Unconventional Monetary Policy and International Risk Premia*

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Abstract

We estimate a structural VAR in US and foreign interest rates and exchange rates. Our objective is to assess the effects of monetary policy shocks at the zero lower bound, with these shocks identified through the method of external instruments, thus avoiding imposing implausible short-run restrictions. Having obtained the dynamic effects of monetary policy shocks on future interest rates and exchange rates, we can compute the effects on financial market risk premia as a by-product. We find that US monetary policy easing shocks significantly lower domestic and foreign bond risk premia, and lead to dollar depreciation. There is some evidence that they may lower foreign exchange risk premia.

*The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

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1 Introduction

In the wake of the Great Recession, the world's largest central banks set short term nominal interest rates to the effective zero lower bound (ZLB) and began adopting unconventional monetary policies, such as forward guidance and large scale asset purchases. These policies have renewed interest in the role of monetary policy in explaining the dynamics of exchange rates, and domestic and foreign interest rates. By affecting exchange rates and foreign interest rates, monetary policy shifts are a potential source of unintended spillovers onto other countries. Indeed, these issues are old ones in empirical international finance, that predate the recent period of unconventional monetary policy (Eichenbaum and Evans, 1995; Kim, 2001; Kim and Roubini, 2000; Faust et al., 2003), but the answers are potentially different at the ZLB.

Much of the literature addresses these questions using a vector autoregression (VAR) in interest rates (domestic and foreign) and exchange rates. The identification of monetary policy shocks is however contentious. Several papers achieve identification by positing a recursive ordering in which it is assumed that US monetary policy shocks have no immediate effect on foreign interest rates (Eichenbaum and Evans, 1995; Kim and Roubini, 2000). However, there is a considerable "event-study" literature showing that global interest rates do indeed respond immediately and substantively to US monetary policy shocks (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). In this paper, we propose a different and, we hope, more credible approach to identification of the structural monetary policy shocks. We use a variant of the method of external instruments (Stock and Watson, 2012; Olea et al., 2013; Gertler and Garadi, 2015; Mertens and Ravn, 2013), where the ordering of the variables does not matter in identification. This structural VAR then allows us to trace out the dynamic effects of a monetary policy shock on domestic and foreign interest rates, as well as exchange rates. As a by-product, we can also compute out the effects of the monetary policy shock on financial market risk premia: the domestic term premium, the foreign term premium, and the foreign exchange risk premium. We focus primarily on the effects of US monetary policy shocks, but we also include a brief analysis of the impact of Bank of England, ECB and Bank of Japan monetary policy shocks.

This framework gives us a complete picture of the international effects of unconventional monetary policy on asset prices and risk premia. It is clear that foreign exchange risk premia are time-varying (Fama, 1984; Engel, 1996), but the existing empirical results on whether monetary policy surprises affect foreign exchange risk premia are more mixed (Kim and Roubini, 2000; Faust and Rogers, 2003). In other words, it is clear that uncovered interest parity (UIP) does not hold *unconditionally*, but the existing evidence is less clear on whether UIP holds *conditional* on monetary policy surprises. We will revisit this issue in the context of unconventional monetary policy.

The plan for the remainder of this paper is as follows. In section 2, we describe our empirical methodology. Section 3 contains the empirical results, and section 4 concludes.

2 Methodology and Data

Our approach starts from an assumption that there is an nx1 vector of monthly variables, Y_t including interest rates and exchange rates, that follows a VAR(p):

$$A(L)Y_t = \varepsilon_t \tag{1}$$

where ε_t denote the reduced form forecast errors. All variables are linearly detrended. We further assume that these reduced form errors can be related to a set of underlying structural shocks :

$$\varepsilon_t = R\eta_t \tag{2}$$

where η_t is a vector of structural shocks. Partition η_t as $(\eta_{1t}, \eta'_{2t})'$ where η_{1t} is the monetary policy shock and η_{2t} is an $(n-1)$x1 vector of other shocks. The fact that the monetary policy shock is ordered first is for notational convenience only. The ordering of variables is irrelevant as a Choleski decomposition will not be used for identification. Our approach to identification instead involves the method of external instruments. We define Z_t as the intraday change in a domestic interest rate in a short window bracketing the time of any monetary policy announcement in month t. If there is no monetary policy announcement in that month, then $Z_t = 0$. If there are multiple monetary policy announcements, then it is the sum of the intraday changes bracketing all of those announcements. Our first assumption is that Z_t, our external instrument, is correlated with the monetary policy shock and uncorrelated with all other structural shocks:

Assumption A1: $E(\eta_{1t}Z_t) = \alpha$ and $E(\eta_{2t}Z_t) = 0$.

We further define X_t as a vector of changes in the elements of Y_t in a daily or intradaily window bracketing the time of any monetary policy announcement in month t.[1] If there is any element of X_t for which these data are not available, set that to the corresponding element of ε_t. Our second assumption is that any shocks to Y_t that occur away from the time of the monetary policy announcement cannot be correlated with the jump that is associated with the monetary policy news:

Assumption A2: $E(Z_t(\varepsilon_t - X_t)) = 0$.

Clearly assumption A2 implies that $E(Z_t X_t) = E(Z_t \varepsilon_t)$. Our approach proceeds as follows. We first estimate the VAR, selecting the lag order by the Bayes Information Criterion (BIC), and take the residuals e_t. We then construct X_t from daily or intradaily data (and e_t, if necessary). We regress X_t onto Z_t. This identifies the first column of R up to scale and sign.[2] Coupled with the estimate of $A(L)$, this allows us to trace out the effect of the monetary policy shock on $E_t(Y_{t+j})$. This methodology essentially involves the external instruments approach, but we extend it by using the fact that data at higher-than-monthly frequency are available for some elements of Y_t. The methodology also draws on the "event study" approach, as we use high-frequency data around announcements in both Z_t and X_t.[3] However, because we embedding this in an identified VAR, we can trace out the full dynamic effect of the monetary policy shock, not just the instantaneous effect as is standard in the event-study literature.

We let Y_t be three-month, five-year and ten-year US zero-coupon bond yields, the log foreign exchange rate, the three-month and ten-year foreign zero-coupon bond yields, and the log of US employment and core CPI, and the BAA-Treasury spread

[1] This window must subsume the entire intraday window used in constructing Z_t.

[2] We could envision multiple instruments, in which the regression of e_t on Z_t involves a reduced rank regression, as described in Olea et al. (2013). But if there is a single monetary policy shock, then it has to be a maintained assumption that $E(\epsilon_t Z_t')$ has rank 1.

[3] The high-frequency data in X_t permits much tighter inference. We could simply regress the full vector of reduced form residuals on Z_t, and this would be the standard external instruments approach, but the resulting confidence intervals for impulse responses would be much wider.

(a widely-used credit spread (Christiano et al., 2014)). There are thus 9 variables in the VAR. The zero-coupon bond yields all come from the dataset of Wright (2011), updated to the present. Let $r_t(m)$ and $r_t^*(m)$ denote the m-month domestic and foreign zero-coupon yields, respectively. Let s_t denote the exchange rate, defined as dollars per unit of foreign currency. For our external instrument, Z_t, we use the change in on-the-run five-year yields from 15 minutes before the time of FOMC announcements to 1 hour 45 minutes afterwards on the days of FOMC meetings. For X_t, we observe daily data on the zero coupon yields and intradaily data on the foreign exchange rate (again from 15 minutes before to 1 hour and 45 minutes after FOMC announcements). The sample period is January 1990 to March 2015 (except January 1999 to March 2015 where the euro area is the foreign country). However, because we are interested in the effects of announcements during the era of unconventional monetary policy, for our external instrument Z_t, we only consider announcements since October 2008—that is we run the regression of X_t on Z_t for this subsample alone. The dates of the unconventional monetary policy period correspond to those in Rogers et al. (2014) updated to the present. As the data are persistent, estimation of the VAR and inference is conducted by the bias-adjusted bootstrap of Kilian (1997).

The VAR immediately allows us to trace out the effects of the monetary policy shock on future values of Y_t. But, because expectations can be measured from the VAR, it also allows us to work out the effects of the monetary policy shock on various financial market risk premia. These include the domestic term premium, defined as:

$$TP_t(m) = r_t(m) - E_t(\frac{1}{m/3}\Sigma_{i=0}^{m/3-1} r_{t+3i}(3)) \tag{3}$$

the foreign term premium, defined as:

$$TP_t^*(m) = r_t^*(m) - E_t(\frac{1}{m/3}\Sigma_{i=0}^{m/3-1} r_{t+3i}^*(3)) \tag{4}$$

and the average annualized foreign exchange risk premium over the next m months, defined as:

$$FP(m) = \frac{1}{m/3}\Sigma_{i=0}^{m/3-1}[E_t r_{t+3i}^*(3) - E_t r_{t+3i}(3) + 400(E_t s_{t+3i+3} - E_t s_{t+3i})] \tag{5}$$

For these definitions, the short rate is a three-month interest rate but the time subscripts refer to months, consistent with the VAR. Examining the effect of the monetary policy shock on each of these risk premia gives us additional insight into the channels by which monetary policy may be effective. Finally, we can compute the effect of the shock on the returns on a portfolio that is long an m-month foreign bond and short a corresponding-maturity domestic bond. This is the effect of the monetary policy shock on $m(r_t^*(m) - r_t(m)) + s_t$. This can be thought of as a generalized carry-trade return of a kind considered by Lustig et al. (2013)—the standard carry-trade instead uses short maturity interest rates.

Our paper is related to the large and fast-growing literature on the effects of unconventional monetary policy. Authors such as Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgenson (2011) and Christensen and Rudebusch (2012) have examined the change in government bond yields and term premia—as estimated by affine term structure models—on the days of specific unconventional monetary policy announcements. Wright (2012) and Rogers et al. (2014) used a methodology based on identification through heteroskedasticity to trace out the effects of monetary policy surprises on interest rates. Kiley (2013) estimates the *one-day* effects of monetary policy surprises on foreign and domestic long-term interest rates and on exchange rates. He defines the UIP deviation as the hold-to-maturity excess returns on the foreign long bond over the domestic long bond, i.e. $\frac{m}{12}(r_t^*(m)-r_t(m))+100(E_{t+m}s_{t+m}-s_t)$. This is different from our (more conventional) definition, and combines the foreign exchange premium with the difference between foreign and domestic term premia[4]. Under the assumption that m is sufficiently large that the monetary policy surprise has no effect on $E_{t+m}s_{t+m}$, Kiley (2013) finds that monetary policy surprises do not significantly affect the UIP deviation defined in this way. The present paper is however the first to use a vector autoregression identified with external instruments to measure the full dynamic effects of unconventional monetary policy surprises on foreign and domestic interest rates, and exchange rates. As a by-product, this then gives us estimates of the effects of monetary policy surprises on the full set of financial market risk premia given by equations (3)-(5).

It should also be emphasized that several papers, including Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgenson (2011) and Christensen and Rudebusch (2012), have analyzed the effects of specific unconventional monetary policy announcements, assuming that they were entirely unanticipated by the markets. This is a reasonable assumption in relation to some announcements, for example during the first phase of quantitative easing in the United States (QE1). But many other unconventional monetary policy announcements have been partially anticipated by markets. This is not a problem for our methodology, as long as there is some news coming out in monetary policy announcements. At the same time, it should be emphasized that the external instruments methodology used in this paper only identifies monetary policy up to a scale factor. Also, we do not separate out the effects of monetary policy

[4] To be precise, in terms of equations (3)-(5), the Kiley (2013) definition of the UIP deviation is $\frac{m}{12}(TP_t^*(m)-TP_t(m)+FP(m))$

operating via forward guidance and asset purchases—rather we are estimating the total effects of monetary policy news.

3 Empirical Results

The monetary policy shock is scaled to lower US five-year yields by 25 basis points. As discussed earlier, the monetary policy announcement is only estimated up to scale—that is, given the size of the shock, we estimate the dynamic effects on interest rates and exchange rates.

First, we check instrument relevance. The "first stage" regression is a regression of the daily change in five-year yields onto the instrument. This is 301—far above the cutoff in the weak instruments literature (Stock and Yogo, 2005; Stock et al., 2002). Weak instruments are not an issue in this application.

Figure 1 shows the estimated effect of the monetary policy shock on the exchange rate at different horizons (in quarters). Bootstrap confidence intervals are also included, constructed as described by Kilian (1997)—here and throughout this paper, all confidence intervals and references to statistical significance are at the 68 percent level. The monetary policy shocks cause the foreign currency to appreciate significantly. The effect tends to wear off over time, but slowly. Unlike Eichenbaum and Evans (1995) (who considered VARs with recursive identification), we find no evidence of delayed overshooting. The exchange rate effect is significantly positive for a few quarters for all three foreign currencies.

Figure 2 shows the estimated effect of the US monetary policy shock on the foreign interest rates, both three-month and ten-year. For all three countries, the monetary policy shock has no significant effect on three-month yields, but has a significantly negative effect on ten-year interest rates. The finding that monetary policy spillovers are greatest for longer term interest rates seems unsurprising because the ZLB was binding on the UK and Japan for this period, and so no easing action by the Fed can lower their short rates much further, while the European Central Bank was close to the ZLB and reached it near the end of the sample. The estimated instantaneous effect on foreign ten-year interest rates is slightly more than 10 basis points for the UK and Germany and a bit less for Japan.

Figure 3 shows the estimated effect of the monetary policy shock on the expected foreign exchange excess returns ($FP(m)$) at different horizons. The monetary policy shock is estimated to lower the foreign exchange risk premium for all three currencies. But the effect is statistically significant only for the pound and the yen at the very shortest horizons. Overall, the effects of the monetary policy shock on the foreign exchange risk premium do not suggest gross violations of UIP conditional on the monetary policy shock, and are instead broadly consistent with Dornbusch (1976). This contrasts with Eichenbaum and Evans (1995), who found that an easing monetary policy surprise would raise the foreign exchange risk premium.

Table 1 shows the estimated instantaneous effect of the monetary policy shock on the ten-year term premium in the UK, Germany and Japan. The point estimates of the effects on term premia are roughly the same as the effects on the ten-year yield—the effect on foreign long bond yields is estimated to be largely due to term premia. The confidence intervals are wide, but do not bracket zero.

Table 2 shows the estimated instantaneous effect of the monetary policy shock on a portfolio that is long the foreign ten-year bond and short the domestic ten-year bond. The monetary policy shock has no significant effect on the returns on this portfolio for the UK or euro area, but has a significantly negative effect on the returns on this portfolio for Japan.

All in all, from the results so far, we conclude that monetary policy easing shocks in the United States both depreciate the dollar and lower foreign term premia.

3.1 Effects of Monetary Policy on Domestic Term Premia

Our main focus in this paper is on the effects of monetary policy surprises on international risk premia, but our methodology also gives estimates of the effects of monetary policy surprises on domestic term premia. We estimated the effects of monetary policy surprises on US term premia in the VARs of the previous section. The precise results of course depend on which foreign country is included, but are qualitatively similar to each other, and to the results in a VAR that includes no foreign variables. Consequently, for the purpose of estimating effects on domestic term premia, we report results from a VAR in US three-month, five-year and ten-year interest rates, the log of employment and core CPI, and the BAA-Treasury spread.

The results are shown in Table 3. The monetary policy shock that lowers the five-year yield by 25 basis points is estimated to lower the term premium by 22 basis points, essentially explaining the full drop in yields. The confidence interval is wide, but there is clear evidence of a meaningful negative effect on term premia. Results for the ten-year term premium are similar.

3.2 Comparison with pre-ZLB era

The methodology that we propose applies in principle to the pre-ZLB era as well. Indeed, monetary policy in the pre-ZLB and ZLB eras have much in common. Kuttner (2001) and Gürkaynak et al. (2005) both show that over the past twenty years, FOMC announcements concerning the target federal funds rate have been largely anticipated by the market. Instead, FOMC announcements and communications have been important mainly because of information that they contain about the future path of monetary policy. But this is just a form of forward-guidance, although less explicit than during the ZLB era.

In Figures 4, 5 and 6, we show the estimated effects of the monetary policy shock on the exchange rate, foreign interest rates, and expected foreign exchange returns, where the VAR is estimated as before, but the external instrument is the fourth eurodollar futures contract from 15 minutes before the time of FOMC announcements to 1 hour 45 minutes afterwards, and the VAR residuals are regressed on this external instrument over the period from February 1994 to September 2008.

The effects of monetary policy surprises over the pre-ZLB era estimated in Figures 4-6 are generally similar to those in Figures 1-3. A 25 basis point reduction in five-year yields that is driven by monetary policy leads to dollar depreciation and lower interest rates abroad. But there are some differences. The point estimates of the exchange rate effects are smaller in the pre-ZLB sample. Also, in the pre-ZLB sample, three-month UK and Japanese interest rates are significantly lowered (unlike the post-October 2008 sample). The point estimates of the effects on foreign ten-year rates are smaller in the pre-ZLB sample. Also, there is no statistically significant effect on the foreign exchange risk premium in the pre-ZLB sample for any of the currencies, although the point estimates indicate that monetary policy easings *raise* the foreign exchange risk premia.

Table 4 shows the estimated effect of the US monetary policy shock on the ten-year term premium in the United Kingdom, Germany and Japan in the pre-ZLB sample. The effect is not statistically significant for Japan, but is significantly negative for the UK and Germany. Overall the evidence that US monetary policy shocks affect foreign term premia seems a little weaker over the pre-ZLB sample.

Table 5 shows the estimated instantaneous effect of the US monetary policy shock on a portfolio that is long the foreign ten-year bond and short the domestic ten-year bond in the pre-ZLB sample. The monetary policy shock has a significantly negative effect on the returns on this portfolio for the UK and Japan.

3.3 Foreign Monetary Policy Surprises

We applied precisely the same methodology to the case where the home country is the UK, the euro area or Japan. For the UK and Japan, the variables in the VAR, Y_t, consist of three-month, five-year and ten-year UK/Japanese zero-coupon bond yields, the log foreign exchange rate, the three-month and ten-year US zero-coupon bond yields, and UK/Japanese unemployment and log CPI. The external instruments are now intraday changes in UK or Japanese ten-year yields on monetary policy announcement days. The monetary policy surprise is normalized to lower UK/Japanese five-year bond yields by 25 basis points. For the euro area, the variables in the VAR consist of three-month, five-year and ten-year Germany zero-coupon bond yields, the log foreign exchange rate, the three-month and ten-year US zero-coupon bond yields, German unemployment and log CPI, and five-year zero-coupon Italian bond yields.[5] The external instrument is the spread between Italian and German yields, and the monetary policy shock is normalized to lower five-year Italian yields by 25 basis points. The somewhat different treatment of euro area monetary policy surprises is because, over this unusual period, accommodative actions of the ECB were clearly aimed at lowering government bond yields in Italy (and other countries whose sovereign bond markets were coming under significant pressure) rather than German bond yields. As in the US framework, the sample period is January 1990 to present for the VAR estimation of the residuals. For our external instrument Z_t, we only consider announcements during the unconventional monetary policy period—the dates of UK, euro-area and Japanese unconventional monetary policy announcements

[5] The Italian zero-coupon bond yields were obtained from the BIS.

correspond to those in Rogers et al. (2014) updated to the present.[6]

Figure 7 shows the estimated effects of UK, euro-area, and Japanese monetary policy shocks on their respective exchange rates. The Bank of England monetary policy easing that lowers five-year UK yields by 25 basis points is estimated to lead to pound depreciation viz-a-viz the dollar that is significant for a few quarters. The ECB monetary policy easing that lowers Italian five-year yields by 25 basis points leads to significant appreciation of the euro, while the corresponding Bank of Japan monetary policy easing has no significant exchange rate effect. The finding that ECB monetary policy easing leads the euro to *appreciate* may seem surprising, but recall that the euro was in danger of falling apart for most of our sample period. This is presumably the reason why actions that lowered Italian-German spreads, which we interpret as monetary policy easings, led to euro appreciation. Note that the January 2015 ECB announcement of larger-than-expected quantitative easing was accompanied by euro depreciation, and commentary attributed much of the depreciation of the euro in late 2014 to building expectations that the ECB would embark on a full-blown quantitative easing program. This however came at the tail end of our sample when concerns about the viability of the euro had ebbed. We conjecture that going forward ECB monetary policy easing surprises will lead to euro depreciation, unless substantial concerns of a disintegration of European monetary union resume.

Figure 8 shows the estimated effects of UK, euro-area and Japanese monetary policy shocks on US interest rates. The UK and Japanese monetary policy shocks significantly lower US ten-year yields for a few quarters. The euro area easing shock actually rasises US yields. Again this is probably because ECB easing shocks raised the chances of the survival of the euro and reduced safe-haven flows into Treasuries.

[6]Since January 2000 for Japan, since August 2007 for the euro area, and since October 2008 for the UK.

Figure 9 shows the estimated effects of UK, euro area, and Japanese monetary policy shocks on the foreign exchange risk premium. Foreign monetary policy easings are estimated to significantly raise the euro and yen foreign exchange risk premia. These foreign exchange risk premia are defined from the perspective of the foreign country. For example, in Figure 9, the euro area panel shows the effect of the ECB monetary policy easing on expected future US short rates less expected future German short rates, adjusted for expected changes in the euro-dollar exchange rate. From this and our earlier results on the effects of US monetary policy easings, we can coinclude that to the extent that condtional UIP fails, it is that monetary policy easing shocks anywhere shifts the foreign exchange risk premium in favor of US interest rates.

Finally, the UK monetary policy shock is estimated to lower the ten-year UK term premium by 30 basis points (confidence interval: -41 to -19 basis points). The ECB monetary policy surprise lowers the ten-year German term premium by 8 basis points (confidence interval: -14 to -2). The Japanese monetary policy shock is estimated to lower the ten-year Japanese term premium by 35 basis points (confidence interval: -54 to -9 basis points).

4 Conclusion

This paper has estimated a structural VAR in domestic and foreign interest rates and exchange rates. Our objective is to assess the effects of monetary policy shocks at the ZLB, with these shocks identified through the method of external instruments. Having obtained the dynamic effects of monetary policy shocks on future interest rates and exchange rates, we can compute the effects on financial market risk premia as a by-product. We find that US monetary policy easing significantly lowers domestic and foreign bond risk premia, and leads to dollar depreciation. There is some evidence that foreign exchange risk premia may be affected.

Table 1: Effects of US Monetary Policy Shock on Foreign Ten-Year Term Premia (in basis points)

	Point Estimate	Confidence Interval
UK	-13.6	(-22.6,-7.1)
Germany	-10.3	(-13.8,-7.1)
Japan	-5.4	(-10.0,-1.0)

Notes: The table reports the point estimates and 68% bootstrap confidence intervals for the effects of a monetary policy shock that lowers the US five-year yield by 25 basis points on the ten-year term premium in the UK, Germany and Japan.

Table 2: Effects of US Monetary Policy Shock on Long Foreign/Short US Ten-Year Portfolio Returns (in basis points)

	Point Estimate	Confidence Interval
UK	12.9	(-28.5,78.0)
Germany	1.7	(-23.8,32.4)
Japan	-93.2	(-113.9,-54.2)

Notes: The table reports the point estimates and 68% bootstrap confidence intervals for the instantaneous effects of a monetary policy shock that lowers the US five-year yield by 25 basis points on the returns on a portfolio that is long foreign ten-year bonds and short US ten-year bonds. The foreign country is the United Kingdom, Germany or Japan.

Table 3: Effects of US Monetary Policy Shock on Domestic Term Premia (in basis points)

	Point Estimate	Confidence Interval
Five-year	-21.5	(-27.0,-12.6)
Ten-year	-20.5	(-25.8,-10.8)

Notes: The table reports the point estimates and 68% bootstrap confidence intervals for the effects of a monetary policy shock that lowers the US five-year yield by 25 basis points on the five- and ten-year US term premium.

Table 4: Effects of US Monetary Policy Shock on Foreign Ten-Year Term Premia in the pre-ZLB era (in basis points)

	Point Estimate	Confidence Interval
UK	-15.5	(-28.6,-6.5)
Germany	-7.1	(-13.6,-1.2)
Japan	0.6	(-4.2,4.3)

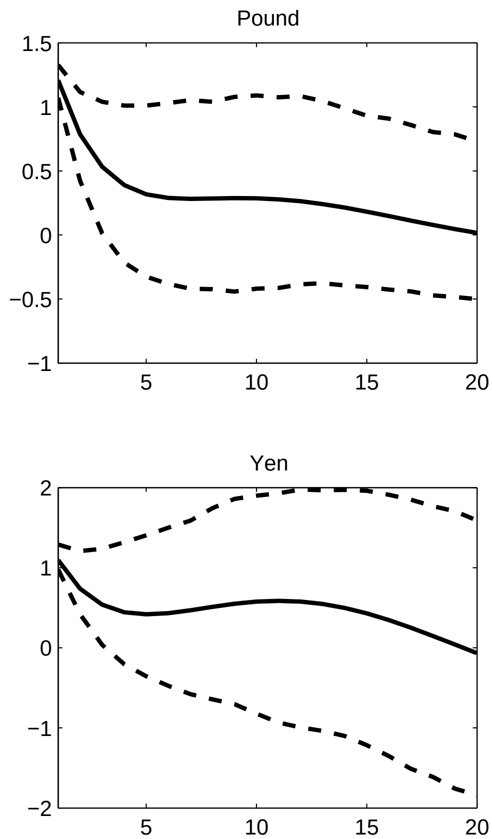
Notes: As for Table 1, except over the pre-ZLB period.

Table 5: Effects of US Monetary Policy Shock on Long Foreign/Short US Ten-Year Portfolio Returns in the pre-ZLB era (in basis points)

	Point Estimate	Confidence Interval
UK	-22.8	(-67.4,20.3)
Germany	30.8	(-25.3,95.1)
Japan	-53.0	(-85.5,-11.9)

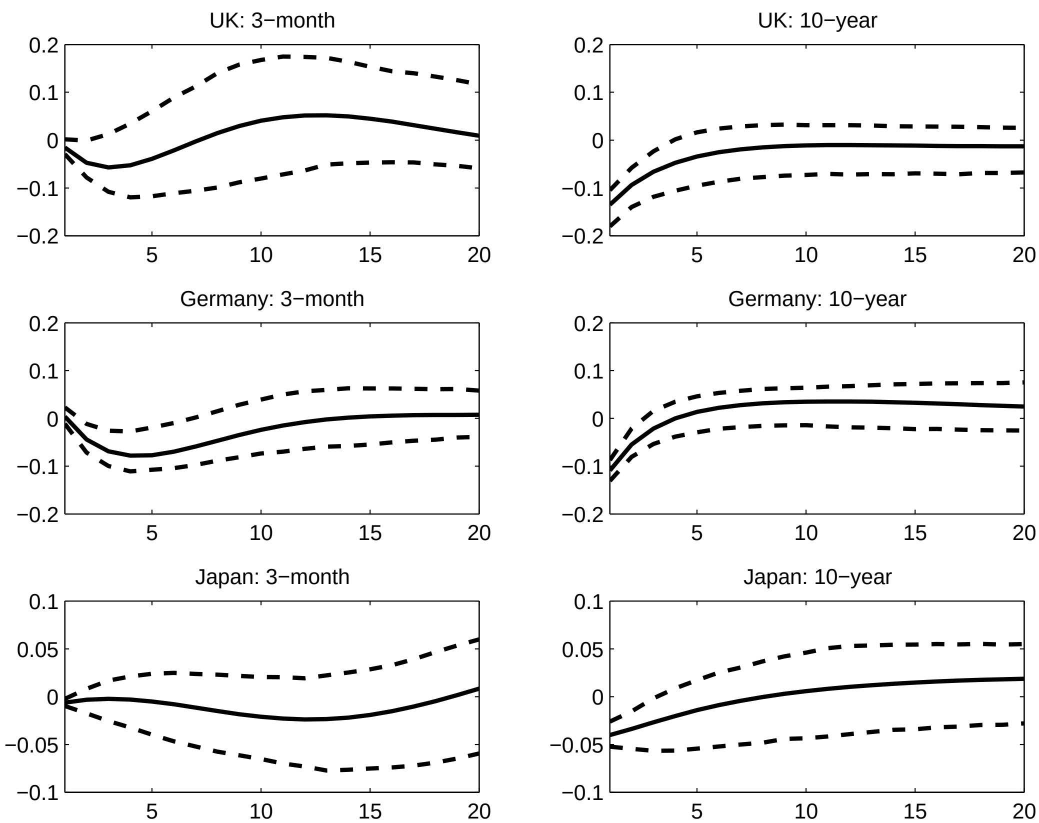
Notes: As for Table 2, except over the pre-ZLB period.

Figure 1: Effects of US Monetary Policy Shock on Exchange Rates



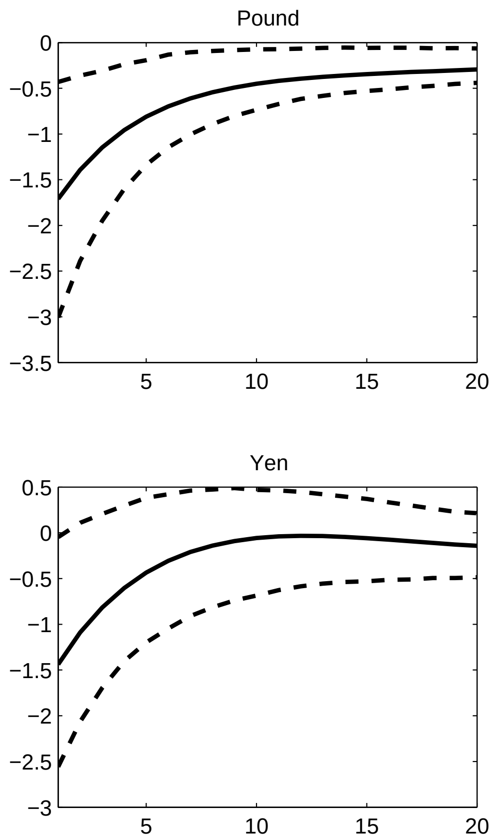
NOTE: This figure plots the effects of a monetary policy shock that lowers the US five-year yield by 25 basis points on exchange rates (in percentage points, measured as dollars per unit of foreign currency) over the subsequent 20 quarters. The dashed lines are 68 percent confidence intervals.

Figure 2: Effects of US Monetary Policy Shock on Foreign Interest Rates



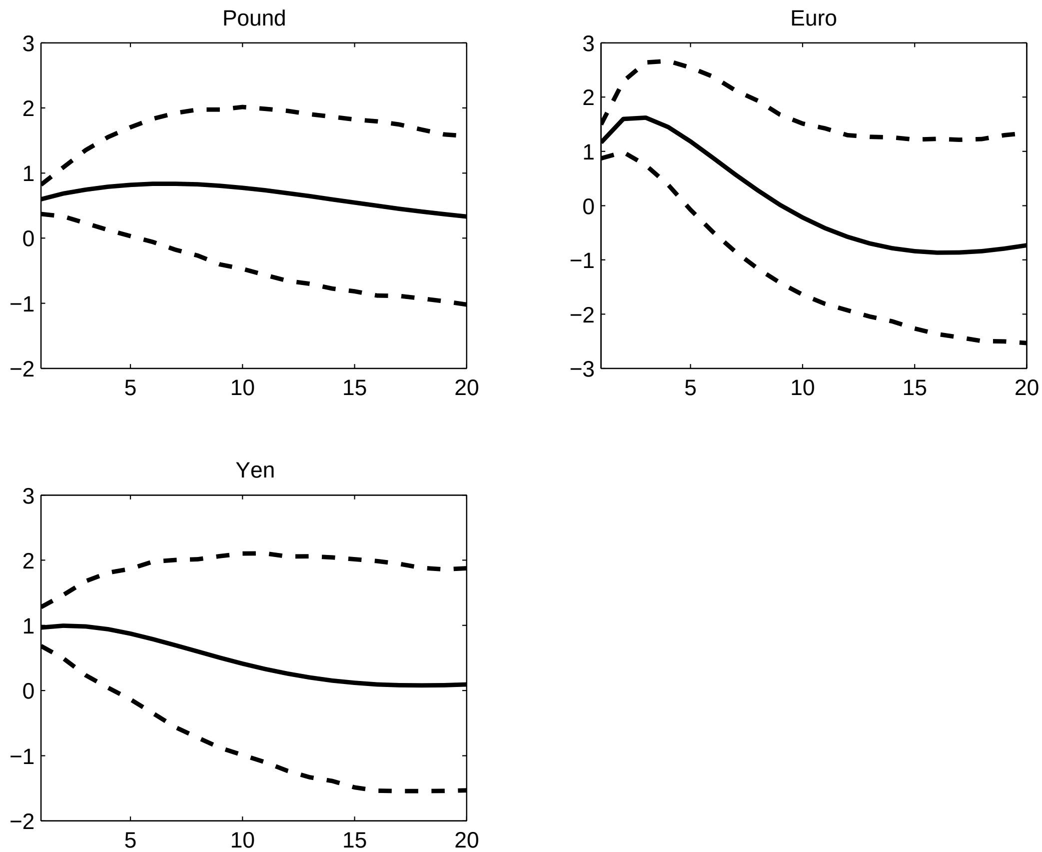
NOTE: This figure plots the effects of a monetary policy shock that lowers the US five-year yield by 25 basis points on foreign interest rates (in percentage points) over the subsequent 20 quarters. The dashed lines are 68 percent confidence intervals.

Figure 3: Effects of US Monetary Policy Shock on Foreign Exchange Risk Premium



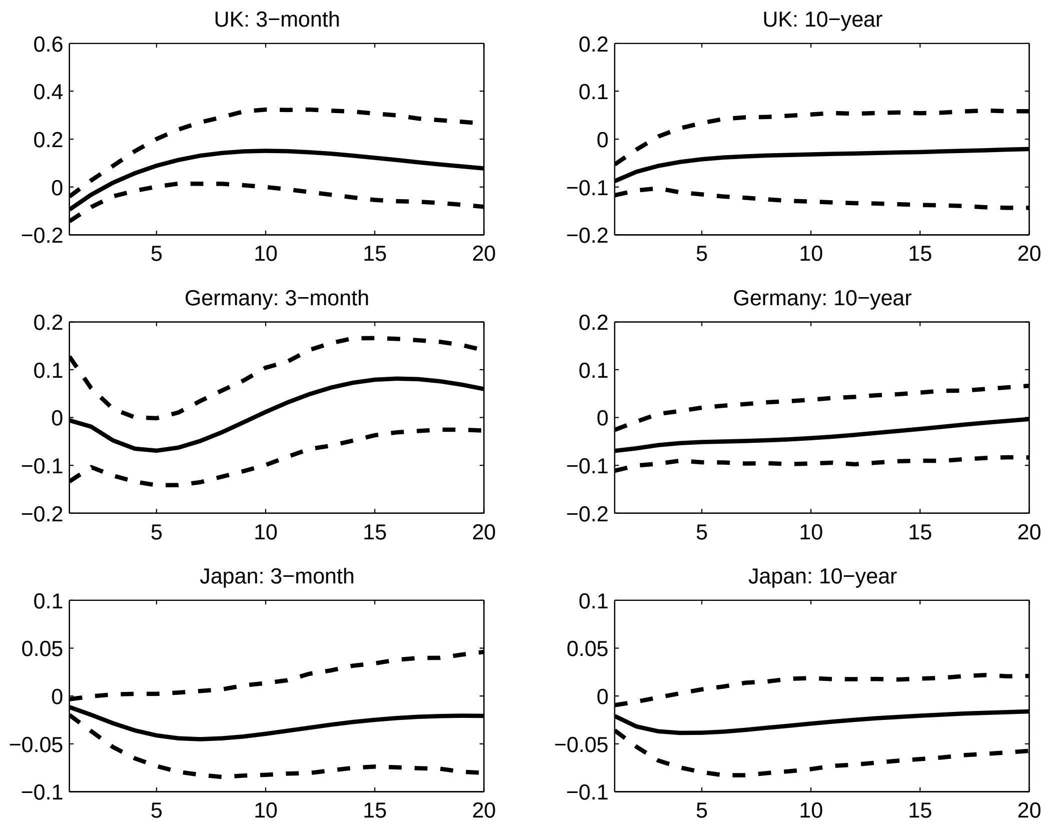
NOTE: This figure plots the effects of a monetary policy shock that lowers the US five-year yield by 25 basis points on the foreign exchange risk premium (as defined in equation (5) in the text, and measured in percentage points) over the subsequent 20 quarters. The dashed lines are 68 percent confidence intervals.

Figure 4: Effects of US Monetary Policy Shock on Exchange Rates: Pre-ZLB Era



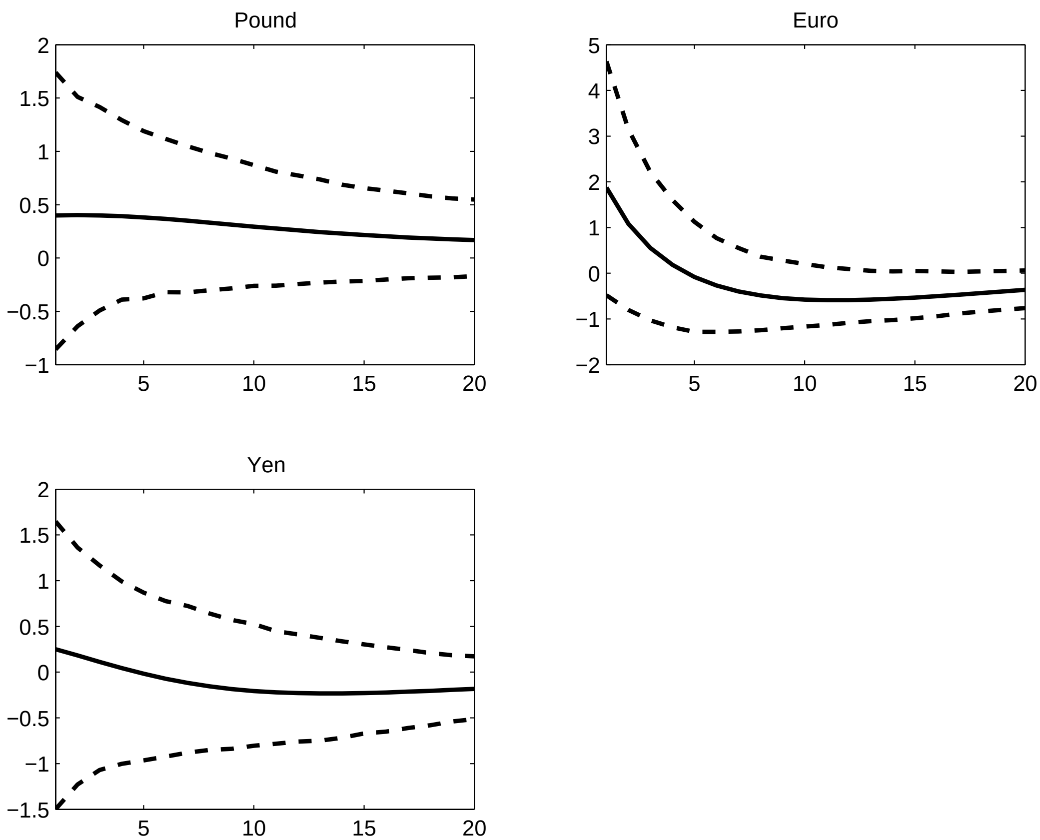
NOTE: This figure plots the effects of a monetary policy shock that lowers the US five-year yield by 25 basis points on exchange rates (in percentage points, measured as dollars per unit of foreign currency) over the subsequent 20 quarters. The monetary policy shock is identified over the pre-ZLB period using FOMC-day intraday changes in the fourth eurodollar futures contract as the external instrument. The dashed lines are 68 percent confidence intervals.

Figure 5: Effects of US Monetary Policy Shock on Foreign Interest Rates: Pre-ZLB Era



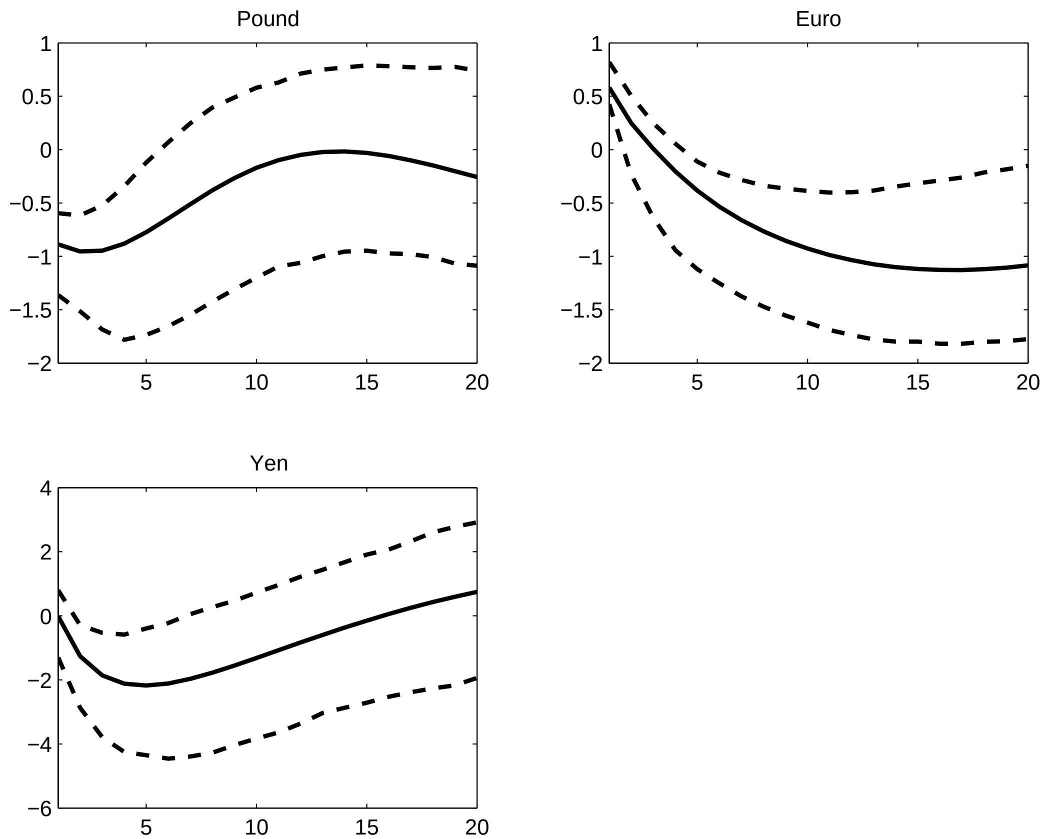
NOTE: This figure plots the effects of a monetary policy shock that lowers the US five-year yield by 25 basis points on foreign interest rates (in percentage points) over the subsequent 20 quarters. The monetary policy shock is identified over the pre-ZLB period using FOMC-day intraday changes in the fourth eurodollar futures contract as the external instrument. The dashed lines are 68 percent confidence intervals.

Figure 6: Effects of US Monetary Policy Shock on Foreign Exchange Risk Premium: Pre-ZLB Era



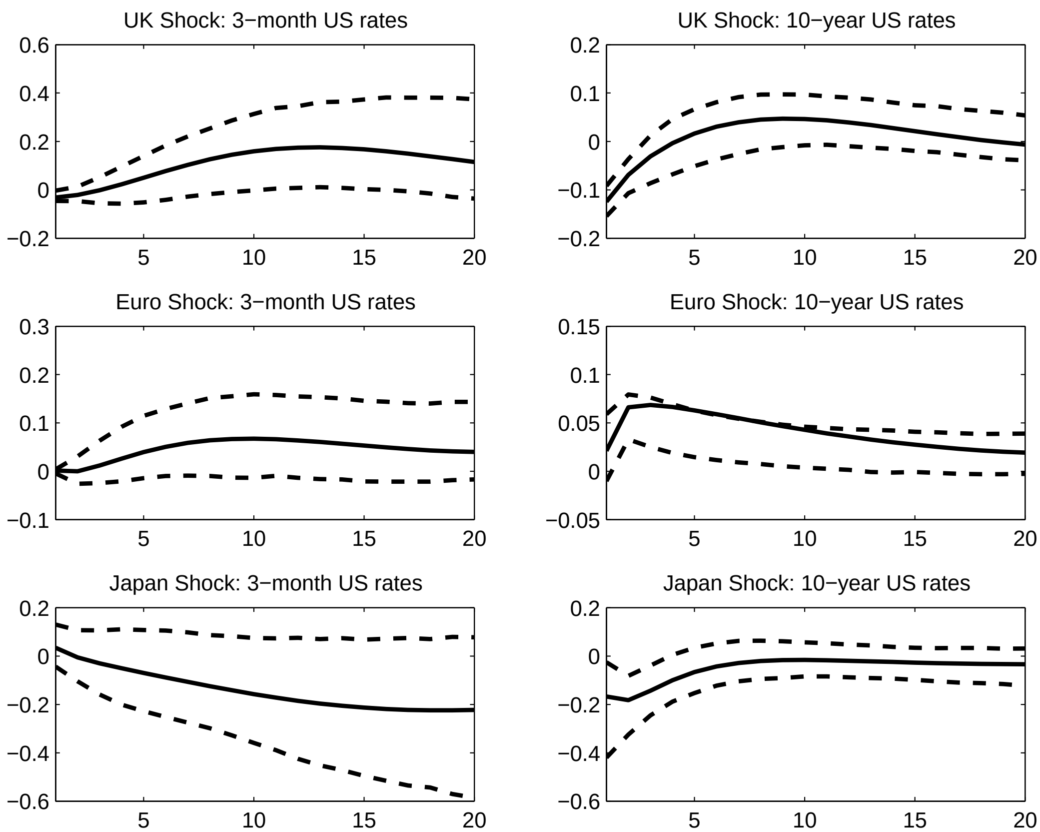
NOTE: This figure plots the effects of a monetary policy shock that lowers the US five-year yield by 25 basis points on the foreign exchange risk premium (as defined in the text, and measured in percentage points) over the subsequent 20 quarters. The monetary policy shock is identified over the pre-ZLB period using FOMC-day intraday changes in the fourth eurodollar futures contract as the external instrument. The dashed lines are 68 percent confidence intervals.

Figure 7: Effects of Non-US Monetary Policy Shocks on Exchange Rates



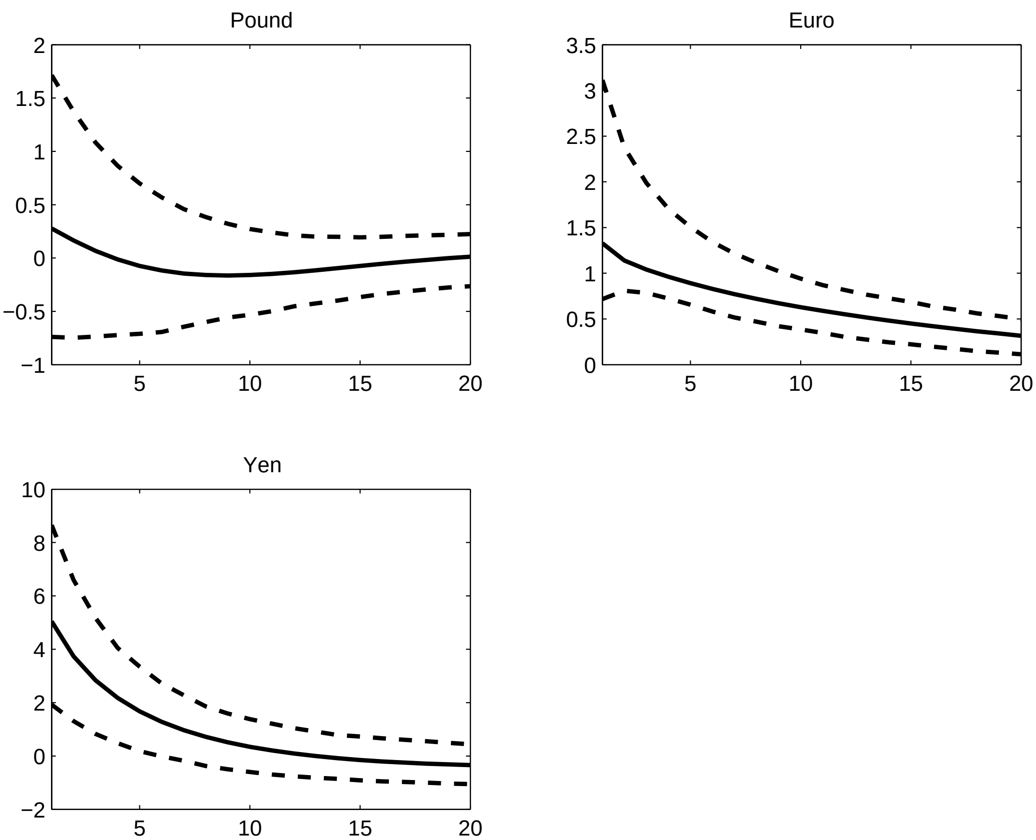
NOTE: This figure plots the effects of a monetary policy shock that lowers the UK, Italian or Japanese five-year yield by 25 basis points on the respective exchange rates (in percentage points, measured as unit of foreign currency per dollar) over the subsequent 20 quarters. The dashed lines are 68 percent confidence intervals.

Figure 8: Effects of Non-US Monetary Policy Shocks on US Interest Rates



Note: This figure plots the effects of a monetary policy shock that lowers the UK, Italian or Japanese five-year yield by 25 basis points on US interest rates over the subsequent 20 quarters. The dashed lines are 68 percent confidence intervals.

Figure 9: Effects of Non-US Monetary Policy Shocks on Foreign Exchange Risk Premium



NOTE: This figure plots the effects of a monetary policy shock that lowers the UK, Italian or Japanese five-year yield by 25 basis points on the respective foreign exchange risk premia (as defined in the text, and measured in percentage points) over the subsequent 20 quarters. The foreign exchange risk premium is defined from the perspective of the UK, euro area or Japan. The dashed lines are 68 percent confidence intervals.

References

Bredin, Don, Stuart Hyde, and Gerard OReilly, "Monetary Policy Surprises and International Bond Markets," *Journal of International Money and Finance*, 2010, *29*, 9881002.

Christensen, Jens H.E. and Glenn D. Rudebusch, "The Response of Interest Rates to US and UK Quantitative Easing," *Economic Journal*, 2012, *122*, F385–F414.

Christiano, Lawrence J., Roberto Motto, and Massimo Rostagno, "Risk Shocks," *American Economic Review*, 2014, *104*, 27–65.

Dornbusch, Rudiger, "Expectations and Exchange Rate Dynamics," *Journal of Political Economy*, 1976, *84*, 1161–1176.

Ehrmann, Michael and Marcel Fratzscher, "Monetary Policy Announcements and Money Markets: A Transatlantic Perspective," *International Finance*, 2003, *6*, 1–20.

_ and _ , "Equal Size, Equal Role? Interest Rate Interdependence between the Euro Area and the United States," 2005.

Eichenbaum, Martin and Charles L. Evans, "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates," *Quarterly Journal of Economics*, 1995, *110*, 975–1010.

Engel, Charles, "The forward discount anomaly and the risk premium: A survey of recent evidence," *Journal of Empirical Finance*, 1996, *3*, 123191.

Fama, Eugene, "Spot and Forward Exchange Rates," *Journal of Monetary Economics*, 1984, *14*, 319–338.

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

_ , _ , Eric T. Swanson, and Jonathan H. Wright, "Identifying the Effects of Monetary Policy on Exchange Rates Using High Frequency Data," *Journal of the European Economic Association*, 2003, *1*, 1031–1057.

Gagnon, Joseph, Matthew Raskin, Julie Remache, and Brian Sack, "Large-Scale Asset Purchases by the Federal Reserve: Did They Work?," *International Journal of Central Banking*, 2011, *7*, 3–44.

Gertler, Mark and Peter Garadi, "Monetary Policy Surprises, Credit Costs and Economic Activity," *American Economic Journal: Macroeconomics*, 2015, *7*, 44–76.

Gilchrist, Simon, Vivian Yue, and Egon Zakrajšek, "US Monetary Policy and Foreign Bond Yields," 2014. Working Paper.

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson, "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking*, 2005, *1*, 55–93.

Hausman, Joshua and Jon Wongswan, "Global Asset prices and FOMC Announcements," *Journal of International Money and Finance*, 2011, *30*, 547571.

Kiley, Michael T., "Exchange Rates, Monetary Policy Statements, and Uncovered Interest Parity: Before and After the Zero Lower Bound," 2013. Finance and Economics Discussion Series, 2013-17.

Kilian, Lutz, "Small-sample confidence intervals for impulse response functions," *Review of Economics and Statistics*, 1997, *80*, 218–230.

Kim, Soyoung, "International transmission of US monetary policy shocks: Evidence from VARs," *Journal of Monetary Economics*, 2001, *48*, 339–372.

_ **and Nouriel Roubini**, "Exchange Rate Anomalies in the Industrial Countries: A Solution with a Structural VAR Approach," *Journal of Monetary Economics*, 2000, *45*, 561–586.

Krishnamurthy, Arvind and Annette Vissing-Jorgenson, "The Effects of Quantitative Easing on Long-term Interest Rates," *Brookings Papers on Economic Activity*, 2011, *2*, 215–265.

Kuttner, Kenneth, "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market," *Journal of Monetary Economics*, 2001, *47*, 523–544.

Lustig, Hanno, Andreas Stathopoulos, and Adrien Verdelhan, "The Term Structure of Currency Carry Trade Risk Premia," 2013. NBER Working Paper 19623.

Mertens, Karel and Morten O. Ravn, "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States," *American Economic Review*, 2013, *103*, 1212–1247.

Olea, José L.M., James H. Stock, and Mark W. Watson, "Inference in Structural VARs with External Instruments," 2013. Working Paper.

Rogers, John, Chiara Scotti, and Jonathan H. Wright, "Evaluating Asset-Market Effects of Unconventional Monetary Policy: A Multi-Country Review," *Economic Policy*, 2014, *29*, 3–50.

Stock, James H. and Mark. W. Watson, "Disentangling the Channels of the 2007-2009 Recession," *Brookings Papers on Economic Activity*, 2012, *1*, 81–156.

_ **and Motohiro Yogo**, "Testing for Weak Instruments in Linear IV Regression," in Donald W.K. Andrews and James H. Stock, eds., *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*, Cambridge University Press 2005.

_ **, Jonathan H. Wright, and Motohiro Yogo**, "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments," *Journal of Business and Economic Statistics*, 2002, *20*, 518–529.

Wright, Jonathan H., "Term Premia and Inflation Uncertainty: Empirical Evidence from an International Panel Dataset," *American Economic Review*, 2011, *101*, 1514–1534.

_ , "What does Monetary Policy do to Long-term Interest Rates at the Zero Lower Bound?," *Economic Journal*, 2012, *122*, F447–F466.