance Decomposition of the Exchange Rate.

(a) Exchange Rate – Impulse Response Functions 1/



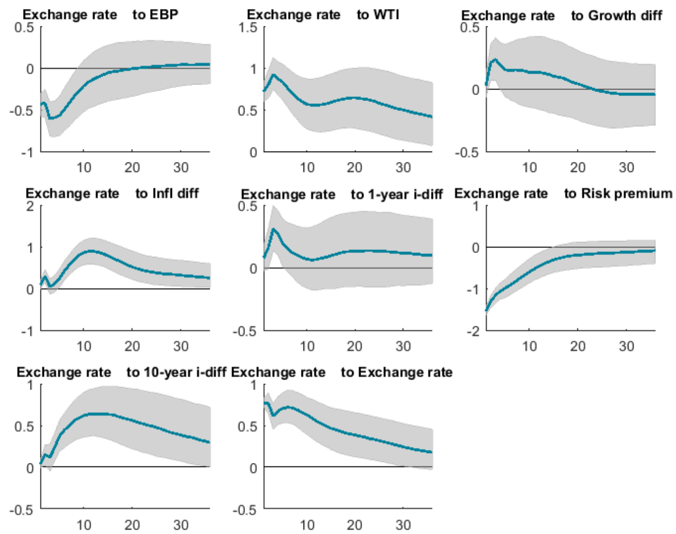
(b) Exchange Rate – Forecast Error Variance Decomposition 2/



Source: Authors' calculations
1/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the Loonie against the Pound.
2/ Forecast Error Variance Decomposition of the exchange rate. x-axis: months, y-axes: share of variance due to the innovations in the VAR. The shaded bands are 68 percent confidence intervals.

Figure A3. Impulse Response Functions of the Exchange Rate – Excess Bond Premium instead if VIX. 1993M1 – 2016M03

(a) Canada 1/



(b) United Kingdom 2/

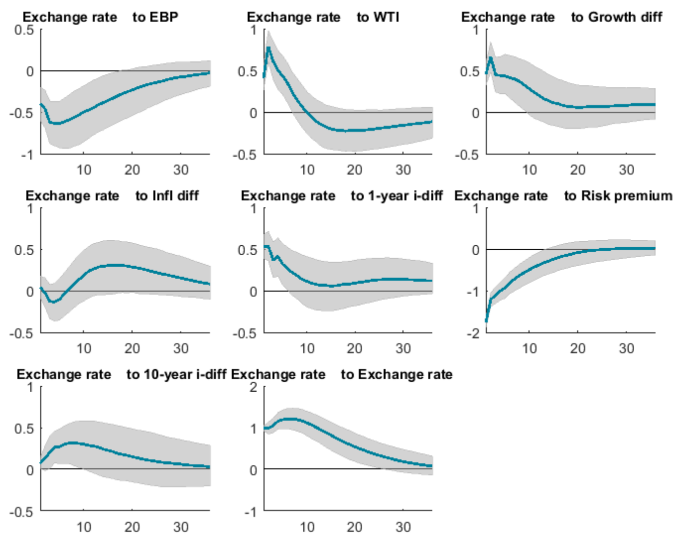
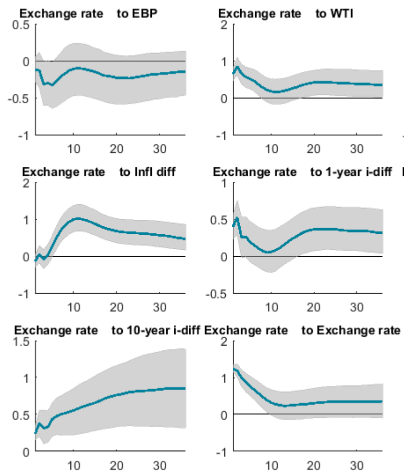
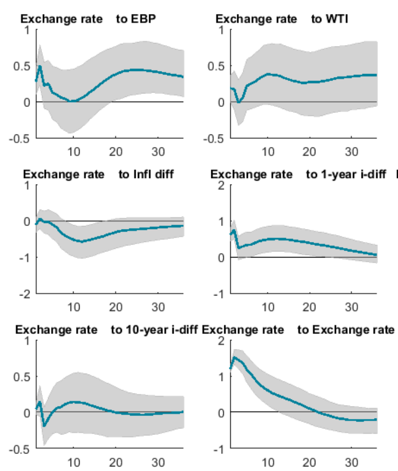


Figure A3. Impulse Response Functions of the Exchange Rate – Excess Bond Premium instead if VIX. 1993M1 – 2016M03 (Concluded)

(c) Euro 3/



(d) Japan 4/



Source: Authors' calculations

1/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S Dollar against the Loonie.

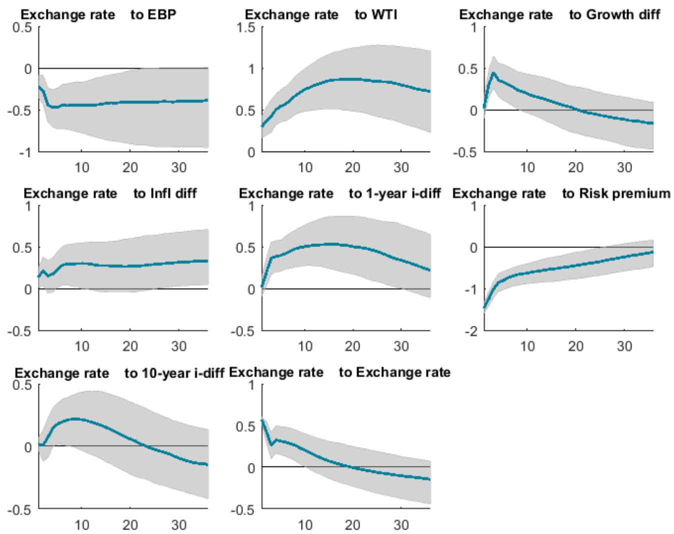
2/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. Dollar against the British Pound.

3/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. Dollar against the Euro.

4/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. Dollar against the Yen.

Figure A4. Impulse Response Functions of the Exchange Rate – Excess Bond Premium instead if VIX. 1993M1 – 2007M12

(a). Canada 1/



(b). United Kingdom

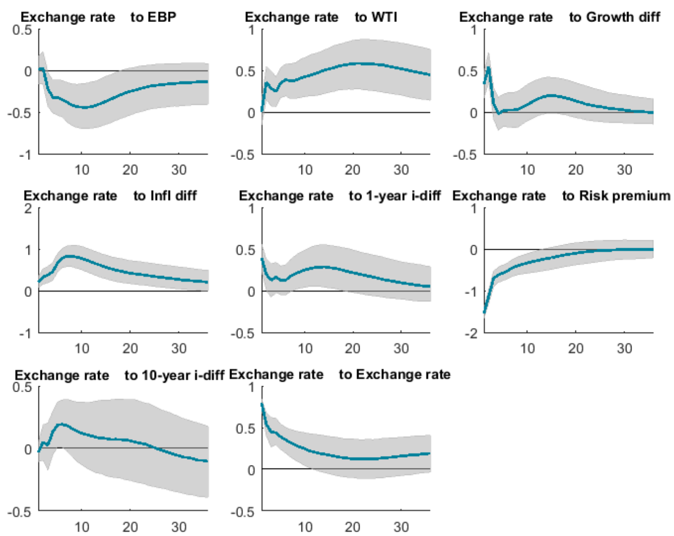
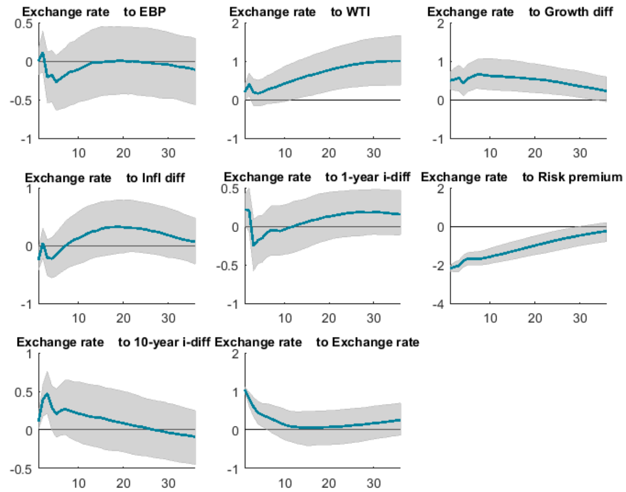
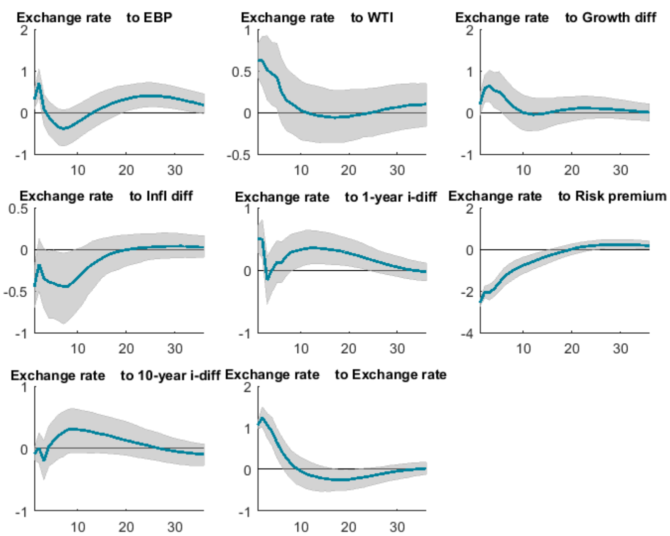


Figure A4. Impulse Response Functions of the Exchange Rate – Excess Bond Premium instead if VIX. 1993M1 – 2007M12 (Concluded)

(c) Euro 3/



(d). Japan 4/



Source: Authors' calculations

1/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. Dollar against the Loonie.

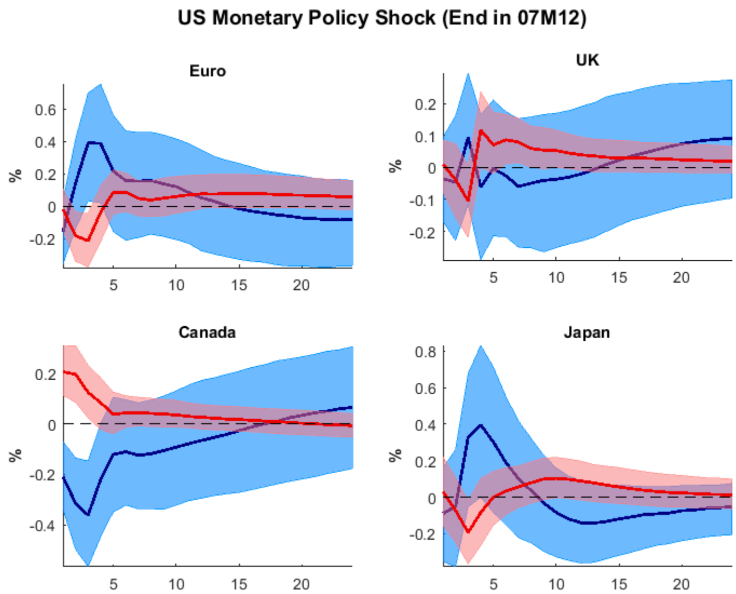
2/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. Dollar against the UK Pound.

3/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. Dollar against the Euro.

4/ Dynamic responses of the exchange rate to a standard deviation innovation to all shocks in the VAR. x-axis: months, y-axes: percentage points. The shaded bands are 68 percent confidence intervals. An increase in the exchange rate implies a depreciation of the U.S. Dollar against the Yen.

Figure A5. Impulse Response Functions of the Exchange Rate and the Risk Premium to a U.S. Monetary Policy Shock 1993M1-2007M12

(a) Gertler and Karadi Shock 1/



(b) Coibion Measures of Monetary Policy Shocks 2/

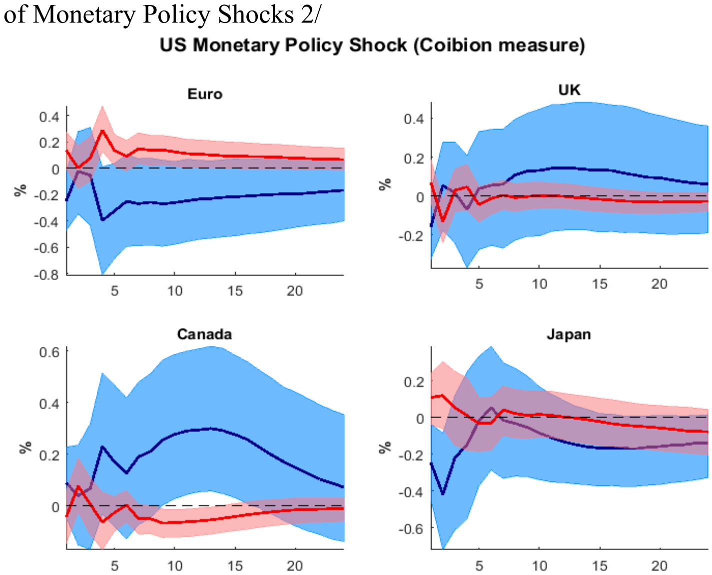
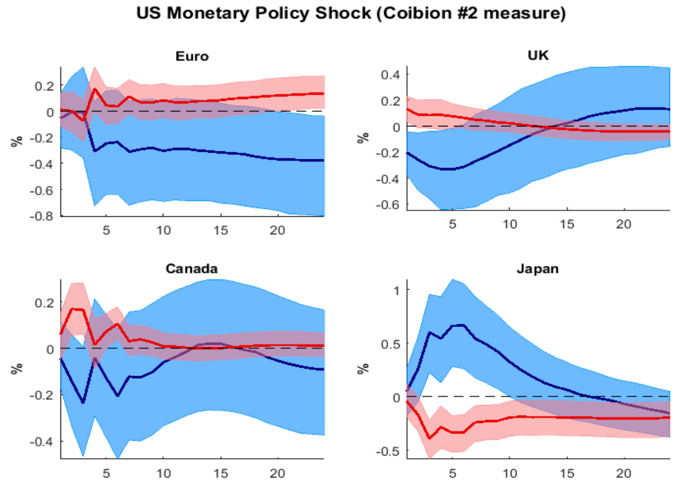


Figure A5. Impulse Response Functions of the Exchange Rate and the Risk Premium to a U.S. Monetary Policy Shock 1993M1-2007M12 (Concluded)



Source: Authors' calculations

1/ Dynamic responses of the exchange rate and the risk premium to a standard deviation innovation to the monetary policy shock. Red lines show impulse responses to the risk premium while blue show impulse responses to the exchange rates. The shaded bands are 68 percent confidence intervals. x-axis: months, y-axes: percentage points. An increase in the exchange rate implies a depreciation of the U.S. dollar and an increase in the risk premium can be interpreted as an increase in the preferences for holding U.S. dollar-denominated assets.

2/ Dynamic responses of the exchange rate and the risk premium to a standard deviation innovation to the monetary policy shock computed by Coibion. Red lines show impulse responses to the risk premium while blue show impulse responses to the exchange rates. The shaded bands are 68 percent confidence intervals. x-axis: months, y-axes: percentage points. An increase in the exchange rate implies a depreciation of the U.S. dollar and an increase in the risk premium can be interpreted as an increase in the preferences for holding U.S. dollar-denominated assets.