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Abstract

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JEL Classification: E52, E58, F31

Keywords: Exchange Rates, Unconventional Monetary Policy, forward guidance, event study, High Frequency Data

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Monetary policy's rising FX impact in the era of ultra-low rates*

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Much has changed in financial markets over the past decade that could alter the relationship between monetary policy and exchange rates. Central banks have taken their policy rates to record, even negative, lows. As a result, many central banks, including all of the major central banks, have engaged in various forms of unconventional monetary policy. Most financial markets – including foreign exchange, money and debt markets – have experienced periods of heightened volatility and shifts in liquidity conditions. There has been a change in the mix of assets available to investors, with a reduced supply of safe assets. And, there have been substantial swings in risk aversion as well as a strengthening of bank regulation.

In this paper we show how the impact of monetary policy on the exchange rate has evolved against this backdrop. We investigate this important issue with an event study using high-frequency interest rate and exchange rate data for seven advanced economies. Event studies using high frequency financial data have become a well established tool for addressing macro-finance topics where endogeneity is a concern (see Gürkaynak & Wright (2013)) and in particular have been widely used to study the impact of monetary policy on exchange rates (for example Faust et al. (2003), Kearns & Manners (2006), Rosa (2011), and Rogers et al. (2014)). A well-identified exogenous shock to monetary policy allows us to map out the response of the exchange rate.[1] Importantly, this methodology enables us to assess how the impact of monetary policy has changed and varies with different types of monetary policy and economic and financial market conditions.

This paper's analysis extends the literature in three dimensions. First, we use a consistent methodology to comprehensively examine the impact of both conventional and unconventional monetary policies on exchange rates, covering the period from before the financial crisis right through the period of near zero policy rates and unconventional monetary policy. Second, we take a dynamic perspective to investigate how the exchange rate transmission has evolved over time and with changing economic and financial market conditions. Third, our paper is much broader than existing work in this area, covering the seven most traded currencies across the globe: the US dollar, euro, Japanese yen, Pound sterling, Australian

[1] This is akin to how the response of output or inflation is mapped out in VAR using shocks that rely on an identification strategy based on the relationships within the VAR.

dollar, Swiss franc and Canadian dollar.[2] Some of these countries did not face the constraints of the effective lower bound (ELB) for interest rates and thus did not resort to unconventional monetary policy. Instead, they continued to implement monetary policy via controlling short-term policy rates. The sample varies by country, but is up to 2004–2015. This provides some important insights into the dynamics between monetary policy and the exchange rate.

The paper has three major conclusions. First, we show that the sensitivity of the exchange rate to monetary policy has increased significantly over time. This result is not just a function of the magnitude of unconventional policies that have been used in recent years, as the finding applies even in countries and periods when the policy rate was above the ELB and conventional monetary policy was implemented with the overnight policy rate. Second, we show that the responsiveness of the exchange rate to monetary policy varies with economic and financial market conditions. In particular, the drop of interest rates to historical lows in some major economies has contributed to the increased sensitivity, consistent with the intermediary model of the exchange rate in Maggiori & Gabaix (2015). As the effective lower bound becomes increasingly binding, the exchange rate bears more and more the burden of adjustment. Third, we show that the sensitivity of the exchange rate to unconventional monetary policy, including forward guidance, is in fact quite conventional in that, conditioning on interest rate effects, it is broadly similar as the sensitivity to conventional monetary policy. This is perhaps not surprising as exchange rates are inherently forwarding looking (Engel & West (2005)) and hence strongly affected by expectation shifts related to the path of future expected interest rates and term premia that are embodied in longer term interest rates. It is particularly via these channels through their impact on bond yields that the important forms of unconventional monetary policies – such as forward guidance and asset purchases – operate.

Related literature. Conceptually, our paper relates to recent work that has examined the impact of unconventional policies on asset prices. Using event studies, quantitative easing policies have been found to have reduced sovereign yields in the euro area, Japan, the United

[2]These have been the seven currencies with the highest global foreign exchange turnover for at least the past 15 years. We order them based on the 2010 BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity, around the middle of our sample. For the latest figures, see BIS (2016).

States, and the United Kingdom (see, for example, Gagnon et al. (2011), Krishnamurthy & Vissing-Jorgensen (2011) and Rogers et al. (2014)).[3] This literature has shown that sovereign yields tend to decline with the announcement of quantitative easing measures, and that the magnitude of the decline of other interest rates in the economy relative to sovereign yields can depend on the types of assets purchased and the structure of financial markets. Importantly for our work, because sovereign yields decline in response to unconventional monetary easing, their reaction can be used as a measure of the 'news' or information content in an announcement of unconventional policy. To rely on changes in yields around key announcements to infer the surprise element of monetary policy has also been common in the period of conventional policies. Drawing on the approach pioneered by Kuttner (2001), but going beyond the the impact of the unanticipated shock to just the target policy rate, Gürkaynak et al. (2005) were better able to account for the response of the exchange rate to a monetary policy announcement using two variables rather than just the surprise change in the policy rate. They extracted two factors from a range of short and long-term interest rates, and then rotated these two factors so that one accounts for the shock to the target policy rate, with the other representing the shock to the anticipated path of policy. Because this path variable is orthogonal to the target shock, it captures changes in longer-term interest rates. Indeed Gürkaynak et al. (2005), and Rosa (2011) who uses the same technique more recently, find that well over three-quarters of the explanatory power of the two monetary policy shock variables comes from the path variable.

Quantitative easing has also been found to depreciate the exchange rate, just as conventional policy easing does. Neely et al. (2011) found that the Federal Reserve's large scale asset purchases depreciated the US dollar and also reduced foreign yields. Similarly, Wright (2012) found that the US dollar depreciated against the Canadian dollar, the euro and the British pound in response to US quantitative easing. Swanson (2016) shows that the US dollar has a statistically significant response of the expected sign to both large-scale asset purchases and forward guidance. Rogers et al. (2015) suggest that the exchange rate has been more sensitive to monetary policy shocks in the ELB era than in the pre-ELB period,

[3]Further important empirical work on the transmission of unconventional policies on asset prices includes e.g. Wright (2012) D'Amico & King (2013); Christensen & Rudebusch (2012); Meaning & Zhu (2012); Bauer & Rudebusch (2014).

although they infer this using VARs separately estimated for the conventional and unconventional policy periods using different instruments for the monetary policy shock. However, Glick et al. (2013) suggest the effect on the US dollar from unconventional policy is similar to that from conventional monetary policy. Mueller et al. (2016) show that a carry trade strategy funded in US dollars earns significantly higher excess returns on scheduled FOMC announcement days. Stavrakeva & Tang (2015) decompose quarterly exchange rate movements to quantify the relative impact of monetary policy. In contrast, Rogers et al. (2014) indicate that the response of the exchange rate to conventional monetary policy shocks was larger than that to large-scale asset purchases.

Structure of the paper. The remainder of the paper is structured as follows. Section I describes the setup and data used for the event study. The results are then presented in three parts. Section II presents the baseline results on the response of the exchange rate to monetary policy news, including the speed and persistence of the exchange rate's response. Section III presents the results for various types of monetary policy events. We draw an important distinctions between conventional monetary policy decisions on the policy interest rate and unconventional monetary policy. Section IV then presents the key results on how the sensitivity of the exchange rate to monetary policy has evolved over time and varied with economic and financial cyclical factors. In Section V, we take a closer look at the Fed's impact on the US Dollar. And, we assess the impact of interest rate spillovers across countries when determining the response of the exchange rate to monetary shocks. The conclusion wraps up the findings. Further results and robustness analysis are contained in a separate Online Appendix.

I. Method and Data

We assess the response of the exchange rate to monetary policy news where the news content is measured as the change in key interest rates in a tight window around the monetary policy announcement. In our baseline analysis, we use two variables to capture the news content in the announcement: the first is the change in the fixed rate on Overnight-Index Swaps (OIS) with a one month tenor (which we refer to as the 'target' shock); and the second is the change in the spread between the 2-year sovereign bond yield and 1-month OIS rate (which we refer to as the 'path' shock).[4] This framework provides a link to earlier event studies of the impact of conventional monetary policy on the exchange rate (such as Gürkaynak et al. (2005)). It also relates to recent studies that have used the change in a bond yield as an instrument to measure the impact of unconventional monetary policy (UMP) in different contexts.

In our baseline, we regress the (log) exchange rate change on target and path shocks:

$$\Delta s_t = \alpha + \beta_{target} \cdot \underbrace{MPS_t^{OIS}}_{\text{target shock}} + \beta_{path} \cdot \underbrace{MPS_t^{Bond - OIS}}_{\text{path shock}} + \epsilon_t, \tag{1}$$

where, for event t, MPS_t^{OIS} is the change in the 1-month OIS interest rate and $MPS_t^{Bond - OIS}$ is the change in the slope of the yield curve (i.e. the change in the spread between 2-year bond yields and the 1-month OIS rate) and the exchange rate is defined as the units of foreign currency per unit of home currency so that a positive value of the log change, Δs_t, indicates an appreciation of the home currency. All changes are recorded in a narrow window around the announcement as outlined below.[5]

This setup is appealing for two reasons. First, it allows us to capture that monetary policy news may be affecting not just the level of money market rates but also longer-dated rates via expectations or term premia channels. Second, when the policy rate is at the ELB and so the 1-month OIS is effectively unchanged with policy announcements, our policy shock measures reduce to the change in the bond yield – the instrument used in studies of unconventional monetary policy. This approach is akin to the two factors used by Gürkaynak et al. (2005) for the United States but does not require as many interest rates to implement and hence is practical for a larger sample of countries.

We also estimate an alternative specification where we include changes in the 2-year bond

[4] OIS contracts are OTC derivatives contracts allowing investors to hedge against (or speculate on) movements the average level of the overnight rate over the maturity of the contract. Unlike futures contracts which refer to the overnight rate in a particular calender month, the maturity in the OIS contract is fixed. Hence they allow investors to more finely calibrate their hedges. OIS contracts are nowadays widely traded in a broad array of currencies.

[5] In robustness exercises reported in the Online Appendix, we use the 10-year bond yields in place of 2-year yields.

yield as well as the orthogonal component of changes in the 10-year bond yield:

$$\Delta s_t = \alpha + \beta_{exp} \cdot \underbrace{MPS_t^{2y}}_{\text{expectations shock}} + \beta_{tp} \cdot \underbrace{MPS_t^{10y\perp}}_{\text{term premium shock}} + \epsilon_t. \tag{2}$$

The motivation here is that movements in the 2-year bond will be to a large extent driven by expectations of future short rates, while those in the orthogonal component in 10-year yields can be mostly traced to changes in term premia (Gilchrist et al. (2014)). This specification is hence particularly useful when investigating UMP news on asset purchases and forward guidance which could operate via signalling and portfolio balance channels, with the latter likely impacting mostly term premia in longer dated bonds (Gagnon et al. (2011)).

A. *High-frequency data on fixed income instruments*

The interest rate and bilateral US dollar exchange rate data are mid-quotes at 1-minute intervals from Thomson Reuters (since these are all OTC markets, quotes are the most readily available and representative prices). The bilateral exchange rates are expressed as USD per one unit of home currency. For studying the impact of US monetary policy, we use the US dollar measured against the euro as this is the most liquid US dollar bilateral rate (so here the exchange rate is euros per US dollar). In Section V, we also investigate the impact of US monetary policy shocks on a US dollar-index and all of our bilateral US dollar exchange rates. The 2- and 10-year yields are for zero coupon bonds. We perform extensive filtering and cross-checking of the high-frequency data to remove stale or implausible quotes. Further details on the cleaning and the preparation of the high-frequency data are provided in the Online Appendix.

B. *A dataset of monetary policy events across the globe*

Our dataset includes three types of monetary policy announcements: scheduled monetary policy decisions regarding the policy interest rate that follow the meeting of the policy committee (MPDs); announcements about unconventional monetary policy (UMP) facilities including key speeches by the central bank governor; and the release of minutes of the policy committee meeting. All these events are directly collected from the relevant central banks. We also perform extensive cross-checking with data sources including Bloomberg to ensure accuracy of the intraday time-stamps.

Within the set of UMP events, we separately identify those events that pertain to forward guidance (FG) related to the future course of monetary policy. It is important to note though that this distinction is imperfect as FG announcements were often made in conjunction with other policy announcements such as asset purchases. While many central banks have included references to the outlook for policy in their communication for many years, we consider FG events to be only those where we judge that the central bank was using the announcement explicitly as an unconventional monetary policy tool. Also note that some announcements about UMP or FG occurred in the scheduled announcement following an ordinary monetary policy committee meeting. Our hierarchy classifies events as UMP (or FG) rather than as MPDs if they provided new information about unconventional policies or explicit forward guidance. This classification rests on the assumption that UMP and forward guidance was the dominant piece of news conveyed in these scheduled announcements.[6]

Because other market-wide developments will also affect interest rates, we use a tight window around the monetary policy announcement when measuring the change in the interest rate.[7] This ensures that we capture the news content of the monetary policy announcement with as little noise as possible. We measure the interest rate before and after the announcement as a 15-minute average to smooth any noise in the minute-by-minute data. More precisely, we measure the target monetary policy shock as:

$$MPS_t = \overline{OIS}_{[t+20min;t+5min]} - \overline{OIS}_{[t-20min;t-5min]},$$

that is, the change in the average OIS interest rate from 20 to 5 minutes before the announcement, to the average interest rate from 5 to 20 minutes after the announcement. We

[6]In our classification of UMP events, we take Rogers et al. (2014) as our starting point and perform an update until the end of our sample period. Likewise, we rely on the classification of FG events by Filardo & Hofmann (2014) and Hattori et al. (2016) and expand the set of dates.

[7]A tight window is appropriate as interest rate markets quickly price in changes in information, see for example Fleming & Remolona (1999) although we also use longer windows in robustness exercises reported in the Online Appendix.

exclude the five minutes before and after the announcement when computing the change in average interest rate levels to allow for possible misalignment of the data time stamp and the central bank announcement, and to give the market some time to process the news and reprice accordingly.[8] The path MPS is computed in an analogous fashion.

C. Summary statistics of the events

The minute-by-minute absolute changes in the 1-month OIS interest rate and 2-year bond yield – averaged across a large number of events and across the seven countries in our sample – are shown in Figure 1. The figure highlights that the monetary policy announcement results in a rapid and sizable change in interest rates but that changes in interest rates occur continuously throughout the day.

[Figure 1 about here]

Figure 2 shows the average cumulative change in the exchange rate separately for events with positive (tightening) and negative (easing) interest rate surprises, demonstrating that there is a sizeable and rapid change in the exchange rate. The symmetry in the exchange rate response to easing and tightening announcements is quite striking, particularly as the magnitudes of the surprise element of these events (tightening or easing) are not controlled for here, just their sign.

[Figure 2 about here]

Our analysis includes the seven most traded currencies, covering announcements by seven central banks: Federal Reserve, European Central Bank, Bank of Japan, Bank of England, Reserve Bank of Australia, Swiss National Bank and Bank of Canada. These central banks not only differ in terms of their operational frameworks, and the relative importance they

[8] Note, for the ECB this event window will include the policy announcement but not the press conference that follows. So long as the 'surprise' in the press conference is not correlated with the 'surprise' in the policy announcement (which it should not be if markets price in all available information from the policy announcement) then this will not bias our results. We do not include the press conferences as separate events to avoid overlapping observations. Future work could explore whether the exchange rate response differs to news delivered in the policy announcement and the press conference.

attach to communication but also by whether their policy rate was constrained by the ELB and so they resorted on unconventional policies.[9]

The number of events by central bank is shown in Table 1, broken down by various event types. We distinguish between scheduled monetary policy decisions (MPDs); unconventional monetary policy announcements (UMP) which include announcements on forward guidance (FG); and the release of the minutes of the policy meeting.

[Table 1 about here]

Our event dataset is very comprehensive, with more than 700 events in total for the seven major central banks in our sample, starting as early as 2004 for some countries, and so predating the financial crisis, and running to 2015. More than one half of all events are scheduled monetary policy decisions, excluding those which are UMP announcements. Announcements of UMP constitute roughly one tenth of all events, but there are none for Australia and Canada, two countries that did not hit or remain at the ELB. Just over a quarter of all events in the sample are the release minutes of policy meetings by the four central banks which made these public in our sample period. The sample period differs by country according to the availability of the high-frequency data, but includes the period immediately prior to the financial crisis through to the era of unconventional monetary policies with policy rates at the effective lower bound. For Switzerland the sample is notably smaller due to data availability and a lower frequency of policy meetings and so the results for Switzerland need to be interpreted with care.

The average change in exchange rates and interest rates in the event window is shown in Table 2.[10] The change in the 1-month OIS ('target') in the event window tends to be much smaller than the average change in actual policy rate, indicating that most policy changes are to a large extent anticipated ahead of the announcement. Thus, the full magnitude of

[9]On the importance of central bank communication, see Blinder et al. (2008) and Ehrmann & Fratzscher (2003). Schmeling & Wagner (2016) show that the tone of central bank communication is informative for future asset price movements.

[10]The periods of available OIS and bond data differ, meaning that the sample can start earlier for some robustness exercises in the Online Appendix that use only a single MPS measure to explain exchange rate movements. The available sample periods for OIS and bond yields are shown in the Online Appendix along with the average change in the instruments during the event window.

the change does not represent news to the market. This also applies to many of the recent UMP announcements, and highlights why it is necessary to use a market interest rate that captures the news content of the announcement, i.e. the monetary policy shock, rather than the headline policy announcement. The change in the slope of the yield curve ('path') is on average larger than the target shock for most economies.

[Table 2 about here]

II. The FX response to news about monetary policy

This section presents the results of our baseline analysis of how the quantitatively most important and liquid FX markets across the globe respond to monetary policy shocks. We start with a high-frequency event study that looks at the exchange rate in a tight window around the release of monetary policy news. In the Online Appendix, we show that regressions using intraday data provide a much better fit than using daily data. We then turn to an analysis of the temporal response to gauge how fast FX markets absorb the monetary policy news and how persistent these effects are.

[Table 3 about here]

The results from the estimation of Equation (1) are shown in Table 3. For all countries, the coefficient on the target shock (β_{target}) is positive and highly significant and the coefficient on the path shock (β_{path}) is positive and significant for all countries except Japan.[11] For most countries, the β_{target} is estimated to be in the range of 4–6. This means that a 10 basis point surprise increase in the target policy rate (that is a 10 basis point increase in the 1-month OIS rate) would appreciate the exchange rate by 0.4–0.6%. The estimated coefficient for Switzerland is larger but, while these coefficients are significant, the Swiss sample is much

[11] These results, and those that follow in the paper, are robust to using an M-estimator to reduce the impact of outliers, as shown in the Online Appendix.

shorter due to data availability.[12] Similarly for Japan where short rates have been around zero for the entire sample period, the estimate of the exchange rate response to a target shock is very large (and the response to a path shock is statistically insignificant).

The estimated coefficients on the path term, β_{path}, are in the range of 6–7 for most countries, indicating that a 10 basis point steepening of the front end of the yield curve (the 2-year – 1-month spread) would appreciate the currency by 0.6–0.7%. For the United States, the coefficient is around half that size, suggesting that the USD/EUR exchange rate responded less to path shocks.[13]

For all countries, monetary policy shocks are able to explain a large share of the movement in the exchange rate over the short window. For the smaller economies, the two monetary shock variables together explain 40–70% of the variance in the exchange rate in the event window. For the G3 economies, the share is somewhat smaller, but still around 15–20%.

Our results suggest that much of the explanatory power in these regressions comes from the path shock, in line with prior work on conventional monetary policy by Gürkaynak et al. (2005) and Rosa (2011). The explanatory power of univariate regressions including only the 1-month OIS (or 6-month OIS) is substantially lower, with the R^2 generally less than 0.1 as shown in the Online Appendix. The univariate regressions containing only the change in the 2- or 10-year bond have substantially greater explanatory power than those with just OIS rates, with the R^2s around 0.1–0.4, but still less than our baseline regressions which include both the target and path shock variables (notably, the explanatory power of the univariate regressions is higher for the Australian and Canadian dollars, but still less than the baseline regressions).

[12] The Swiss franc was subject to heavy intervention and a floor system for much of the period covered by our Swiss data and so it is possible that the large coefficient reflects actual or expected intervention that correlated with the surprise element of monetary policy announcements. The Swiss franc floor applied to the euro bilateral rate, not the US dollar bilateral rate we use in our study, but the results are very similar using the constructed CHF/EUR exchange rate.

[13] One explanation for the smaller US response could be interest rate spillovers. If an increase in US bond yields resulted in other countries' bond yields also rising, then the increase in foreign yields could mitigate the appreciation of the US dollar resulting in a smaller estimated coefficient. Evidence gauging the impact of spillovers on the exchange rate response is presented in Section V.

Expectations vs term premium shocks. We also evaluate our second model specification to analyze which shocks matter more for exchange rates, those manifesting themselves via changes in expectations of future short rates or in term premia. In this specification, Equation (2), we include changes in the 2-year yield (which will be mostly driven by expectations) and the orthogonalized component of 10-year yields (which will capture more of term premium shocks, see also Gilchrist et al. (2014)).

[Table 4 about here]

The results are shown in Table 4. Monetary shocks that move 2-year yields have a considerable impact on the exchange rate for all the countries (except Japan). This suggests that expectations related to monetary policy are a key driver of the exchange rate response. The orthogonalised component of the 10-year bond is significant for all economies, except Canada and Japan, suggesting that changes in term premia are an important conduit for how monetary policy transmits to the exchange rate.

Overall, monetary shocks that lead to a repricing of 2-year bonds have the most powerful impact on the exchange rate. This highlights the significance of central bank communication and forward guidance which tend to primarily influence the shorter end of the yield curve (see, e.g., Swanson & Williams (2014) and Dick et al. (2015)).

A. Temporal response of exchange rates

The temporal response of the exchange rate to monetary policy is important for two reasons. First, to determine the appropriate window length to use in the study it is important to know how quickly the exchange rate responds to monetary policy. Second, to know whether the impact is economically significant it is desirable to know whether the effects are persistent. To address these questions, we estimate the following equation:

$$\Delta s_{[t,t+k]} = \alpha + \beta^{(k)}_{target} \cdot MPS^{OIS}_t + \beta^{(k)}_{path} \cdot MPS^{Bond\text{ – }OIS}_t + \epsilon^{(k)}_t, \tag{3}$$

where $\Delta s_{[t,t+k]}$ is the change in the exchange rate from t to $t+k$ minutes around each event with $k \in [-60, 120]$, and the exchange rate change is measured without averaging. Again, in our baseline analysis we rely on the 1-month OIS rate and the 2-year bond yield (and 10-year bond yield in robustness exercises reported in the Online Appendix) when measuring target and path shocks. In addition to the persistence of the intraday response, we also run tests that look at longer horizons up to one week.

The setup is akin to the local linear projection method of Jordà (2005) to estimate impulse response function. The method fits well in our context, as the high-frequency data allow for a very precise and unambiguous identification of monetary policy shocks. The estimated sequence of $\beta^{(k)}_{target}$ and $\beta^{(k)}_{path}$ coefficients are displayed for varying horizons k in Figure 3.

[Figure 3 about here]

The figures show that exchange rates respond very promptly to the news content in the monetary policy announcement. Most importantly, the effect appears to be fairly persistent, at least within the day. We find that the response to a path shock is just as rapid as it is to a target shock, indicating that the market digests information of a more qualitative nature just as swiftly as unexpected changes in the policy interest rate.

The US dollar responds quickly to announcements by the Federal Reserve, but surprisingly not as rapidly as the smaller economy currencies respond to monetary shocks of their respective central banks. The coefficients for the path shock are estimated with less precision, with relatively wide standard errors. Interestingly for the euro, these estimates indicate that the exchange rate only responds gradually to announcements by the ECB. While some of the more significant announcements by the ECB in this period pertain to unconventional policy measures which may have taken longer for the full ramifications to be processed by the market, if interpreted this way, the result would suggest that OIS and bond markets processed the monetary policy announcement much faster than the foreign exchange market. This would require an explanation and further inquiry.

For the UK, Australia, Switzerland and Canada the full effect of the monetary policy announcement is priced in within just a few minutes, and the effect is persistent. Over time, the standard errors widen, at least for Australia and Canada, as the monetary policy news becomes a smaller portion of the daily news flow impacting the currency.

[Figure 4 about here]

Further evidence on persistence. There is also evidence that the effects of monetary policy on the exchange rate last beyond the day of impact. We estimate Equation (1) using the same target and path shocks measured in the narrow window used earlier, but instead measure the change in the exchange rate using end of day rates. Among the G3 economies, only the euro area shows a statistically significant impact of policy shocks on the exchange rate lasting five days, as seen in Figure 4, consistent with the earlier result that the impact on the euro seems to build gradually after the event (full results are shown in the Online Appendix Table A.VII). For the G3 economies, including the euro area, monetary policy has little explanatory power for movements of the exchange rate over the subsequent days; the R^2 are relatively small, no larger than 0.06. There is greater evidence of a lasting impact in the smaller economies with Australia and the UK showing significant impacts out to day five, and Canada and Switzerland displaying significant impacts for some days. For these economies, monetary policy shocks play a larger role in explaining exchange rate movements with R^2 in the range 0.1–0.3.

III. Which monetary shocks matter for exchange rates?

Unconventional policies have been credited with having a large impact on exchange rates in the period since the financial crisis, but it is not clear whether these policies actually have an impact that differs from that of conventional monetary policy actions. In this section, we analyse how the exchange rate responds to different *types* of monetary policy news, again controlling for the fixed income response. Our focus is on the impact on the exchange rate to conventional monetary policy decisions versus unconventional monetary policy, and as a subset of those, forward guidance events.[14]

We investigate the impact of different types of monetary policy actions by augmenting our baseline specification with an additional term that interacts the monetary policy shock

[14] In the Online Appendix, we also estimate whether there is a different impact on the exchange rate between policy interest rate announcements and central bank communication through the release of policy meeting minutes.

with a dummy variable taking the value of one for UMP events or FG events. The coefficient on the interaction term indicates whether the exchange rate response to a particular type of shock, say UMP, differs from the response to conventional monetary policy news. In all specifications, the base set of events is only monetary policy interest rate decisions (MPDs).

In the analysis on unconventional monetary policy we focus on three central banks, the Federal Reserve, the ECB and the Bank of England.[15] For each of the three countries, we estimate the following two equations

$$\Delta s_t = \alpha + (\beta_{target} + \beta_{target}^{type} \cdot \mathbb{1}^{type}) \cdot MPS_t^{OIS} + (\beta_{path} + \beta_{path}^{type} \cdot \mathbb{1}^{type}) \cdot MPS_t^{Bond\,-\,OIS} + \epsilon_t,$$

and

$$\Delta s_t = \alpha + (\beta_{exp} + \beta_{exp}^{type} \cdot \mathbb{1}^{type}) \cdot MPS_t^{2y} + (\beta_{tp} + \beta_{tp}^{type} \cdot \mathbb{1}^{type}) \cdot MPS_t^{10y\perp} + \epsilon_t,$$

where $\mathbb{1}^{type}$ is a dummy that takes value equal to 1 if the event type is a UMP event (or a FG event). The results for target and path shocks are presented in the left-hand panel of Table 5, and those for expectations and term premium shocks are reported in the right-hand panel. Given that UMP and FG may operate via different channels, it is particularly interesting to assess what types of shocks matter the most for exchange rates, those manifesting themselves in expectations or term premium shifts.

[Table 5 about here]

Are UMP shocks special? Differentiating by the type of the monetary policy event, we find that UMP events only had an additional impact on the exchange rate in the US and not in the euro area or UK (left panel of Table 5). For the US, this effect is statistically and economically significant. Notably the effect comes through the path shock rather than the target shock which is consistent with UMP having an impact on the path of monetary policy through the suppression of bond yields, but having no impact on short-term policy rates.

[15] Given the ambiguous results for Japan in our baseline case, we omit it from the subsequent analysis while for the other countries there were either no, or too few, unconventional monetary policy events.

According to the second specification, reported in the right-hand panel, it is particularly UMP events inducing expectations shocks that have the largest impact on the US dollar. These findings suggest that UMP events are indeed special in their impact on the exchange rate, despite the fact that we are controlling for the magnitude in the interest rate response in this empirical setup. For the euro area and United Kingdom, we find that the impact of UMP events is insignificantly different from that of conventional monetary policy decisions.[16]

Forward guidance and the exchange rate. Table 6 investigates the impact of forward guidance on the exchange rate. As a caveat, it is important to keep in mind that there are only a small number of forward guidance events in our sample, and these cannot be completely separated from other types of unconventional policy actions. That said, for all three countries these FG events are found to have an economically meaningful impact on the exchange rate that differs from that of conventional policy announcements. This is especially visible when relying on the setup where we look at expectations and term premium shocks. As indicated by the right-hand panel of Table 6, forward guidance news manifesting itself via shifts in expectations tend to have a significantly higher impact on the exchange rate than regular monetary announcements do (at the 10% level).

[Table 6 about here]

IV. How has the impact of monetary policy evolved?

The substantial changes during the past decade in the ways in which central banks implement their policies and the market environment in which they operate have potentially altered the responsiveness of exchange rates to monetary policy. For many central banks, large-scale asset purchases and forward guidance have come to the fore as preferred methods for implementing monetary policy given that influencing short-term money market rates via conventional tools has become increasingly constrained by the ELB. This form of monetary

[16]Note that UMP events all occur at the end of the sample and as shown in Section IV the sensitivity of the exchange rate to monetary policy shocks has increased over time. This would bias our results in favour of finding that UMP events have a larger impact on the exchange rate than conventional monetary policy.

policy implementation has quite different implications for asset markets, and hence it could also have a different impact on exchange rates. Our framework enables us to use a consistent methodology over the periods of conventional and unconventional monetary policies to examine whether the impact of monetary policy on the exchange rate has indeed changed.

A. *Time-varying sensitivity to monetary policy announcements*

To investigate whether the sensitivity of the exchange rate to monetary policy has changed we use the non-parametric estimation technique in Ang & Kristensen (2012) which allows the coefficients (and confidence bands) to vary over time

$$\Delta s_t = \alpha_t + \beta_{target,\ t} \cdot MPS_t^{OIS} + \beta_{path,\ t} \cdot MPS_t^{Bond\ -\ OIS} + \epsilon_t \tag{4}$$

where $\beta_{target,\ t}$ and $\beta_{path,\ t}$ are the time-varying coefficients that measure the changing impact of monetary policy shocks on the exchange rate, and all other variables are as defined earlier.

This non-parametric method estimates the coefficients for any point in time by placing greater weight on adjacent data observations, and less weight on data observations further from that point in time. For further details, see the Online Appendix. This technique has the advantage that it uses all the available data, but allows the coefficients to vary over time in an unconstrained and smooth manner by changing the weight on each observation.

The results from the non-parametric time-varying estimation are shown in Figure 5.[17] For all five countries for which estimation is feasible, the responsiveness of exchange rates to both the target and path shocks have increased substantially over time. These changes are both statistically and economically significant. For example, in 2007 the US dollar appreciated by 0.42% in response to a positive surprise 10 basis point change in the policy target, but by 2015 this had increased to closer to 0.5%.

The increased sensitivity to the path of monetary policy is equally striking. The US dollar response to a 10 basis point steepening of the yield curve (the spread between 2-year

[17] Again we do not report time-varying estimates for Japan and Switzerland due to the ambiguous baseline results above and small sample size. The upward drift in time-varying coefficients is also seen using a longer sample of daily data, as shown in the Online Appendix, although it is less pronounced given the reduced accuracy of the fit with daily data.

bond yield and 1-month OIS) increased from 0.28% to 0.38%. The increased sensitivity is even larger for the euro and Canadian dollar, but is a bit less for Sterling. However, this does not imply that monetary policy is responsible for greater FX volatility. The size of monetary policy target and path shocks has actually moderated for most economies over this period as policy rates converged to zero and forward guidance was used more prominently.[18] Notably however, the estimated coefficients for Australia show a similar, albeit slightly less pronounced, increase even though there is substantially less decline in the magnitude of target and path shocks in Australia.

[Figure 5 about here]

B. Exchange rate sensitivity to macroeconomic data releases

To assess whether the changing sensitivity of the exchange rate to monetary policy announcements reflects something specific to monetary policy, we also examine the relationship between changes in interest rates and the exchange rate at the time of the release of macroeconomic data. We use the same narrow window length as before, and consider how the change in the exchange rate in that window relates to the change in interest rates. The interest rate and exchange rate prior to the announcement will incorporate the market's expectation for the data release and so the change in interest rates and the exchange rate in the narrow window will reflect the news content in the data release. We examine three major data releases that have been shown to have a significant impact on asset prices: GDP, CPI inflation and employment.

The results for a regression specification equivalent to Equation (1), using macroeconomic data releases as opposed to monetary policy announcements, are shown in Table 7. The estimates are similar to those for monetary policy announcements and are statistically significant for most countries (again with the exception of Japan and Switzerland). The most striking finding is, however, that the FX impact of macroeconomic data releases has been relatively stable over time as shown in Figure 6 (with the exception of small increases in the UK and Australia). This stands in stark contrast to rise in the FX impact of monetary policy

[18]See Figure A.I in the Online Appendix which depicts the evolution of monetary shocks over time

announcements shown in Figure 5,

[Table 7 about here]

[Figure 6 about here]

C. Is the FX impact of monetary policy state-dependent?

In light of the finding that the cross-section of exchange rate returns is related to various risk factors, we explore how the response of the exchange rate to monetary shocks varies with the state of economic and financial conditions.[19] We augment our baseline regression with terms that interact the response to the policy shock with a various state variable, as given by Equation (5).

$$\Delta s_t = \alpha + \beta_{target} MPS_t^{OIS} + \beta_{path} MPS_t^{Bond\text{-}OIS} + \beta_{target}^{Int} \cdot \left(MPS_t^{OIS} \times Z_t\right) + \beta_{path}^{Int} \cdot \left(MPS_t^{Bond\text{-}OIS} \times Z_t\right) + \epsilon_t \quad (5)$$

For the state variable, Z_t, we consider financial market conditions (the VIX), economic conditions (the difference in the unemployment rates between the two economies of the exchange rate), and the level of interest rates (the 2-year bond yield in the country with the monetary policy announcement). A role for the latter naturally arises in the intermediary framework of Maggiori & Gabaix (2015). As interest rates are increasingly constrained by the ELB for an expanding set of countries, a greater burden of adjustment falls onto the exchange rate when there are changes to expected currency excess returns.

The results are shown in Figure 7. For ease of interpretation, we standardize the VIX but keep the others in percentage points. For the United States, euro area, and to a lesser extent United Kingdom, the addition of cyclical interaction variables substantially improves the ability of the policy shocks to explain the exchange rate in the event window. For the United States and euro area, including the level of the bond yield doubles the explanatory power. In contrast, for Australia and Canada where the policy shocks alone explain around

[19] See for example Menkhoff et al. (2012) and Riddiough & Sarno (2016).

70% of the movement in the exchange rate in the event window, the addition of the cyclical interaction makes little difference to the fit of the equation.

[Insert Figure 7 about here]

Financial conditions. We start by assessing if the FX impact of monetary policy varies with financial conditions, as proxied by the VIX which can be seen as an amalgam of financial uncertainty and risk appetite (Bekaert et al. (2010)). The coefficient on the VIX is negative and statistically significant for all countries except the United States, for which it is positive (and significant when interacted with the path shock).[20] In an environment of benign financial conditions and strong risk appetite (low VIX), a surprise monetary policy tightening results in a smaller exchange rate appreciation for the US dollar, but a larger appreciation for other currencies. These effects can be quite large. For example, a 10 basis point steepening of the US yield curve (the path shock) would result in a 35 basis point appreciation of the US dollar when the VIX is at its mean, but a 53 basis point appreciation if the VIX is one standard deviation above its mean.

The phase of the business cycle. We assess whether the FX impact of monetary policy is different in episodes when the country faces a business cycle downturn, which we proxy by the relative unemployment rate vis-à-vis the US (or the euro area for US monetary shocks). The impact of monetary policy announcements is found to be generally larger if the country has a higher unemployment rate. Across the five economies, a 10 basis point monetary policy target surprise appreciates the currency by 14 basis points more for every one percentage point higher is the relative unemployment rate. For a 10 basis point path shock, the average additional impact is slightly larger at 16 basis points. For the euro area and United Kingdom this effect is highly significant, while for the other three economies there is some significance.

The level of interest rates. Intermediary models of exchange rate determination in the spirit of Maggiori & Gabaix (2015) predict that the FX impact of monetary policy may depend

[20]This pattern of a positive sign for the United States and negative for other countries is also seen with other measures of market conditions (e.g. volatility in fixed income markets or the measure of systematic FX liquidity put forth by Karnaukh et al. (2016)). These results are available from the authors upon request.

on the level of interest rates. With interest rates close to their lower bound, expected excess returns are less able to adjust to policy changes through the usual adjustments in interest rates and so more adjustment comes through the exchange rate. The evidence presented in Figure 7 is in line with this channel. We find that the FX impact of monetary policy is larger when interest rates have been low.[21] On average across the five economies, for every one percentage point lower is the two-year bond yield, the appreciation in response to a 10 basis point positive target shock is 22 basis points greater, and in response to a 10 basis point path shock is 26 basis points larger. The strength of this result differs across economies and the degree to which interest rates fell during our sample period. For the United States and euro area – countries facing a substantial decline in bond yields over the sample period – the result goes a large way to explaining the increased sensitivity of the exchange rate to monetary policy. However for Australia and Canada – two economies which were not constrained by the effective lower bound over our sample – the explanatory power of the level of interest rates is smaller. For these two economies, the decline in yields has not been a substantial driver of the increased sensitivity of the exchange rate to monetary policy.

D. Alternative explanations for the rise in the FX impact of monetary policy

Besides the impact of lower interest rates discussed above, there are several alternative explanations for the increased FX impact of monetary policy. It is important to point out, though, that each is incomplete or at least partly inconsistent with the observed facts.

One possible explanation for the increased sensitivity is the increasing importance of FX risk premia, although it is not clear that these have continued to increase over the full sample when other risk premia (e.g. term premia) have moderated at the same time. Market functioning could play a role as well. Reduced liquidity and intermediation ability of dealers may lead to reduced willingness of market participants to bear inventory risk when risk is high with the arrival of substantive news on monetary policy event days (e.g., Lucca & Moench (2015) and Cieslak et al. (2014)). However, this explanation would also point to a decline in

[21] Alternatively we can interact the slope coefficient with a dummy for when the policy interest rate is at the ELB. These results, shown in the Online Appendix, find some evidence that the impact of monetary shocks is greater at the ELB.

the sensitivity toward the end of the sample as market conditions have generally improved. Another possible driver could have been a greater alertness and speed with which market participants process monetary policy news, possibly reinforced by a more widespread use of algorithmic trading. Finally, it could be that monetary policy announcements may be seen to contain more information about the long-run level of the exchange rate, potentially because of information inferred about long-run inflation prospects. Further work may be able to identify if these factors have also played a role.

V. Further results

We conduct a battery of further types of analyses and robustness checks. In the following, we take a more detailed look at the impact of the Federal Reserve on the US dollar. And, we account for interest rate spillovers when gauging the response of monetary policy shocks to the exchange rate. The results of the additional tests are reported in the Online Appendix.

A. A closer look at the Fed's impact on the US dollar

The estimated impact of Fed policy actions on the US dollar is robust to using alternatives to the euro bilateral exchange rate. Results are shown in Table 8 using the yen, pound, Australian dollar, Swiss franc and Canadian dollar bilateral exchange rates against the US dollar. We also consider the impact of Fed monetary shocks on a broad US dollar index which weights the six bilateral rates using turnover shares from the BIS Triennial Survey. For target and path shocks, the coefficient estimates are similar to the baseline results for the USD/EUR and are all significant. Again, for the expectations and term premia shocks these alternative coefficient estimates are highly significant. For this specification, the explanatory power using the US dollar index is particularly strong, with an R^2 of 0.44.

[Table 8 about here]

B. The impact of interest rate spillovers

In the following, we analyze the impact of interest rate spillovers on the FX impact of monetary policy.[22] The idea is that the change in domestic interest rates as a response to a monetary policy shock in a large economy may influence the response of the bilateral exchange rate between those economies to the monetary shock. One possible explanation for the smaller coefficient on US monetary suprises (as reported in Table 3) is the spillover to other economies' interest rates which mutes the response of the US dollar. Conversely, spillovers are less likely from small economies to large economies, and so the exchange rate response to the monetary policy shock is less likely to be influenced by spillovers.

To quantitatively assess the impact that spillovers have on the exchange rate response to a monetary shock, we consider a system of two equations. For simplicity and clarity we measure the monetary policy shock using the change in only one interest rate (either the 1-month OIS or 2- or 10-year bond yield), rather than the two shocks (target and path) used earlier. Equation (6) accounts for how changes in the interest rate in the economy in which there is a monetary policy announcement, MPS_t, spillover to the 'foreign' economy, $MPS^{\star}_{j,t}$ (denoted with a star). Equation (7) then accounts for how the change in interest rates in both economies affect the exchange rate. The bilateral exchange rate between these two economies is expressed in terms of units of foreign currency per unit of home currency.

$$MPS^{\star}_t = \gamma MPS_t + \epsilon^1_t \tag{6}$$

$$\Delta s_t = \beta_{system}[MPS_t - MPS^{\star}_t] + \epsilon^2_t \tag{7}$$

If there are positive, but incomplete, spillovers of interest rates then we would expect $0 < \delta < 1$. We assume that the impact of the two economies' interest rates is symmetric and so it is the change in the interest differential that affects the exchange rate in Equation (7). We estimate the system of equations jointly by GMM to account for the potential

[22]Interest rate spillovers are an important mechanism through which financial conditions in one economy can spillover to others (see for example, Chen et al. (2016), Craine & Martin (2008), Fratzscher et al. (2013) and Rogers et al. (2014)).

errors-in-variable problem when measuring MPS_t^* using the moment conditions specified as Equations (8) and (9):

$$\mathbb{E}(MPS_t^\star - \delta \cdot MPS_t) = 0 \tag{8}$$

$$\mathbb{E}\left\{(\Delta s_t - \beta_{system}[MPS_t - MPS_t^\star] \cdot \mathbf{x}_t\right\} = \mathbf{0}, \tag{9}$$

with $\mathbf{x}_t = [1, MPS_t, MPS_t^\star]$.

The results for the estimation of this system by GMM are shown in Tables 9 and 10 along with results from the univariate regression in Equation (1) (using the same bilateral exchange rate and sample period; for example, GBP per EUR for spillovers from ECB announcements, but EUR per GBP for spillovers from Bank of England announcements). There are positive and significant spillovers when using changes in bond yields to measure the policy shock, but as expected these are only partial with estimates of γ less than one. Notably, the spillovers are larger from a bigger economy to a smaller economy (γ is larger for euro area to the UK and US to Canada than the reverse), although it is interesting that spillovers are estimated to be larger from the euro area to the US than in reverse.[23] In contrast to the results for both 2- and 10-year bond yields, most estimates indicate there are no spillovers for for 1-month OIS interest rates, which indicates that near-term policy rate expectations are little influenced by global forces.

However, the interest rate spillover does not seem to have a substantial impact on the exchange rate response of monetary policy announcements. The response of the exchange rate to a policy announcement accounting for the interest rate spillover, given by $\beta_{system}(1-\gamma)$ is not consistently larger than the univariate estimate, β.

[Tables 9 and 10 about here]

[23]Note that the cash euro bond prices are not available when most US monetary policy announcements occur and so we use a longer window to measure the change in euro bond yields from the close to the subsequent open.

VI. Conclusion

Monetary policy is a key driver of exchange rates, just as the exchange rate is an important element in central banks' policy deliberations. With questions about the efficacy of domestic channels of monetary policy following years of ultra-low interest rates, it is not surprising that the exchange rate channel has received more attention.

Using a comprehensive and carefully designed event study to account for different types of monetary policy and to control for the endogeneity of interest rates and exchange rates, we show that despite the substantial changes in financial markets and the implementation of monetary policy over the past decade, monetary policy continues to exert a strong impact on exchange rates. Unconventional policy affects the exchange rate in much the same way as does conventional monetary policy, through the expected path of monetary policy and longer-term interest rates. Indeed, we find that the impact of unconventional monetary policy on the exchange rate is in most cases broadly similar to that of conventional monetary policy.

Our most striking finding is that the sensitivity of the exchange rate to monetary policy has grown over time. We observe the rising FX impact for both central banks that have engaged in unconventional monetary policy and those that have not been constrained by the effective lower bound and thus continued to use conventional tools. It is also noteworthy that the increased sensitivity seemingly pertains to monetary policy only. We find that common macro data releases show little evidence of an increased FX impact. We find that for some, but notably not all countries, the drop of interest rates to historical lows has contributed to the increased sensitivity. Such effects naturally arise in the intermediary model of exchange rate of Maggiori & Gabaix (2015). As the effective lower bound becomes increasingly binding, the exchange rate bears more and more the burden of adjustment when expected currency excess returns change. We also find that the impact of monetary policy on the exchange rate is state-dependent and varies in a meaningful way with business cycle and financial conditions. Overall, the FX impact of monetary policy is far from stable over time, but has become even stronger in recent years.

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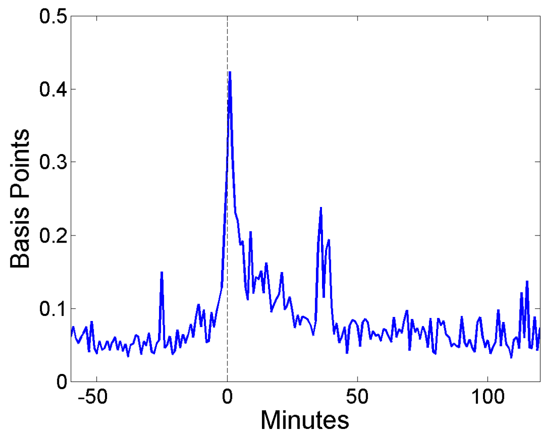
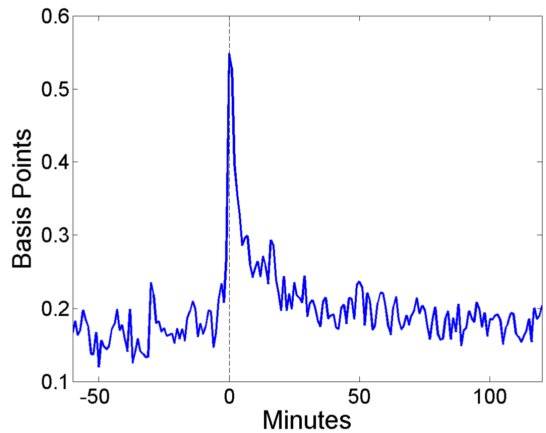
Tables and Figures

Figure 1: Interest rate variation around monetary policy announcements



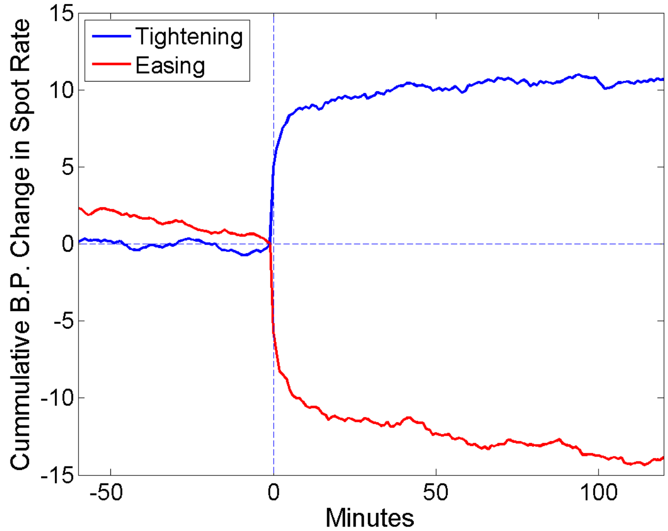
(a) Absolute change in 1-month OIS rate



(b) Absolute change in 2-year yield

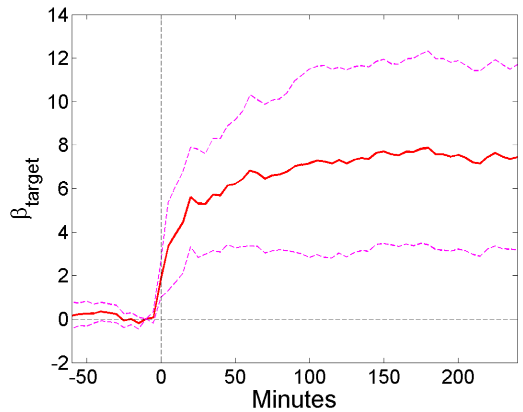
Notes: Minute-by-minute observations of absolute interest rate changes (expressed in basis points), averaged across all events and across all seven economies. The event occurs at $t = 0$ and is highlighted by a vertical dashed line.

Figure 2: Cumulative change in the exchange rate around monetary policy events

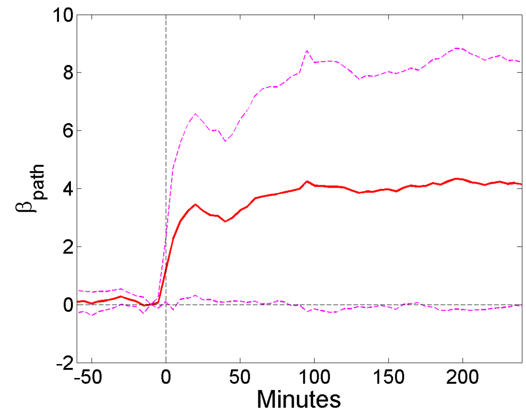


Notes: Minute-by-minute cumulative change in the exchange rate (in basis points). The events are either classified as tightening (rise in the 2-year bond yield), or easing (drop in the 2-year bond yield). The exchange rate response is normalised to zero at the time of the event (t=0). The average, pooled across all seven currencies, is computed separately for monetary easing and tightening events.

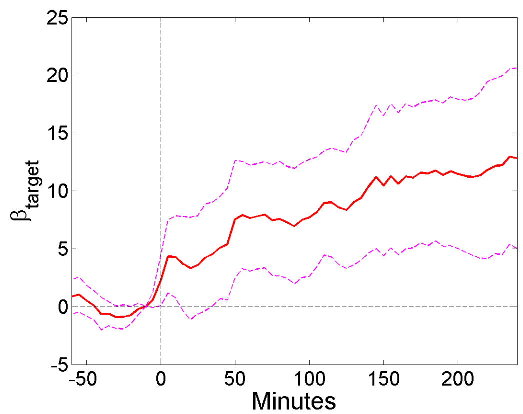
Figure 3: Intraday time path of the exchange rate response



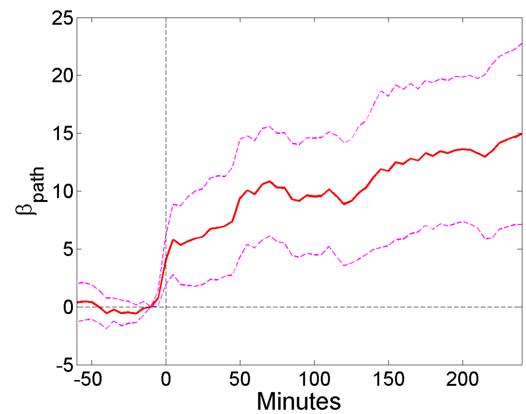
(a) USD response to target shock (β_{target})



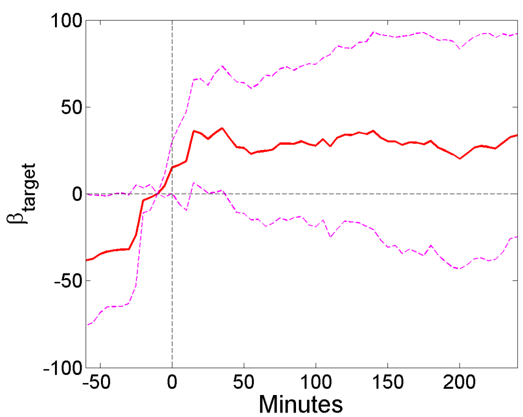
(b) USD response to path shock (β_{path})



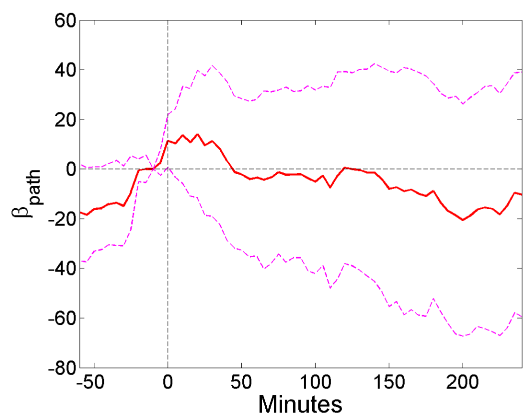
(c) EUR response to target shock (β_{target})



(d) EUR response to path shock (β_{path})

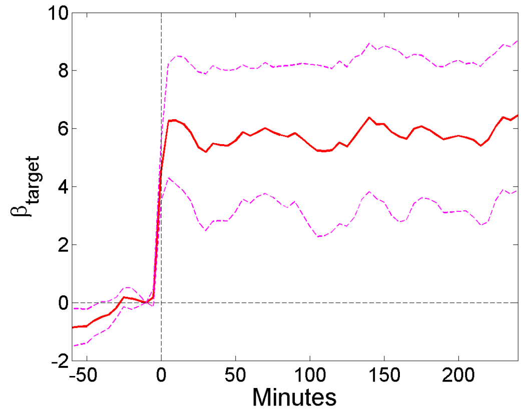


(e) JPY response to target shock (β_{target})

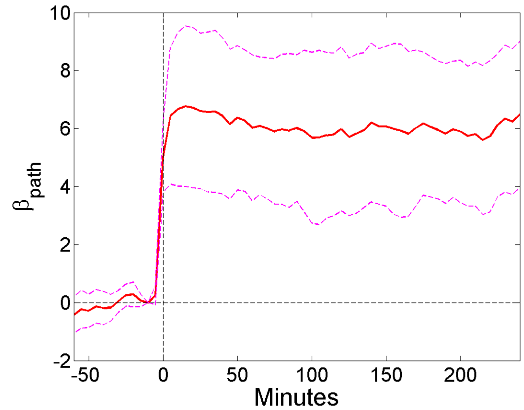


(f) JPY response to path shock (β_{path})

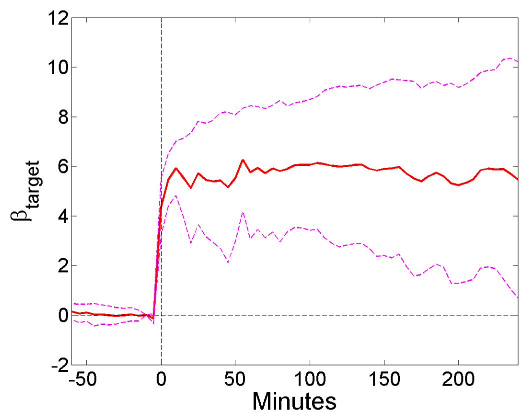
Figure 3 cont. Intraday time path of exchange rate response



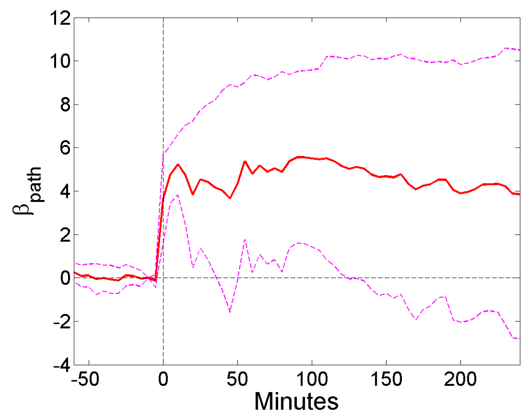
(g) GBP response to target shock (β_{target})



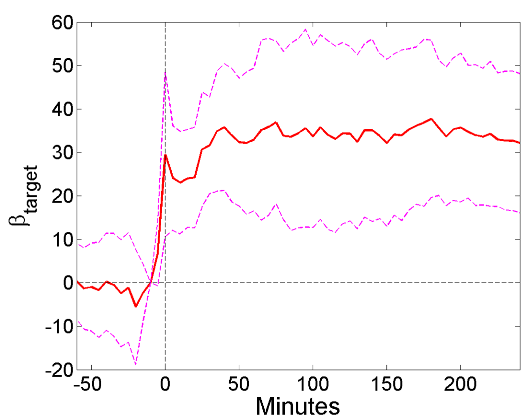
(h) GBP response to path shock (β_{path})



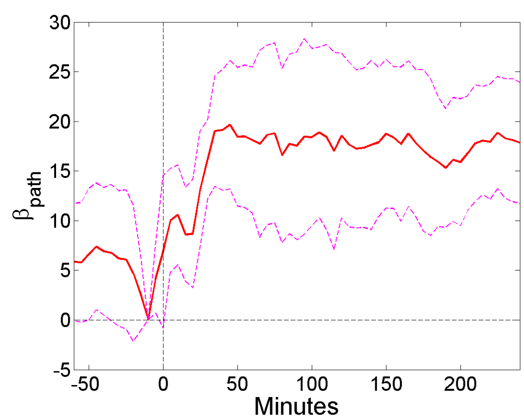
(i) AUD response to target shock (β_{target})



(j) AUD response to path shock (β_{path})

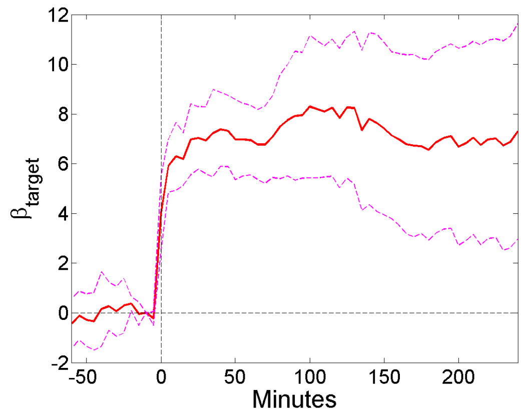


(k) CHF response to target shock (β_{target})

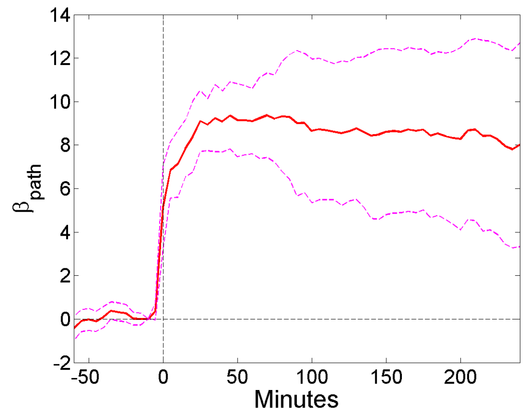


(l) CHF response to path shock (β_{path})

Figure 3 cont. Intraday time path of the exchange rate response



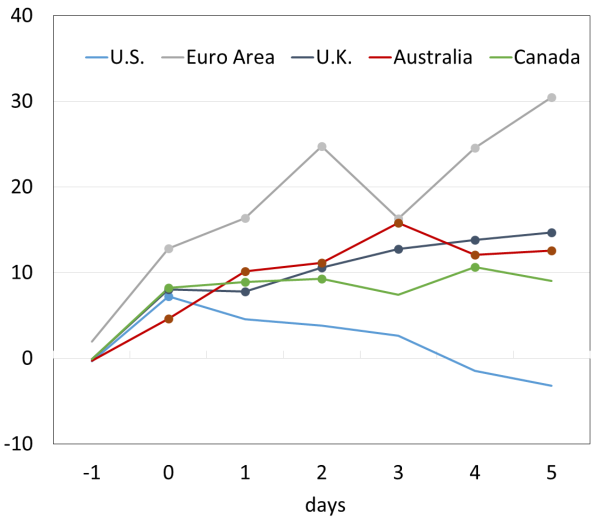
(m) CAD response to target shock (β_{target})



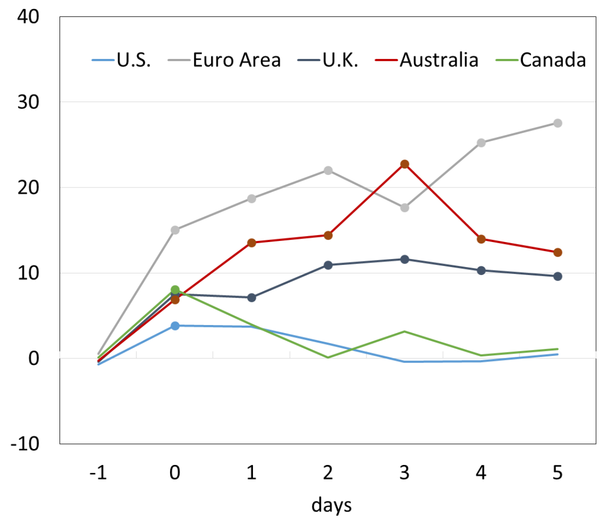
(n) CAD response to path shock (β_{path})

Notes: The timing of the monetary policy announcement is depicted by the vertical line at $t = 0$. Coefficient estimates for target and path shocks are obtained from Equation (3) based on the local linear projection method of Jordà (2005) for different horizons k.

Figure 4: Persistence of the exchange rate response over subsequent days



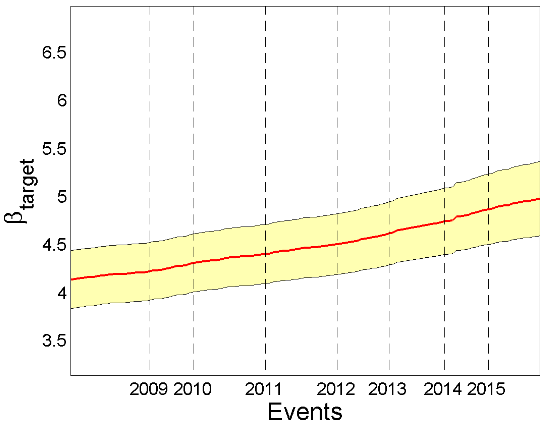
(a) $\beta^{(k)}_{target}$



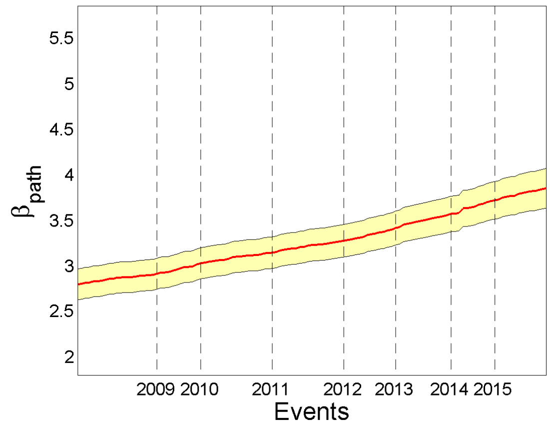
(b) $\beta^{(k)}_{path}$

Notes: Coefficient estimates for target and path shocks are obtained from Equation (3) for changes from close of day $t-1$ to day $t+k$. Dots indicate statsitically significant coefficients.

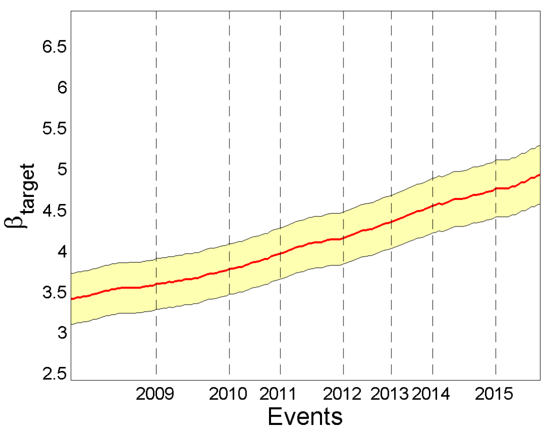
Figure 5: Time-varying FX impact of monetary policy shocks



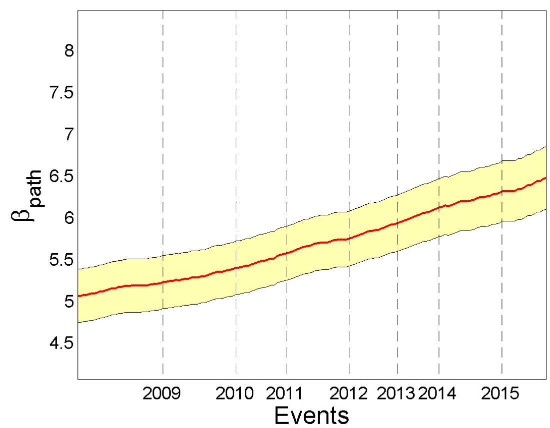
(a) USD estimation of β_{target} by time



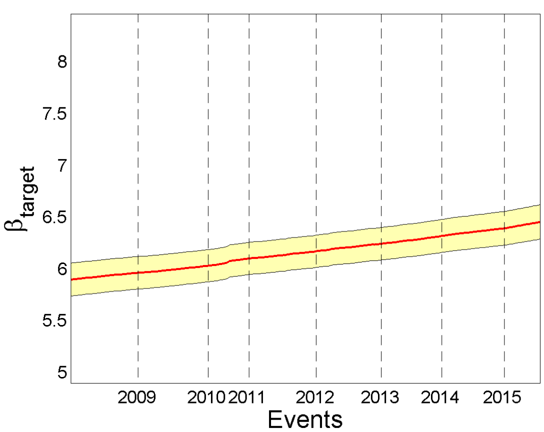
(b) USD estimation of β_{path} by time



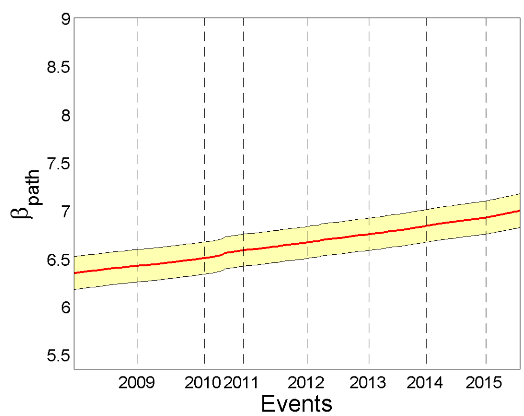
(c) EUR estimation of β_{target} by time



(d) EUR estimation of β_{path} by time

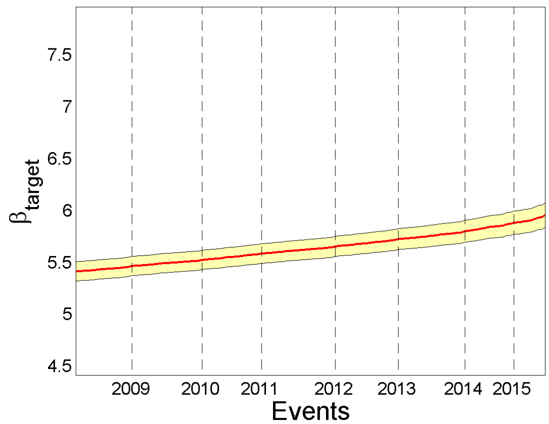


(e) GBP estimation of β_{target} by time

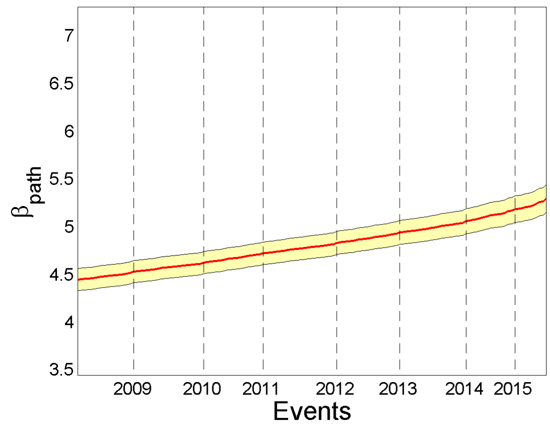


(f) GBP estimation of β_{path} by time

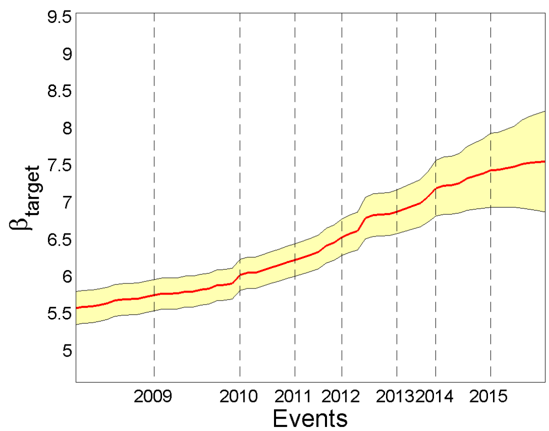
Figure 5 cont. Time-varying FX impact of monetary policy shocks



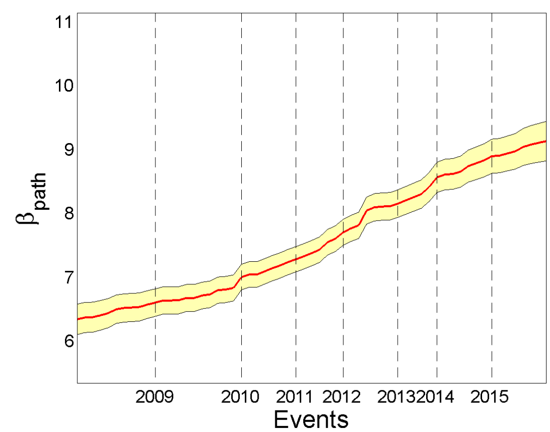
(g) AUD estimation of β_{target} by time



(h) AUD estimation of β_{path} by time



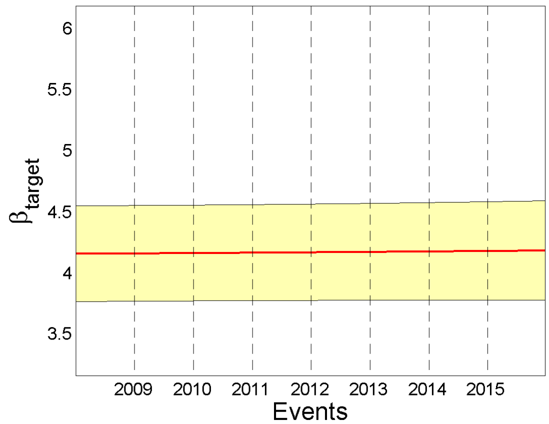
(i) CAD estimation of β_{target} by time



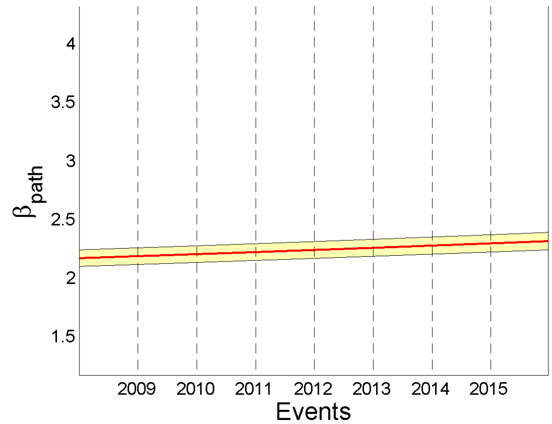
(j) CAD estimation of β_{path} by time

Notes: Time-varying coefficient estimates are obtained via the non-parametric regression given by Equation (4).

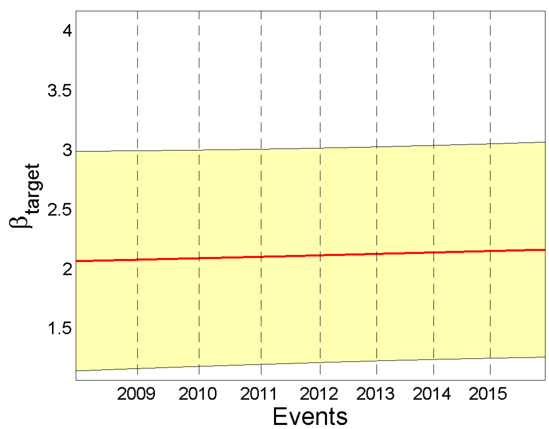
Figure 6: Time-varying FX impact of macro data surprises



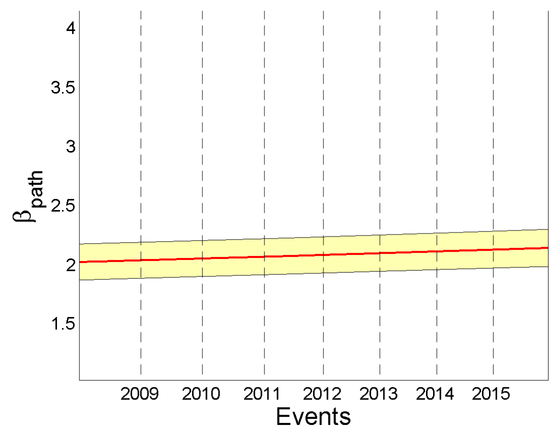
(a) USD estimation of β_{target} by time



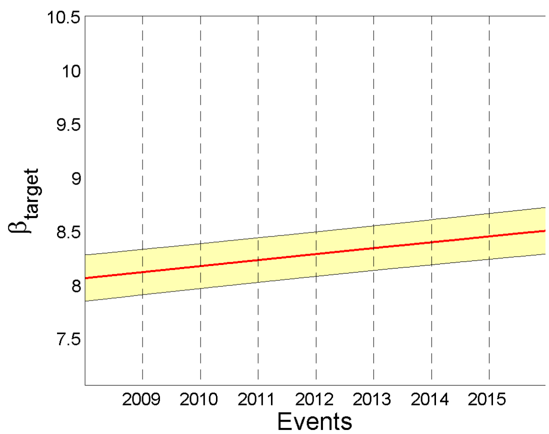
(b) USD estimation of β_{path} by time



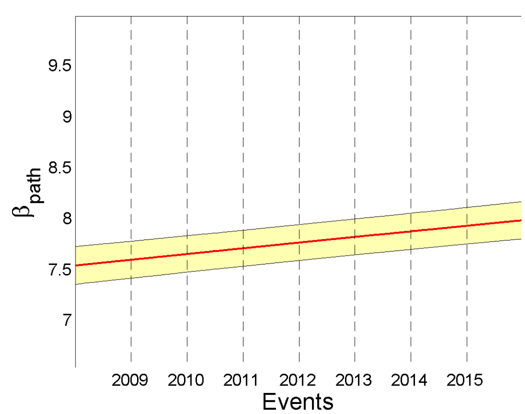
(c) EUR estimation of β_{target} by time



(d) EUR estimation of β_{path} by time

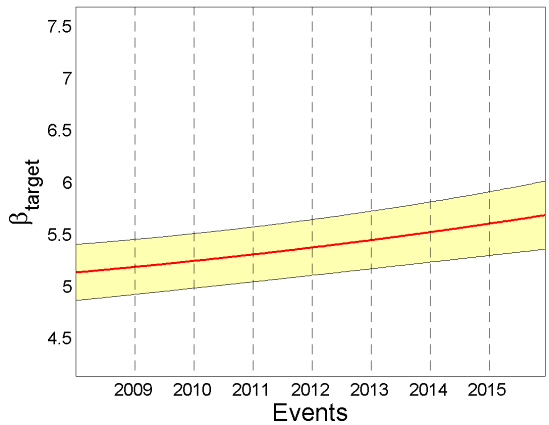


(e) GBP estimation of β_{target} by time

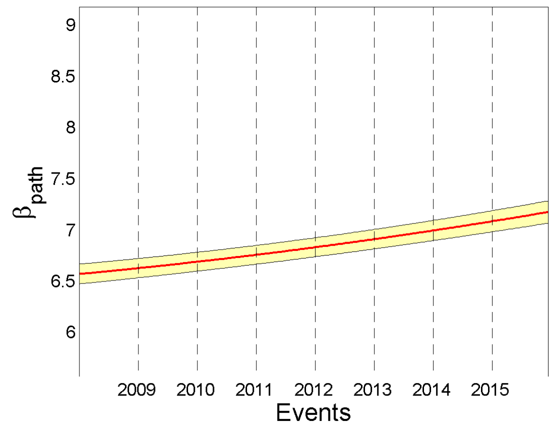


(f) GBP estimation of β_{path} by time

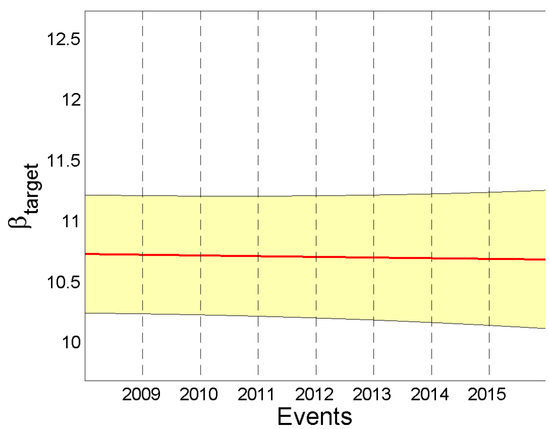
Figure 6 cont. Time-varying FX impact of macro data surprises



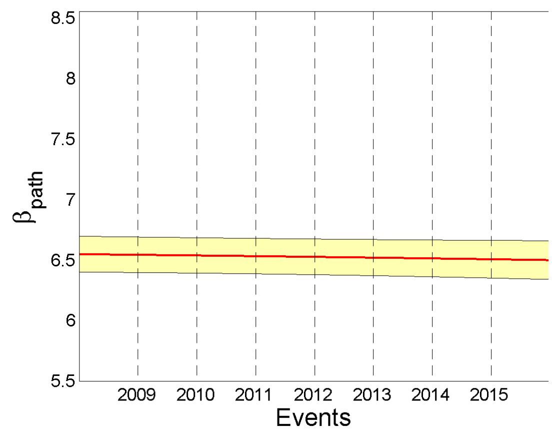
(g) AUD estimation of β_{target} by time



(h) AUD estimation of β_{path} by time



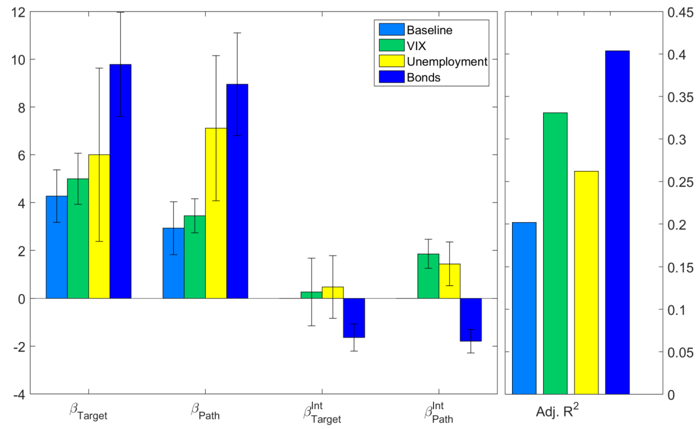
(i) CAD estimation of β_{target} by time



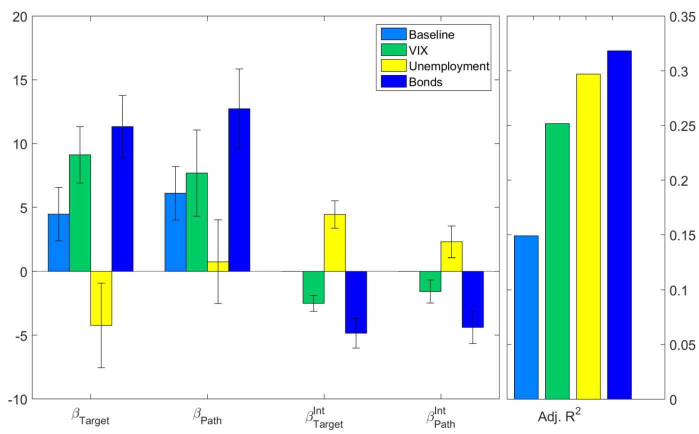
(j) CAD estimation of β_{path} by time

Notes: Time-varying coefficient estimates for the FX response to interest rate changes around CPI, GDP and employment data releases are obtained via the non-parametric regression given by Equation (4).

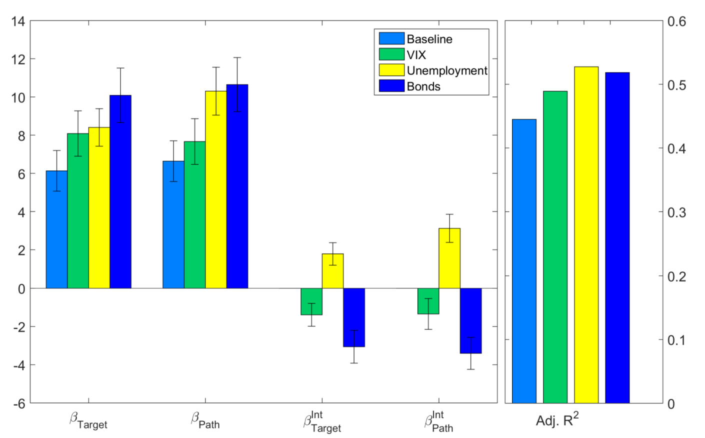
Figure 7: State-dependence of the FX impact of monetary policy



(a) United States

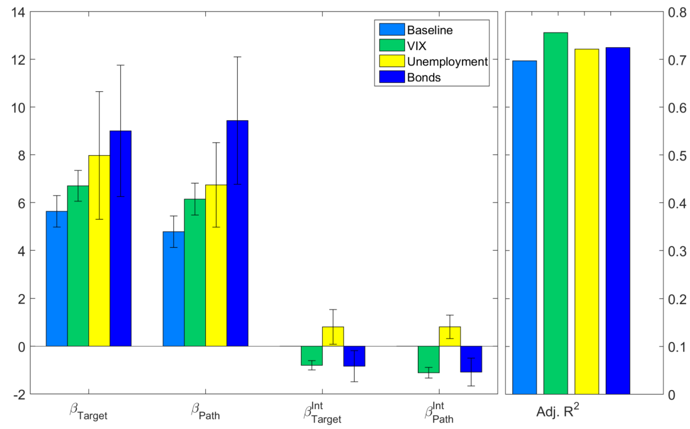


(b) Euro Area

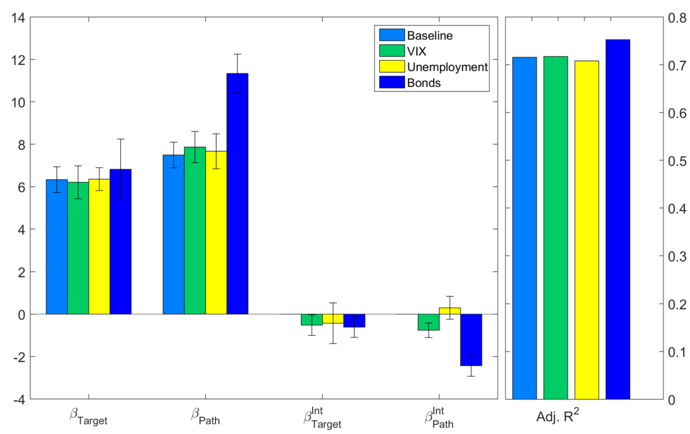


(c) United Kingdom

Figure 7 cont. State-dependence of the FX impact of monetary policy



(d) Australia



(e) Canada

Notes: Results from estimation of Equation (5). The VIX is standardised, the unemployment rate is the difference between the home and foreign country unemployment rates (in percentage points) and bonds is the home country 2-year yield. Standard errors are shown by the lines.

Table 1: Overview of monetary policy events

	MPD	UMP	o/w FG	Minutes	Total
U.S.					
(05.2004-12.2015)	**59**	**25**	10	**47**	131
Euro Area					
(04.2004-11.2015)	**113**	**32**	8	–	145
Japan					
(12.2009-11.2015)	**17**	**6**	1	**40**	63
U.K.					
(09.2007-11.2015)	**74**	**16**	11	**89**	179
Australia					
(07.2006-15.2015)	**92**	–	–	**57**	149
Switzerland					
(09.2010-09.2015)	**23**	–	–	–	23
Canada					
(01.2007-12.2015)	**51**	–	–	–	51

Notes: Number of events: scheduled monetary policy decision (MPD) events (excluding any UMP events); Unconventional Monetary Policies (UMP), of which Forward Guidance (FG); and the release of central bank minutes (minutes). Some unconventional policies were announced at the time of a scheduled monetary policy decision, in which case the event is classified as an UMP and not an MPD event.

Table 2: Magnitude of market responses around monetary policy events

	Sample Period	Policy Rate	FX Spot	Target	Path	$\Delta y^{(2)}$	$\Delta y_{\perp}^{(10)}$
U.S.	05.2004-12.2015	7.8	17.4	1.0	2.2	1.7	1.8
Euro Area	04.2004-11-2015	5.5	12.6	0.9	1.1	0.8	0.7
Japan	12.2009-11.2015	0.0	10.3	0.2	0.3	0.3	0.9
U.K.	09.2007-11.2015	4.9	16.5	1.4	2.1	1.6	0.9
Australia	07.2006-15.2015	9.5	21.8	2.9	2.8	2.6	0.8
Switzerland	09.2010-09.2015	6.3	29.1	0.6	1.2	1.0	0.5
Canada	01.2007-12.2015	7.9	31.9	1.9	3.1	2.6	0.8

Notes: For all monetary policy decision events, the Table reports average absolute changes in the policy rate, FX Spot and monetary policy shocks in the 25 minute window in basis points. Column 3 reports the average absolute change in the policy rate at the MPD events of each central bank. Columns 4-8 report the average absolute changes. The target is computed as the change in the 1-month OIS monetary policy and the path using the change in the difference between 2-year bonds and 1-month OIS rates. $\Delta y_{\perp}^{(10)}$ is the change in the 10-year bond yield that is orthogonal to that in the 2-year bond yield.

Table 3: FX response to monetary policy announcements

$$\Delta s_t = \alpha + \beta_{target} MPS_t^{OIS} + \beta_{path} MPS_t^{Bond\text{-}OIS} + \epsilon_t$$

	U.S.	**Euro area**	**Japan**	**U.K.**	**Australia**	**Switzerland**	**Canada**
β_{target}	4.27	4.46	27.34	6.13	5.63	25.23	6.33
p-val.	(0.00)	(0.03)	(0.04)	(0.00)	(0.00)	(0.00)	(0.00)
β_{path}	2.93	6.10	11.58	6.64	4.78	7.07	7.49
p-val.	(0.04)	(0.00)	(0.20)	(0.00)	(0.00)	(0.07)	(0.00)
R^2	0.21	0.16	0.17	0.45	0.70	0.40	0.72

Notes: The Table reports coefficient estimates of Equation (1). Coefficients describe the impact on the exchange rate (in basis points) of "target" or "path" monetary policy shocks (also measured in basis points). P-values (in parentheses) are computed with HAC standard errors. The estimation pools all types of monetary policy events.

Table 4: Response to expectations and term premium shocks

$$\Delta s_t = \alpha + \beta_{exp} MPS_t^{2y} + \beta_{tp} MPS_t^{10y\perp} + \epsilon_t$$

	U.S.	**Euro area**	**Japan**	**U.K.**	**Australia**	**Switzerland**	**Canada**
β_{exp}	3.07	5.02	1.21	3.94	5.41	11.31	7.09
p-val.	(0.00)	(0.00)	(0.38)	(0.00)	(0.00)	(0.00)	(0.00)
β_{tp}	2.65	8.25	-0.10	4.12	4.56	24.33	-0.89
p-val.	(0.00)	(0.00)	(0.87)	(0.04)	(0.00)	(0.00)	(0.73)
R^2	0.36	0.35	0.00	0.45	0.68	0.39	0.67

Notes: The Table reports coefficient estimates of Equation (2). Coefficients describe the impact on the exchange rate (in basis points) of "expectations" (exp) or "term premium" (tp) monetary policy shocks (also measured in basis points). We proxy for expectations shocks via the change in the 2-year bond yield and for term premium shocks via the change in the 10-year yield orthogonalized against the change in the 2-year bond yield. P-values (in parentheses) are computed with HAC standard errors.

Table 5: Regular monetary policy decisions vs Unconventional Monetary Policy (UMP)

$$(A) \quad \Delta s_t = \alpha + (\beta_{target} + \beta^{UMP}_{target} \mathbb{1}^{UMP}) MPS^{OIS}_t + (\beta_{path} + \beta^{UMP}_{path} \mathbb{1}^{UMP}) MPS^{Bond\text{ - }OIS_t} + \epsilon_t$$

$$(B) \quad \Delta s_t = \alpha + (\beta_{exp} + \beta^{UMP}_{exp} \mathbb{1}^{UMP}) MPS^{2y}_t + (\beta_{tp} + \beta^{UMP}_{tp} \mathbb{1}^{UMP}) MPS^{10y\perp}_t + \epsilon_t$$

	Panel A. Target and Path				Panel B. Expectations and Term Premium Shocks		
	Coefficient	P-Value	R^2		Coefficient	P-Value	R^2
U.S.							
β_{target}	3.19	(0.00)	0.52	β_{exp}	2.33	(0.00)	0.55
β_{path}	1.63	(0.01)		β_{tp}	2.41	(0.02)	
β^{UMP}_{target}	9.76	(0.22)		β^{UMP}_{exp}	7.42	(0.00)	
β^{UMP}_{path}	10.92	(0.00)		β^{UMP}_{tp}	-0.58	(0.63)	
Euro Area							
β_{target}	4.57	(0.10)	0.27	β_{exp}	5.12	(0.06)	0.39
β_{path}	6.56	(0.02)		β_{tp}	7.21	(0.00)	
β^{UMP}_{target}	6.75	(0.35)		β^{UMP}_{exp}	4.93	(0.20)	
β^{UMP}_{path}	3.38	(0.50)		β^{UMP}_{tp}	-0.95	(0.69)	
U.K.							
β_{target}	6.91	(0.00)	0.51	β_{exp}	3.72	(0.00)	0.45
β_{path}	8.29	(0.00)		β_{tp}	4.16	(0.04)	
β^{UMP}_{target}	-0.35	(0.87)		β^{UMP}_{exp}	0.52	(0.83)	
β^{UMP}_{path}	-0.97	(0.76)		β^{UMP}_{tp}	-1.28	(0.71)	

Notes: The Table reports coefficient estimates from Equation (A) and (B). $\mathbb{1}^{UMP}$ is a dummy that takes value equal to 1 if the event type is a UMP event. β^{UMP}_{target} and β^{UMP}_{path} (β^{UMP}_{exp}, β^{UMP}_{tp}) measure the additional impact on the exchange rate of UMP events. Coefficients describe the impact of the exchange rate (in basis points) to "target", "path", "expectation" (exp) or "term premium" (tp) monetary policy shocks (also measured in basis points). P-values (in parentheses) are computed with HAC standard errors. The estimation uses monetary policy decisions and UMPs only.

Table 6: Regular monetary policy decisions vs Forward Guidance (FG)

$$(A) \quad \Delta s_t = \alpha + (\beta_{target} + \beta^{FG}_{target}\mathbb{1}^{FG})MPS^{OIS}_t + (\beta_{path} + \beta^{FG}_{path}\mathbb{1}^{FG})MPS^{Bond\text{ - }OIS_t} + \epsilon_t$$

$$(B) \quad \Delta s_t = \alpha + (\beta_{exp} + \beta^{FG}_{exp}\mathbb{1}^{FG})MPS^{2y}_t + (\beta_{tp} + \beta^{FG}_{tp}\mathbb{1}^{FG})MPS^{10y\perp}_t + \epsilon_t$$

	Panel A. Target and Path				Panel B. Expectations and Term Premium Shocks		
	Coefficient	P-Value	R^2		Coefficient	P-Value	R^2
U.S.							
β_{target}	4.21	(0.00)	0.23	β_{exp}	2.88	(0.00)	0.54
β_{path}	2.84	(0.08)		β_{tp}	3.59	(0.00)	
β^{FG}_{target}	-3.63	(0.46)		β^{UMP}_{exp}	6.29	(0.09)	
β^{FG}_{path}	1.91	(0.37)		β^{UMP}_{tp}	3.36	(0.54)	
Euro Area							
β_{target}	4.94	(0.06)	0.32	β_{exp}	5.58	(0.05)	0.40
β_{path}	7.12	(0.01)		β_{exp}	7.48	(0.00)	
β^{FG}_{target}	2.83	(0.48)		β^{FG}_{exp}	5.15	(0.07)	
β^{FG}_{path}	2.38	(0.39)		β^{FG}_{exp}	4.03	(0.47)	
U.K.							
β_{target}	6.28	(0.00)	0.45	β_{exp}	3.62	(0.00)	0.37
β_{path}	7.48	(0.00)		β_{tp}	4.01	(0.03)	
β^{FG}_{target}	4.02	(0.20)		β^{FG}_{exp}	4.07	(0.06)	
β^{FG}_{path}	1.81	(0.46)		β^{FG}_{tp}	3.15	(0.44)	

Notes: The Table reports coefficient estimates from Equation (A) and (B). $\mathbb{1}^{FG}$ is a dummy that takes value equal to 1 if the event type is a FG event. β^{FG}_{target} and β^{FG}_{path} (β^{FG}_{exp}, β^{FG}_{tp}) measure the additional impact on the exchange rate of FG events. Coefficients describe the impact on the exchange rate (in basis points) of "target", "path", "expectation" (exp) or "term premium" (tp) monetary policy shocks (also measured in basis points). P-values (in parentheses) are computed with HAC standard errors. The estimation uses monetary policy decisions and FGs only.

Table 7: FX response to macro data surprise

$$\Delta s_t = \alpha + \beta_{target}(News\ Shock)_t^{OIS} + \beta_{path}(News\ Shock)_t^{Bond\text{-}OIS} + \epsilon_t$$

	U.S.	**Euro area**	**Japan**	**U.K.**	**Australia**	**Switzerland**	**Canada**
β_{target}	4.16	2.06	8.98	8.25	5.33	9.44	10.70
p-val.	(0.00)	(0.30)	(0.09)	(0.00)	(0.00)	(0.52)	(0.00)
β_{path}	2.22	2.04	7.92	7.72	6.87	11.43	6.52
p-val.	(0.00)	(0.06)	(0.14)	(0.00)	(0.00)	(0.45)	(0.00)
R^2	0.17	0.03	0.28	0.40	0.77	0.00	0.40

Notes: The Table reports coefficient estimates of Equation (1). Coefficients describe the impact on the exchange rate (in basis points) of "target" or "path" macroeconomic data release shocks (also measured in basis points). P-values (in parentheses) are computed with HAC standard errors.

Table 8: Fed monetary policy shocks and the US Dollar

	EUR	JPY	U.K.	AUD	CHF	CAD	**USD Index**
		Target and Path					
β_{target}	4.27	2.19	3.71	5.78	3.69	3.16	**3.71**
p-val.	(0.00)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
β_{path}	2.93	2.98	2.22	2.72	3.35	1.60	**2.76**
p-val.	(0.04)	(0.05)	(0.04)	(0.10)	(0.04)	(0.07)	**(0.04)**
R^2	0.21	0.24	0.22	0.15	0.24	0.26	**0.24**
		Expectations and term premia					
β_{exp}	3.07	2.96	2.37	2.96	3.41	1.76	**2.87**
p-val.	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	**(0.00)**
β_{tp}	2.65	3.08	2.09	2.72	2.45	1.55	**2.58**
p-val.	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
R^2	0.36	0.55	0.37	0.22	0.39	0.20	**0.44**

Notes: Estimated coefficients of Equation (1) and Equation (2) with bilateral and weighted U.S. dollar exchange rate. The USD Index is weighted based on the turnover in the BIS Triennial survey of the six currency pairs. Coefficients describe the impact on the exchange rate (in basis points) of "target", "path" "expectations" (exp) or "term premium" (tp) monetary policy shocks (also measured in basis points). P-values (in parentheses) are computed with HAC standard errors.

Table 9: Spillovers - Bonds

$$Univariate:\ \ \Delta s_t = \beta MPS_t^{Bond} + \epsilon_t$$

$$System:\ \begin{cases} MPS_t^{\star} = \gamma MPS_t^{Bond} + \epsilon_t^1 \\ \Delta s_t = \beta_{system}[MPS_t^{Bond} - MPS_t^{\star\, Bond}] + \epsilon_t^2 \end{cases}$$

	USD⇒EUR	EUR⇒USD	EUR⇒GBP	GBP⇒EUR	USD⇒CAD	CAD⇒USD
			2 Year Bonds			
Univariate						
β	3.05	4.99	3.99	3.78	3.19	7.10
p-val.	(0.02)	(0.02)	(0.01)	(0.01)	(0.00)	(0.00)
R^2	0.17	0.11	0.10	0.28	0.17	0.67
System						
γ	0.19	0.41	0.35	0.15	0.45	0.02
p-val.	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.52)
β_{system}	1.05	3.97	2.14	4.17	3.47	6.24
p-val.	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\beta_{sys}(1-\gamma)$	0.84	2.32	1.39	3.56	1.92	6.09
p-val.	(0.03)	(0.26)	(0.17)	(0.01)	(0.25)	(0.05)
R^2	0.02	0.09	0.04	0.27	0.08	0.21
			10 Year Bonds			
Univariate						
β	3.26	8.70	4.81	5.11	2.04	13.10
p-val.	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.28	0.33	0.16	0.38	0.17	0.38
System						
γ	0.28	0.82	0.75	0.22	0.41	0.09
p-val.	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.32)
β_{system}	1.33	4.78	5.08	6.34	2.88	7.55
p-val.	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\beta_{system}(1-\gamma)$	0.83	0.84	1.25	4.97	1.71	6.89
p-val.	(0.03)	(0.48)	(0.37)	(0.02)	(0.06)	(0.46)
R^2	0.04	0.05	0.09	0.39	0.14	0.58

Notes: The Table reports coefficient estimates of the system composed by Equation (6) and Equation (7). The system is estimated jointly via GMM with p-values reported in parentheses. All series are demeaned and the estimation pools all types of monetary policy events. As the European market is generally closed at U.S. events, we use close to open quotes to measure the shock in that case.

Table 10: Spillovers - OIS

$$Univariate: \ \ \Delta s_t = \beta MPS_t^{OIS} + \epsilon_t$$

$$System: \begin{cases} MPS_t^{\star} = \gamma MPS_t^{OIS} + \epsilon_t^1 \\ \Delta s_t = \theta[MPS_t^{OIS} - MPS_t^{\star\, OIS}] + \epsilon_t^2 \end{cases}$$

	USD⇒EUR	EUR⇒USD	EUR⇒GBP	GBP⇒EUR	USD⇒CAD	CAD⇒USD
Univariate						
β	2.36	-0.68	0.79	0.18	2.05	2.69
p-val.	(0.00)	(0.53)	(0.22)	(0.53)	(0.00)	(0.13)
R^2	0.02	0.01	0.02	0.00	0.05	0.08
System						
γ	0.00	0.25	-0.01	0.07	-0.001	-0.01
p-val.	(0.97)	(0.00)	(0.63)	(0.00)	(0.63)	(0.70)
θ	0.88	0.29	0.55	0.18	2.00	2.56
p-val.	(0.14)	(0.63)	(0.17)	(0.52)	(0.01)	(0.00)
$\theta(1-\gamma)$	0.88	0.22	0.56	0.17	2.01	2.58
p-val.	(0.09)	(0.09)	(0.02)	(0.00)	(0.15)	(0.25)
R^2	0.01	0.01	0.01	0.00	0.05	0.07

Notes: The Table reports coefficient estimates of the system composed by Equation (6) and Equation (7). The system is estimated jointly via GMM with p-values reported in parentheses. All series are demeaned and the estimation pools all types of monetary policy events. As the European market is generally closed at U.S. events, we use close to open quotes to measure the shock in that case.

Supplementary Internet Appendix

Monetary policy's rising FX impact in the era of ultra-low rates

A. Data filtering

Our intraday data (at a 1-minute frequency) are sourced from Thomson Reuters TickHistory, covering the FX spot exchange rate, 2-year and 10-year bond yields and 1-month and 6-month OIS interest rates. We first check for possible outliers and data reporting errors. At first, we implement a standard filter for outliers. We are very cautious in defining outliers, restricting our choice to observations more than 5 standard deviations away from the sample mean. This filtering choice allows us to exclude implausible quotes that are the results of extreme events.[24]

Furthermore, there could be days with very infrequent updating of quotes in relatively illiquid markets. In our analysis, however, it is crucial to understand if a monetary policy decision has an impact or not on a specific instrument. No change in the quote, for example, means the decision was fully expected by the market and already priced in. For illiquid markets, however, there is the possibility that quotes remain constant because not enough trades and hence updating of quotes is taking place. In that case, a monetary shock would possibly be considered as fully anticipated, potentially leading to a bias in the results. For the same reason, however, we do not want to exclude possibly fully anticipated shocks. It is thus crucial to distinguish these two cases. In the first case, we would simply exclude the observation from the sample as a data error, while in the second we need to keep it. To take this decision, we do some extensive cross-checking of our high-frequency against Bloomberg daily quotes. We then compute daily changes based on our database using opening and closing quotes for each market at each event day. If the shock measure for any given event is zero, we check the daily change on that trading day as results from Thomson Reuters data. If that is zero as well we compare it with the daily change from Bloomberg. If this change is not zero, then we consider the observation as a data reporting error and exclude it from the sample.

B. Time-varying parameter model: Methodology

To test if the impact of monetary policy news on the exchange rate has changed over time, we estimate a time-varying parameter model based on non-parametric regression techniques along the lines of Ang & Kristensen (2012). This method allows us to use all the information contained in

[24]For example we apply this filter to the decision of the 15^{th} of January 2015 of the SNB to abandon its fixed exchange rate of the Swiss franc against the Euro. The change in the exchange rate was more than 7 standard deviations away from the sample mean on that day.

the regressors, yet assigning more weight to observations close to a specific time observation.

Assume that there is a sequence of events at time $0 < t_1 < t_2 < t_3 < .... \leq T$ and we are interested in estimating α_τ, $\beta_{target,\tau}$ and $\beta_{slope,\tau}$ for a specific time $\tau \in (0, T)$. For each given point in time τ it is possible to estimate the parameters of interest $\left(\hat{\alpha}_\tau, \hat{\beta'}_\tau\right)'$ by minimizing the following objective function

$$arg \min_{(\alpha,\beta)} \sum_{i=1}^{N} K_h\left(t_i - \tau\right)\left[\Delta s_{t_i} - \alpha - \beta_{target} \cdot MPS_{t_i}^{OIS} - \beta_{path} \cdot MPS_{t_i}^{Bond-OIS}\right]^2$$

with $K_h(\bullet)$ a kernel function.

The optimization defined above leads to:

$$\left(\hat{\alpha}_\tau, \hat{\beta'}_\tau\right)' = \left[\sum_{i=1}^{N} K_{h_c}\left(t_i - \tau\right) X_{t_i} X_{t_i}'\right]^{-1} \left[\sum_{i=1}^{N} K_h\left(t_i - \tau\right) X_{t_i} \Delta s_{t_i}'\right]^{-1} \tag{10}$$

where X_{t_i} is a vector of regressors containing the monetary policy shocks and a constant term while Δs_{t_i} is the exchange rate change described previously.

This estimator can be thought of as a weighted least squared estimator with weights that are proportional to the distance of each observation from time τ. In this way we can construct a sequence $\left\{\hat{\beta'}_\tau\right\}_{\tau=1}^{T}$ of estimated coefficients using for each event all the information contained in the regressors matrix, effectively discounting proportionally more more distant events. Defining $\psi = \left(\hat{\alpha}_\tau, \hat{\beta'}_\tau\right)'$ it can be shown that the variance of the estimator is given by:

$$\left(\hat{\psi} - \psi\right) \to N\left(0, \frac{k}{Th_c}\Lambda_\tau^{-1} \otimes \Omega_\tau\right) \tag{11}$$

with $\Lambda_\tau = \frac{1}{T}\sum_{i=1}^{N} K_h\left(t_i - \tau\right) X_{t_i} X_{t_i}'$, $\Omega_\tau = \sum_{i=1}^{N} K_{h_c}\left(t_i - \tau\right) \hat{\varepsilon}_{t_i} \hat{\varepsilon}_{t_i}'$ and $\hat{\varepsilon}_{t_i}$ the estimated residuals.

To implement this procedure, we need to choose a specific kernel function and an optimal bandwidth. The combination of these two elements determines how much weight is given to observations distant from τ. We choose a standard Gaussian density as kernel:

$$K(z) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{z^2}{2}\right) \tag{12}$$

with $z_i = \frac{t_i - \tau}{h_c T}$; we divide by T to take into account the sample size. Finally we compute the optimal bandwidth h for each country individually. As outlined in Ang & Kristensen (2012) the optimal bandwidth can be computed with a two stage procedure. First assume that Λ_τ and Ω_τ are constant and that ψ_τ can be described as a polynomial:

$$\psi_\tau = \alpha_0 + \alpha_1 \tau + ... + \alpha_n \tau \tag{13}$$

we can estimate this equation and get

$$\hat{v}_1 = k\hat{\Lambda}_\tau^{-1} \otimes \sigma_\psi \quad \hat{v}_2 = \mu \frac{1}{T} \sum_{i=1}^{N} \hat{\psi}_{t_i}{}'' \tag{14}$$

Notice that in the case of a normal kernel $k = \int K(z) = 0.2821$ and $\mu = c2(RMSE)/h$ with $c = 0.7737$. The optimal bandwidth in this case is given by:

$$h_c^\star = \left[\frac{\| \hat{v}_1 \|}{\| \hat{v}_2 \|^2} \right]^{\frac{1}{5}} T^{-\frac{1}{5}} \tag{15}$$

C. Further tests and robustness

We conduct a battery of robustness checks. We assess whether our main results would be altered when considering 10-year rates instead of the 2-year rates when measuring path shocks. To shed more light on the growing impact of monetary policy surprises on exchange rates, we also assess whether simple rolling regressions point in a similar direction as our non-parametric kernel regression method. We assess if the length of the event window matters and if the release of minutes of policy meetings has a different impact than scheduled monetary policy announcements do. Some main takeaways are discussed in the following.

A. Measuring path shocks based on long-term rates

We show that our results are qualitatively robust to using the 10-year bond yield rather than 2-year bond yield to measure the path shock (these results are shown in the Online Appendix in Table A.V). Both the estimated coefficients, β_{target} and β_{path}, however, tend to be somewhat larger than when 2-year yields are employed for measuring path shocks. This stems from the fact that the 10-year bond yield tends to move less than the 2-year bond yield in response to a given monetary policy announcement. Note that, for the G3 economies, the explanatory power of the regression is greater when using 10-year bond yields.

B. Lengthening the event window

Some UMP announcements may have taken the market some time to interpret and to fully incorporate into prices. It is therefore possible that our narrow window does not capture the complete information in the monetary policy announcement. This will not necessarily bias our estimates of exchange rate *responsiveness* so long as the exchange rate responds at least as quickly to the news as OIS and bond markets. However, our robustness exercises show that the results are little changed with the use of longer windows of up to one and half hours after the event (see Table A.IX in the Online Appendix).

C. The role of minutes releases

To assess whether the release of minutes of the policy meeting has a different impact on the exchange rate than the announcement of interest rate decisions we repeat the analysis in Section III, but – instead of UMP events – our dummy variable takes a value of one to identify the release of minutes of the monetary policy meetings. We estimate this equation for the United States, United Kingdom and Australia, three countries with a sufficient history of releasing meeting minutes. To conserve space, these results are reported in Table A.VIII of the Online Appendix.

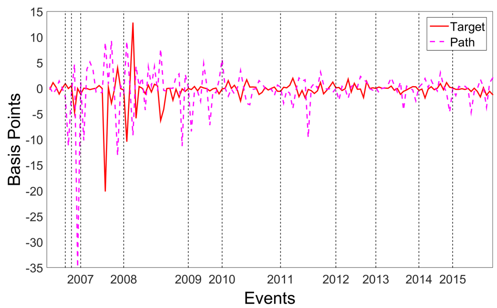
For both the United States and Australia, the release of minutes tends to have a smaller impact on the exchange rate, conditional on its impact on interest rates. The coefficients on the interaction terms, $\beta^{minutes}_{target}$ and $\beta^{minutes}_{path}$ are negative (and in Australia's case statistically significant). In contrast for the United Kingdom, the release of minutes is estimated to have a larger impact on the exchange rate, with $\beta^{minutes}_{target}$ significantly greater than zero. All of these results are robust to using the 10-year bond yield in place of the 2-year yield in the computation of the path shock.

D. Rolling window regressions

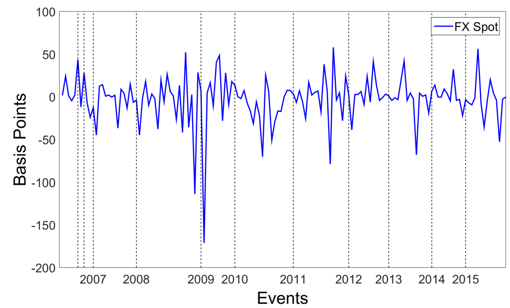
The increased sensitivity of the exchange rate to monetary policy is also generally robust to using simple rolling window regressions rather than the non-parametric estimation technique used in the analysis above. Due to the relatively small number of observations, we look at univariate regressions here, with monetary policy shocks identified via the response in 2-year bond yields. Of course, with short samples the estimated coefficients are unsurprisingly more volatile and hence the non-parametric kernel regression is our overall preferred methodology. That said, results reported in the Figure A.II in the Online Appendix show that qualitatively similar results are obtained when using more simple techniques.

Tables and Figures

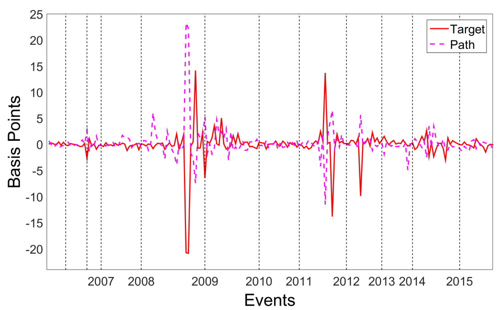
Figure A.I: Evolution of monetary policy shocks and FX movements



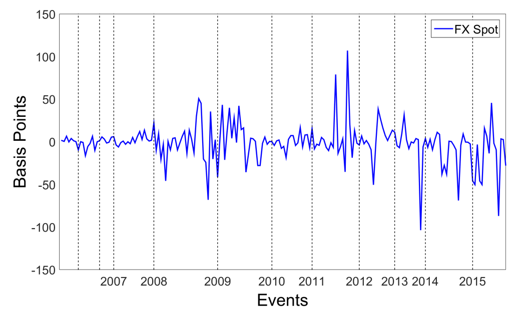
(a) United States



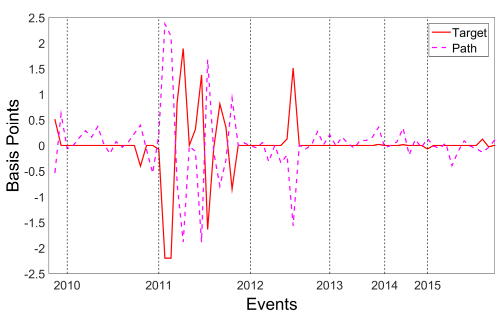
(b) United States



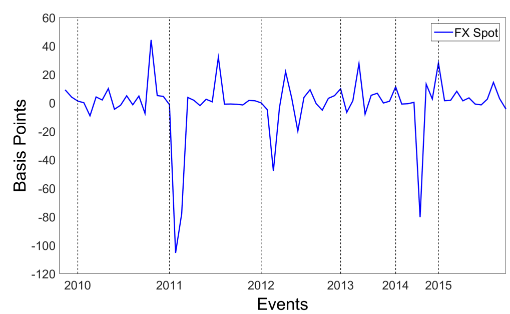
(c) Euro Area



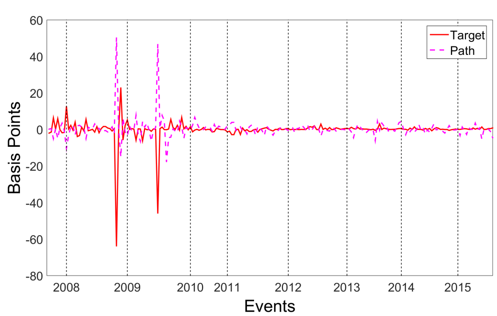
(d) Euro Area



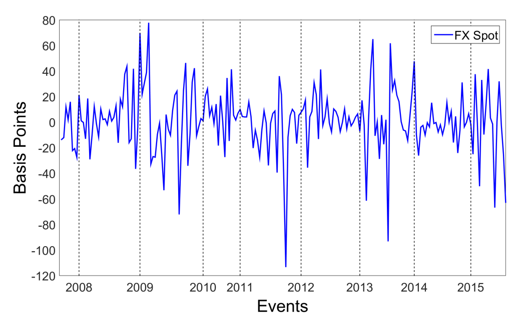
(e) Japan



(f) Japan

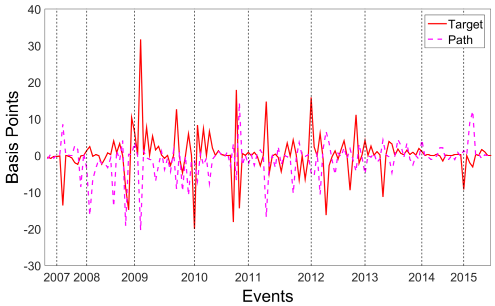


(g) United Kingdom

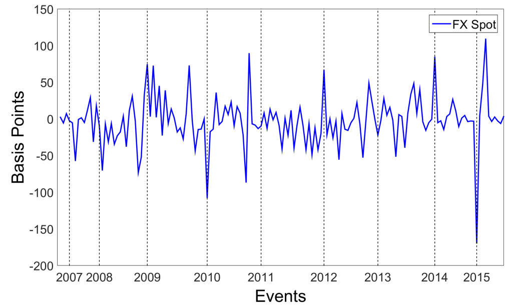


(h) United Kingdom

Figure A.I cont. Evolution of monetary policy shocks and FX movements

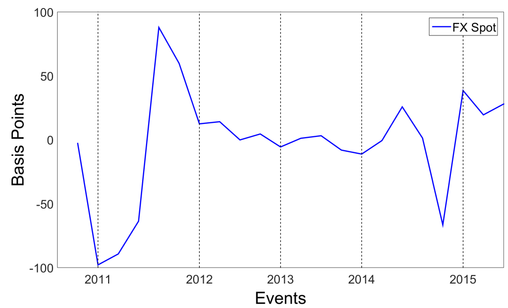


(i) Australia

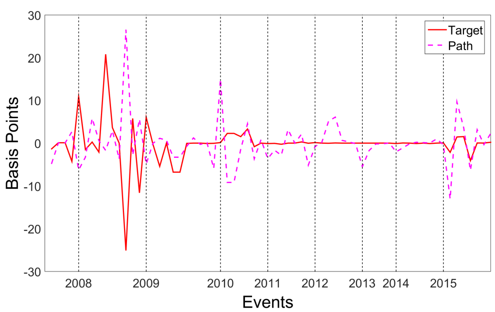


(j) Australia

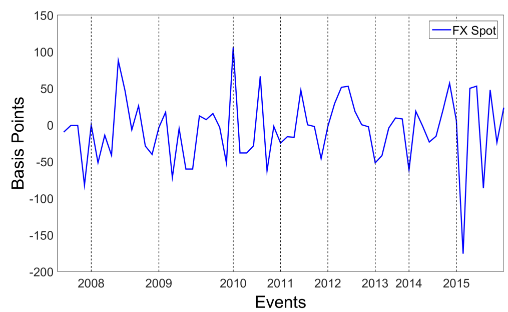
(k) Switzerland



(l) Switzerland

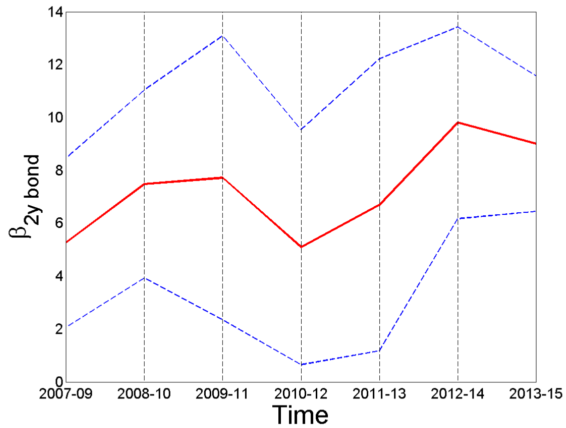


(m) Canada

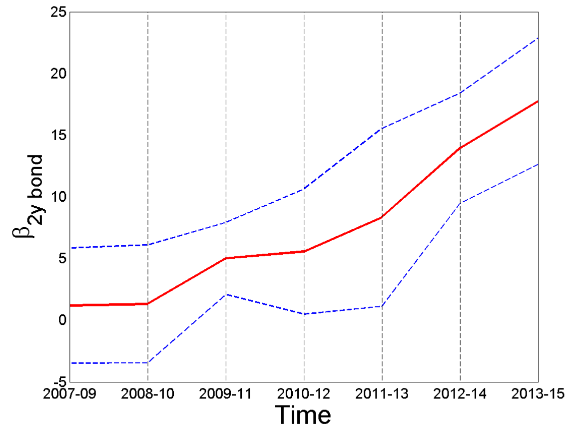


(n) Canada

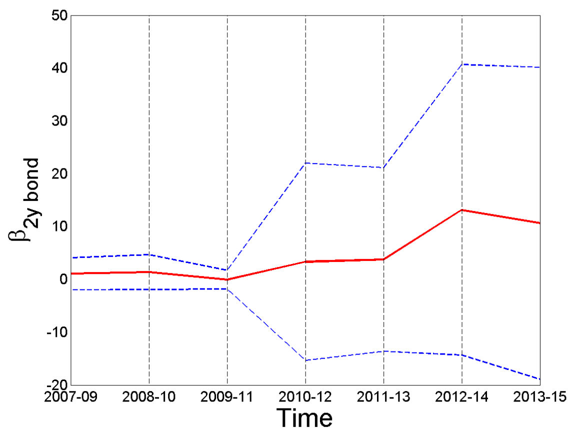
Figure A.II: Rolling window impact of monetary policy shocks on the exchange rate



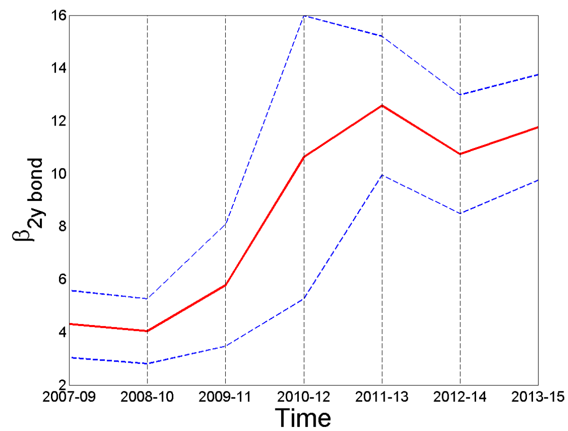
(a) USD response to 2 year bond shock ($\beta_{2y\ bond}$)



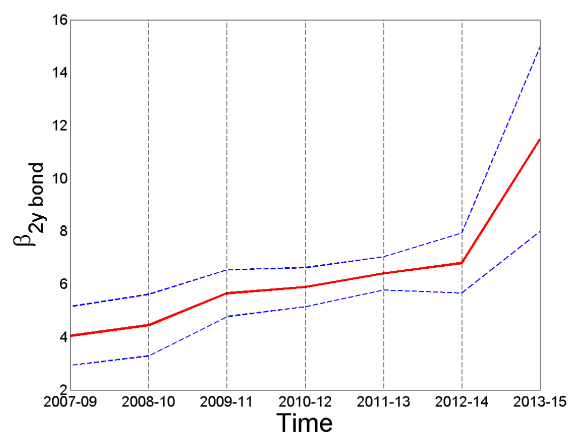
(b) EUR response to 2 year bond shock ($\beta_{2y\ bond}$)



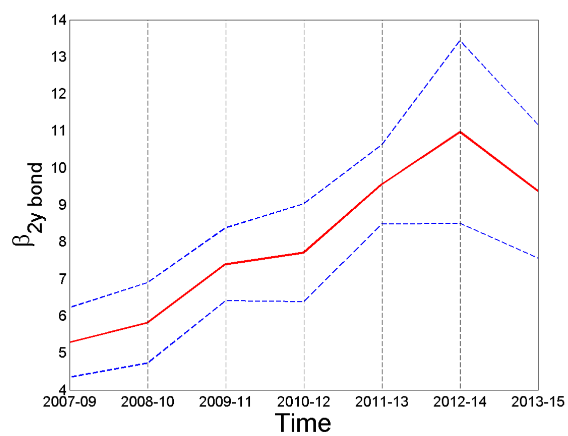
(c) JPY response to 2 year bond shock ($\beta_{2y\ bond}$)



(d) GBP response to 2 year bond shock ($\beta_{2y\ bond}$)



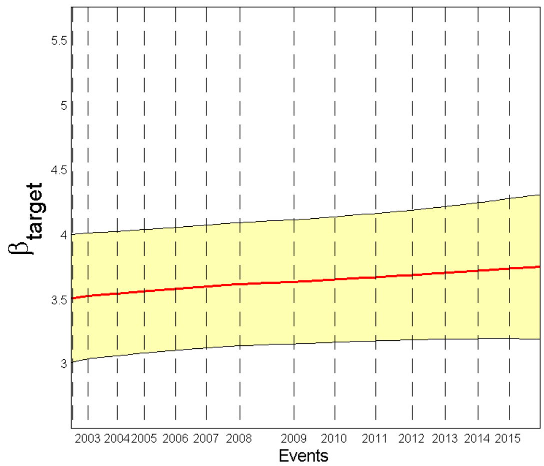
(e) AUD response to 2 year bond shock ($\beta_{2y\ bond}$)



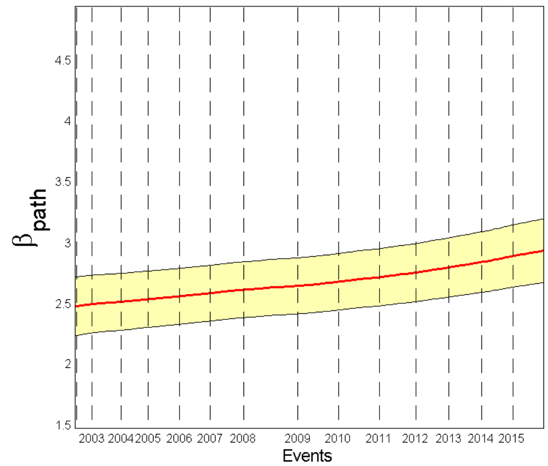
(f) CAD response to 2 year bond shock ($\beta_{2y\ bond}$)

Notes: The Figure depicts estimates of the sensitivity of the exchange rate to monetary policy shocks based on a three-year rolling window regression. The monetary shock is proxied by the change in the 2-year bond yield around the monetary policy event.

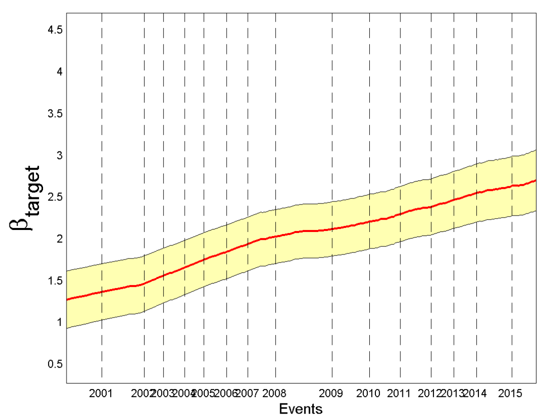
Figure A.III: Time-varying impact of monetary policy shocks using daily data



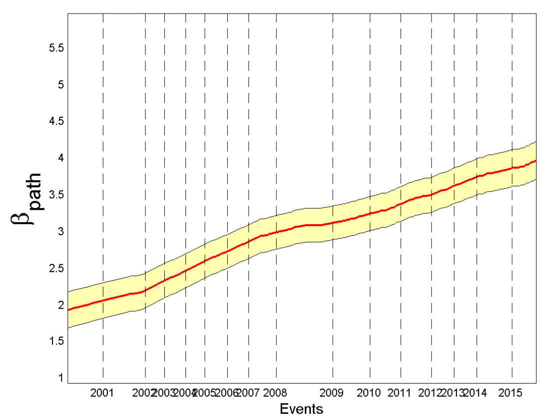
(a) USD estimation of β_{target} by time



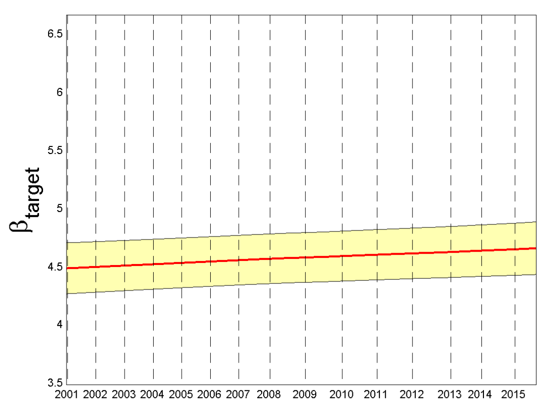
(b) USD estimation of β_{path} by time



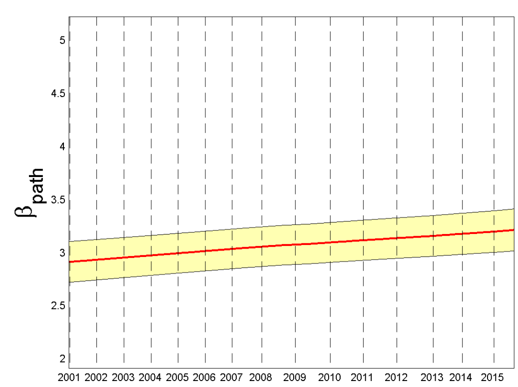
(c) EUR estimation of β_{target} by time



(d) EUR estimation of β_{path} by time

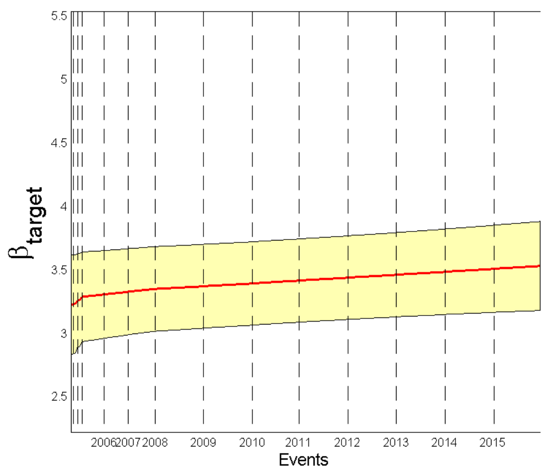


(e) GBP estimation of β_{target} by time

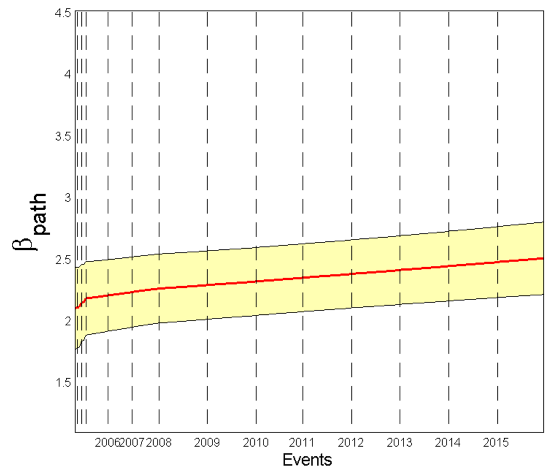


(f) GBP estimation of β_{path} by time

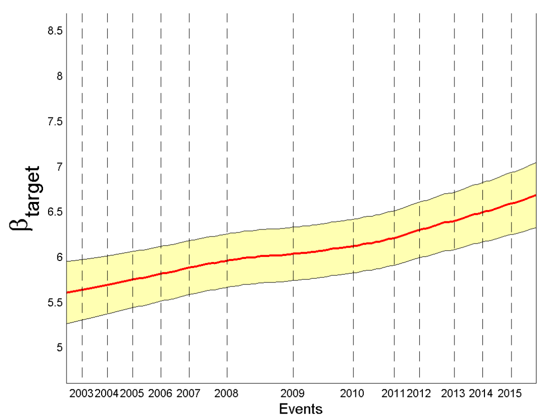
Figure A.III cont. Time-varying impact of monetary policy shocks using daily data



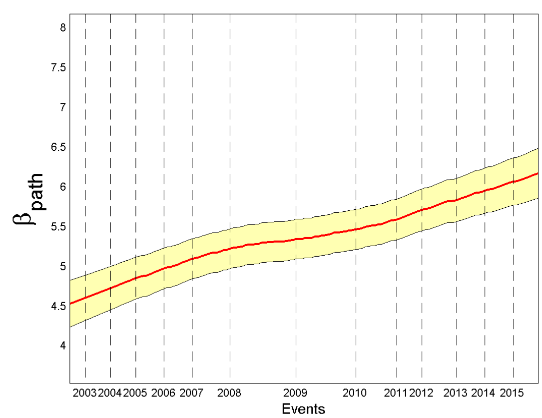
(g) AUD estimation of β_{target} by time



(h) AUD estimation of β_{path} by time



(i) CAD estimation of β_{target} by time



(j) CAD estimation of β_{path} by time

Notes: The figure depicts the time-varying impact of target and path monetary policy shock on the exchange rate. Time-varying coefficient estimates are obtained via the non-parametric regression given by Equation (4). The path shock is computed based on the 2-year bond yield. Data are at daily frequency.

Table A.I: Sample period and summary statistics monetary Policy Decisions (MPDs)

	Sample Period	Policy Rate	2-Year Bonds	10-Year Bonds	FX	No. of events
U.S.	05.2004-5.2015	7.7	3.2	3.1	30.3	220
Euro Area	04.2004-11.2015	5.6	0.7	0.6	10.6	302
Japan	04.2004-11.2015	0.5	0.2	0.3	6.4	347
U.K.	04.2004-11.2015	5.1	1.6	1.2	12.9	335
Australia	12.2005-12.2015	9.0	4.0	1.8	31.0	200
Switzerland	09.2010-09.2015	6.5	0.7	0.6	22.6	32
Canada	01.2007-12.2015	7.9	3.3	1.4	35.3	115

	Sample Period	Policy Rate	OIS 1-Month	OIS 6-Months	FX	No. of events
U.S.	12.2003-5.2015	7.7	1.7	2.2	30.6	226
Euro Area	01.2000-11.2015	5.7	2.5	1.2	10.9	392
Japan	12.2009-11.2015	0.0	0.1	0.0	9.5	178
U.K.	09.2007-11.2015	4.9	2.1	1.6	13.8	253
Australia	07.2006-12.2015	9.5	3.9	4.4	30.7	194
Switzerland	11.2008-09.2015	7.3	1.0	1.6	24.4	42
Canada	09.2004-12.2015	8.3	1.8	2.7	39.5	137

Notes: For all monetary policy decision events, the Table reports average absolute changes in the policy rate, FX Spot, bond yields and OIS rates in the 25 minute window. Column 3 reports the average absolute change in the policy rate at the MPD events of each central bank.

Table A.II: Regression results using intraday vs daily data

	U.S.		**Euro Area**		**Japan**		**U.K.**		**Australia**		**Switzerland**		**Canada**	
	Intraday	Daily	Intraday	Daily	Intraday	Daily	Intraday	Daily	Intraday	Daily	Intraday	Daily	Intraday	Daily
Target vs Path shock - 2 year bonds														
β_{target}	4.27	3.89	4.46	3.89	27.34	-74.66	6.13	5.15	5.63	3.27	25.23	13.28	6.33	6.02
p-val.	(0.00)	(0.05)	(0.03)	(0.01)	(0.04)	(0.23)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
β_{path}	2.93	2.16	6.10	6.64	11.58	11.28	6.64	4.06	4.78	1.35	7.07	1.42	7.49	6.02
p-val.	(0.04)	(0.33)	(0.00)	(0.00)	(0.20)	(0.40)	(0.00)	(0.00)	(0.00)	(0.57)	(0.07)	(0.70)	(0.00)	(0.00)
R^2	0.21	0.06	0.16	0.22	0.17	0.06	0.45	0.12	0.70	0.06	0.40	0.28	0.72	0.39
Target vs Path shock - 10 year bonds														
β_{target}	6.24	8.02	9.48	7.41	17.20	-87.27	5.53	4.54	11.02	1.57	33.90	12.45	14.14	6.08
p-val.	(0.00)	(0.01)	(0.00)	(0.00)	(0.14)	(0.20)	(0.00)	(0.00)	(0.00)	(0.30)	(0.00)	(0.00)	(0.00)	(0.00)
β_{path}	3.53	2.56	9.00	7.15	1.67	9.39	5.23	2.51	9.27	-1.41	16.98	-3.41	14.39	1.95
p-val.	(0.00)	(0.02)	(0.00)	(0.00)	(0.76)	(0.15)	(0.00)	(0.01)	(0.00)	(0.26)	(0.00)	(0.06)	(0.00)	(0.19)
R^2	0.39	0.08	0.35	0.24	0.16	0.08	0.44	0.08	0.67	0.05	0.50	0.33	0.43	0.14
Expectations vs Term Premium shock														
β_{exp}	3.07	2.75	5.02	5.68	1.21	-6.28	3.94	4.16	5.41	2.83	11.31	4.50	7.09	5.78
p-val.	(0.00)	(0.07)	(0.00)	(0.00)	(0.38)	(0.02)	(0.00	(0.00))	(0.00)	(0.10)	(0.00)	(0.26)	(0.00)	(0.00)
β_{tp}	2.65	1.90	8.25	4.79	-0.10	-0.39	4.12	-0.76	4.56	-1.57	24.33	-2.26	-0.89	1.27
p-val.	(0.00)	(0.05)	(0.00)	(0.02)	(0.20)	(0.87)	(0.85)	(0.04)	(0.50)	(0.00)	(0.00)	(0.17)	(0.73)	(0.42)
R^2	0.36	0.09	0.35	0.25	0.00	0.00	0.45	0.11	0.68	0.08	0.39	0.07	0.67	0.35

Notes: The Table reports coefficient estimates of Equation (1) and Equation (2). Equations are estimated both with intraday data and daily data. Coefficients describe the impact on the exchange rate (in basis points) of "target" and "path" or "expectations" (exp) and "term premia" (tp) monetary policy shocks (also measured in basis points). P-values (in parentheses) are computed with HAC standard errors.

Table A.III: Univariate results based on shocks for individual instruments – all events

$$\Delta s_t = \alpha + \beta MPS_t^j + \epsilon_t$$

		OIS 1-Month	OIS 6-Months	2-Year Bonds	10-Year Bonds
U.S.	β	2.36	4.20	3.07	3.26
	P-value	(0.00)	(0.00)	(0.01)	(0.00)
	R^2	0.04	0.10	0.19	0.30
Euro area	β	-0.04	0.07	5.01	8.73
	P-value	(0.63)	(0.88)	(0.02)	(0.00)
	R^2	0.00	0.00	0.11	0.35
Japan	β	15.27	-0.33	1.21	0.16
	P-value	(0.18)	(0.83)	(0.42)	(0.60)
	R^2	0.15	0.00	0.00	0.00
U.K.	β	0.57	1.15	3.95	5.38
	P-value	(0.00)	(0.03)	(0.01)	(0.00)
	R^2	0.02	0.03	0.29	0.41
Australia	β	3.62	3.47	5.41	11.25
	P-value	(0.00)	(0.00)	(0.00)	(0.00)
	R^2	0.38	0.50	0.65	0.57
Switzerland	β	2.39	4.67	11.31	23.68
	P-value	(0.09)	(0.05)	(0.00)	(0.00)
	R^2	0.04	0.07	0.26	0.38
Canada	β	2.66	6.35	7.09	13.10
	P-value	(0.10)	(0.00)	(0.00)	(0.00)
	R^2	0.08	0.48	0.68	0.39

Notes: The table reports regression results based on a univariate specification, where monetary shocks are measured via the high-frequency reaction of the indicated interest rate. Coefficients describe the impact of monetary policy shock (in basis points) on the exchange rate (also measured in basis points). P-values (in parentheses) reported below coefficients computed with HAC standard errors. This specification pools all events (MPD, UMP and minutes).

Table A.IV: Univariate results based on shocks for individual instruments – only MPDs

$$\Delta s_t = \alpha + \beta MPS_t^j + \epsilon_t$$

		OIS 1-Month	OIS 6-Months	2-Year Bonds	10-Year Bonds
U.S.	β	2.22	4.18	2.65	3.90
	P-value	(0.00)	(0.00)	(0.10)	(0.00)
	R^2	0.05	0.13	0.18	0.55
Euro area	β	-0.02	0.06	4.77	8.76
	P-value	(0.74)	(0.95)	(0.08)	(0.00)
	R^2	0.00	0.00	0.18	0.34
Japan	β	-13.14	-4.84	2.40	-5.43
	P-value	(0.01)	(0.78)	(0.49)	(0.06)
	R^2	0.14	0.00	0.00	0.05
U.K.	β	0.50	0.79	2.24	4.83
	P-value	(0.00)	(0.00)	(0.10)	(0.01)
	R^2	0.04	0.05	0.19	0.29
Australia	β	3.79	3.47	5.60	12.37
	P-value	(0.00)	(0.00)	(0.00)	(0.00)
	R^2	0.40	0.51	0.70	0.63
Switzerland	β	2.39	4.67	12.84	21.96
	P-value	(0.09)	(0.05)	(0.00)	(0.00)
	R^2	0.04	0.07	0.45	0.45
Canada	β	2.57	6.56	7.53	15.87
	P-value	(0.09)	(0.00)	(0.00)	(0.00)
	R^2	0.08	0.51	0.71	0.47

Notes: The table reports regression results based on a univariate specification, where monetary shocks are measured via the high-frequency reaction of the indicated interest rate. Coefficients describe the impact of a monetary policy shock (in basis points) on the exchange rate (also measured in basis points). P-values (in parentheses) reported below coefficients computed with HAC standard errors. This specification considers only monetary policy decisions MPDs.

Table A.V: Response of the exchange rate using 10-year bond in path shock

$$\Delta s_t = \alpha + \beta_{target} MPS_t^{\textit{1m OIS}} + \beta_{path}\left(MPS_t^{\textit{10y bond – 1m OIS}}\right) + \epsilon_t$$

	U.S.	**Euro area**	**Japan**	**U.K.**	**Australia**	**Switzerland**	**Canada**
β_{target}	6.24	9.48	17.20	5.53	11.02	33.90	14.14
p-val.	(0.00)	(0.00)	(0.14)	(0.00)	(0.00)	(0.00)	(0.00)
β_{path}	3.53	9.00	1.67	5.23	9.27	16.98	14.39
p-val.	(0.00)	(0.00)	(0.76)	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.39	0.35	0.16	0.44	0.67	0.50	0.43

Notes: Estimated coefficients of Equation (1). Coefficients describe the impact of the exchange rate (in basis points) to "target" or "path" monetary policy shocks (also measured in basis points). P-values (in parentheses) are computed with HAC standard errors. The path shock is computed using the 10-year bond yield.

Table A.VI: Response of the exchange rate to monetary policy announcements, M-estimator

$$(A) \quad \Delta s_t = \alpha + \beta_{target} MPS_t^{OIS} + \beta_{path} MPS_t^{Bond\text{-}OIS} + \epsilon_t$$

$$(B) \quad \Delta s_t = \alpha + \beta_{exp} MPS_t^{2y} + \beta_{tp} MPS_t^{10y\perp} + \epsilon_t$$

Panel A	**U.S.**	**Euro area**	**Japan**	**U.K.**	**Australia**	**Switzerland**	**Canada**
β_{target}	4.44	4.32	6.21	6.76	5.64	19.43	6.07
P-Value	(0.00)	(0.03)	(0.32)	(0.00)	(0.00)	(0.01)	(0.00)
β_{path}	3.49	5.84	3.73	6.70	5.04	10.70	7.26
P-Value	(0.00)	(0.00)	(0.51)	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.21	0.14	0.04	0.45	0.70	0.36	0.72

Panel B	**U.S.**	**Euro area**	**Japan**	**U.K.**	**Australia**	**Switzerland**	**Canada**
β_{exp}	3.99	6.12	0.08	4.63	5.32	12.69	7.04
P-Value	(0.92)	(0.00)	(0.38)	(0.00)	(0.00)	(0.00)	(0.00)
β_{tp}	2.29	7.15	-0.15	4.33	3.28	24.51	-0.22
P-Value	(0.56)	(0.00)	(0.87)	(0.04)	(0.00)	(0.01)	(0.90)
R^2	0.34	0.33	0.00	0.44	0.68	0.38	0.67

Notes: Panel A reports estimated coefficients of Equation (1) and Panel B reports estimated coefficients of Equation (2), both with huber M estimator. The path shock is computed using the 2 year bond yield. We proxy for expectations shocks via the change in the 2-year bond yield and for term premium shocks via the change in the 10-year yield orthogonalized against the change in the 2-year bond yield.

Table A.VII: Persistence of the impact of monetary policy on the exchange rate

End of day:	–1	0	+1	+2	+3	+4	+5
U.S.							
β_{target}	-0.34	7.23	4.55	3.79	2.63	-1.50	-3.20
p-val.	(0.78)	(0.01)	(0.20)	(0.51)	(0.70)	(0.85)	(0.74)
β_{path}	-0.70	3.83	3.73	1.72	-0.39	-0.33	0.46
p-val.	(0.50)	(0.05)	(0.29)	(0.59)	(0.87)	(0.90)	(0.86)
R^2	0.00	0.11	0.03	0.01	0.00	0.00	0.00
Euro Area							
β_{target}	1.27	12.92	19.35	26.06	17.5	24.04	29.09
p-val.	(0.61)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
β_{path}	-0.2	15.17	22.13	23.6	19.08	24.46	25.58
p-val.	(0.94)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R^2	0.01	0.09	0.08	0.10	0.06	0.06	0.07
Japan							
β_{target}	62.55	2.19	27.48	49.16	3.85	8.37	-30.26
p-val.	(0.27)	(0.97)	(0.73)	(0.67)	(0.98)	(0.94)	(0.81)
β_{path}	57.85	-13.5	15.74	20.59	-28.28	-24.06	-64.67
p-val.	(0.23)	(0.81)	(0.84)	(0.85)	(0.8)	(0.81)	(0.58)
R^2	0.03	0.03	0.01	0.03	0.03	0.03	0.04

Notes: The Table reports coefficient estimates of Equation (1). Coefficients describe the impact on the exchange rate (in basis points) of "target" or "path" monetary policy shocks (also measured in basis points). Estimation is performed using 2-year bonds to calculate the path shock and with the policy shocks measured using the narrow 25 minute window and the exchange rate changes are measured as daily changes using end-day quotes. P-values (in parentheses) are computed with HAC standard errors.

Table A.VII **cont.** Persistence of the impact of monetary policy on the exchange rate

End of day:	–1	0	+1	+2	+3	+4	+5
U.K.							
β_{target}	-0.11	8.05	7.78	10.6	12.74	13.81	14.68
p-val.	(0.93)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
β_{path}	-0.42	7.52	7.14	10.95	11.64	10.34	9.61
p-val.	(0.68)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
R^2	0.00	0.14	0.06	0.07	0.07	0.08	0.10
Australia							
β_{target}	-0.28	4.61	10.12	11.12	15.78	12.05	12.58
p-val.	(0.72)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
β_{path}	-0.25	6.91	13.58	14.42	22.74	13.97	12.45
p-val.	(0.74)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
R^2	0.00	0.10	0.22	0.18	0.23	0.11	0.09
Switzerland							
β_{target}	-0.50	39.26	17.22	29.14	26.12	-2.75	-25.27
p-val.	(0.93)	(0.01)	(0.14)	(0.12)	(0.17)	(0.96)	(0.61)
β_{path}	-5.03	5.78	1.67	1.38	-22.49	-37.52	-35.04
p-val.	(0.01)	(0.07)	(0.56)	(0.74)	(0.01)	(0.31)	(0.38)
R^2	0.07	0.40	0.05	0.09	0.26	0.10	0.05
Canada							
β_{target}	-0.13	8.2	8.91	9.27	7.41	10.64	9.05
p-val.	(0.91)	(0.01)	(0.01)	(0.04)	(0.16)	(0.04)	(0.13)
β_{path}	0.08	8.06	3.99	0.08	3.13	0.32	1.12
p-val.	(0.95)	(0.01)	(0.22)	(0.99)	(0.58)	(0.96)	(0.82)
R^2	0.00	0.37	0.13	0.12	0.04	0.08	0.05

Notes: The Table reports coefficient estimates of Equation (1). Coefficients describe the impact on the exchange rate (in basis points) of "target" or "path" monetary policy shocks (also measured in basis points). Estimation is performed using 2-year bonds to calculate the path shock and with the policy shocks measured using the narrow 25 minute window and the exchange rate changes are measured as daily changes using end-day quotes. P-values (in parentheses) are computed with HAC standard errors.

Table A.VIII: Regular monetary policy decisions vs release of minutes

$$(A) \quad \Delta s_t = \alpha + (\beta_{target} + \beta_{target}^{minutes} \mathbb{1}^{minutes}) MPS_t^{OIS} + (\beta_{path} + \beta_{path}^{UMP} \mathbb{1}^{minutes}) MPS^{Bond\text{ - }OIS_t} + \epsilon_t$$

$$(B) \quad \Delta s_t = \alpha + (\beta_{exp} + \beta_{exp}^{UMP} \mathbb{1}^{minutes}) MPS_t^{2y} + (\beta_{tp} + \beta_{tp}^{minutes} \mathbb{1}^{minutes}) MPS_t^{10y\perp} + \epsilon_t$$

	Panel A. Target and Path				Panel B. Expectations and Term Premium Shocks		
	Coefficient	P-Value	R^2		Coefficient	P-Value	R^2
U.S.							
β_{target}	4.14	(0.00)	0.23	β_{exp}	2.79	(0.00)	0.52
β_{path}	2.81	(0.08)		β_{exp}	3.61	(0.00)	
$\beta_{target}^{minutes}$	-3.53	(0.03)		β_{exp}	-0.41	(0.74)	
$\beta_{path}^{minutes}$	-1.33	(0.39)		β_{exp}	-2.79	(0.00)	
U.K.							
β_{target}	6.42	(0.00)	0.50	β_{exp}	3.65	(0.00)	0.47
β_{path}	7.64	(0.00)		β_{tp}	4.10	(0.02)	
$\beta_{target}^{minutes}$	2.65	(0.06)		$\beta_{exp}^{minutes}$	1.22	(0.25)	
$\beta_{path}^{minutes}$	0.88	(0.66)		$\beta_{tp}^{minutes}$	4.20	(0.03)	
Australia							
β_{target}	5.67	(0.00)	0.70	β_{exp}	5.56	(0.00)	0.70
β_{path}	4.86	(0.00)		β_{tp}	5.40	(0.04)	
$\beta_{target}^{minutes}$	-2.44	(0.01)		$\beta_{exp}^{minutes}$	-4.80	(0.00)	
$\beta_{path}^{minutes}$	-2.31	(0.03)		$\beta_{tp}^{minutes}$	-2.11	(0.48)	

Notes: $\mathbb{1}^{Minutes}$ is a dummy that takes value equal to 1 if the event type is a FG event. $\beta_{target}^{Minutes}$ and $\beta_{path}^{Minutes}$ ($\beta_{exp}^{Minutes}$, $\beta_{tp}^{Minutes}$) measure the additional impact on the exchange rate of FG events. Coefficients describe the impact on the exchange rate (in basis points) of a monetary policy shock "target", "path", "expectation" or "term premium" monetary policy shock (also measured in basis points). P-values (in parentheses) are computed with HAC standard errors. The estimation uses monetary policy decisions and minutes releases only.

Table A.IX: UMP effects using longer windows

	Target vs path shocks					Expectations vs term premium shocks			
Minutes:	20	45	75	105		20	45	75	105
U.S.									
β_{target}	3.95	4.00	4.06	4.08	β_{exp}	2.33	2.14	2.69	2.99
p-val.	(0.00)	(0.00)	(0.00)	(0.00)	p-val.	(0.00)	(0.00)	(0.00)	(0.00)
β_{path}	1.53	1.51	1.53	1.52	β_{tp}	2.41	2.22	2.50	2.25
p-val.	(0.01)	(0.01)	(0.01)	(0.01)	p-val.	(0.02)	(0.10)	(0.03)	(0.05)
β_{target}^{UMP}	14.21	16.45	17.65	18.75	β_{exp}^{UMP}	7.42	5.83	6.69	9.00
p-val.	(0.27)	(0.22)	(0.18)	(0.14)	p-val.	(0.00)	(0.04)	(0.00)	(0.00)
β_{path}^{UMP}	11.03	10.65	10.46	10.39	β_{tp}^{UMP}	-0.58	1.08	0.48	-1.16
p-val.	(0.00)	(0.00)	(0.00)	(0.00)	p-val.	(0.63)	(0.50)	(0.76)	(0.50)
R^2	0.53	0.54	0.56	0.57	R^2	0.66	0.66	0.67	0.64
Euro Area									
β_{target}	4.57	5.25	6.54	5.63	β_{exp}	5.13	7.25	7.21	6.79
p-val.	(0.09)	(0.03)	(0.00)	(0.00)	p-val.	(0.06)	(0.00)	(0.00)	(0.00)
β_{path}	6.55	6.45	6.78	6.36	β_{tp}	7.21	6.45	5.51	6.53
p-val.	(0.02)	(0.00)	(0.00)	(0.00)	p-val.	(0.00)	(0.00)	(0.01)	(0.00)
β_{target}^{UMP}	6.76	12.74	-2.86	-4.95	β_{exp}^{UMP}	4.93	5.38	0.96	0.16
p-val.	(0.36)	(0.01)	(0.27)	(0.10)	p-val.	(0.20)	(0.03)	(0.53)	(0.92)
β_{path}^{UMP}	3.38	7.48	1.30	1.67	β_{tp}^{UMP}	-0.96	0.78	2.58	3.01
p-val.	(0.50)	(0.09)	(0.57)	(0.47)	p-val.	(0.68)	(0.79)	(0.28)	(0.19)
R^2	0.27	0.35	0.43	0.37	R^2	0.39	0.51	0.56	0.55

Notes: The left panel reports estimated coefficients from Equation (1) using 2 year bond yields to compute the path shock. The right hand panel reports estimated coefficients from Equation (2) using expectation and term premia shocks. Policy and exchange rate shocks are measured averaging from 20 to 5 minutes before each event and from 5 to k minutes after each events, with $k \in [20, 45, 75, 105]$. P-values (in parentheses) are computed with HAC standard errors.

Table A.IX cont. UMP effects using longer windows

	Target vs path shocks					Expectations vs term premium shocks			
Minutes:	20	45	75	105		20	45	75	105
U.K.									
β_{target}	6.91	4.66	3.44	2.69	β_{exp}	3.72	4.27	3.77	3.15
p-val.	(0.00)	(0.00)	(0.00)	(0.04)	p-val.	(0.00)	(0.00)	(0.00)	(0.01)
β_{path}	8.29	6.84	4.32	3.88	β_{tp}	4.16	4.38	2.65	2.13
p-val.	(0.00)	(0.00)	(0.01)	(0.04)	p-val.	(0.04)	(0.06)	(0.07)	(0.09)
β_{target}^{UMP}	-0.35	-1.56	14.39	10.41	β_{exp}^{UMP}	0.52	1.27	3.79	2.68
p-val.	(0.87)	(0.72)	(0.07)	(0.03)	p-val.	(0.83)	(0.54)	(0.08)	(0.37)
β_{path}^{UMP}	-0.97	0.41	-0.50	3.07	β_{tp}^{UMP}	-1.29	-1.16	-0.46	-1.31
p-val.	(0.76)	(0.89)	(0.84)	(0.22)	p-val.	(0.71)	(0.64)	(0.77)	(0.35)
R^2	0.51	0.35	0.20	0.14	R^2	0.45	0.38	0.27	0.17

Notes: The left panel reports estimated coefficients from Equation (1) using 2 year bond yields to compute the path shock. The right hand panel reports estimated coefficients from Equation (2) using expectation and term premia shocks. Policy and exchange rate shocks are measured averaging from 20 to 5 minutes before each event and from 5 to k minutes after each events, with $k \in [20, 45, 75, 105]$. P-values (in parentheses) are computed with HAC standard errors.

Table A.X: Regressions with ZLB dummy

$$(A) \quad \Delta s_t = \alpha + (\beta_{target} + \beta_{target}^{ZLB}\mathbb{1}^{ZLB})MPS_t^{OIS} + (\beta_{path} + \beta_{path}^{ZLB}\mathbb{1}^{ZLB})MPS^{Bond\text{ - }OIS_t} + \epsilon_t$$

$$(B) \quad \Delta s_t = \alpha + (\beta_{exp} + \beta_{exp}^{ZLB}\mathbb{1}^{ZLB})MPS_t^{2y} + (\beta_{tp} + \beta_{tp}^{ZLB}\mathbb{1}^{ZLB})MPS_t^{10y\perp} + \epsilon_t$$

	U.S.	**Euro area**	**U.K.**	**Canada**
(A) Target and Path				
β_{target}	1.20	2.23	1.02	5.81
P-Value	(0.18)	(0.23)	(0.37)	(0.00)
β_{path}	1.71	3.85	0.55	6.73
P-Value	(0.05)	(0.02)	(0.69)	(0.00)
β_{target}^{ZLB}	7.13	22.09	6.63	-0.80
P-Value	(0.00)	(0.00)	(0.00)	(0.77)
β_{path}^{ZLB}	6.47	12.71	6.77	3.32
P-Value	(0.00)	(0.00)	(0.00)	(0.02)
R^2	0.43	0.32	0.49	0.74
(A) Target and Path - 10 year bond				
β_{target}	4.42	7.20	4.75	12.60
P-Value	(0.02)	(0.04)	(0.00)	(0.00)
β_{path}	3.90	7.25	4.46	12.860
P-Value	(0.01)	(0.01)	(0.01)	(0.00)
β_{target}^{ZLB}	1.62	14.56	0.92	20.56
P-Value	(0.60)	(0.00)	(0.63)	(0.05)
β_{path}^{ZLB}	0.21	3.15	0.80	-5.41
P-Value	(0.90)	(0.31)	(0.693)	(0.48)
R^2	0.52	0.42	0.44	0.50
(B) Expectations and term premia				
β_{exp}	2.18	3.43	3.91	6.45
P-Value	(0.00)	(0.08)	(0.00)	(0.00)
β_{tp}	2.21	7.25	5.09	0.35
P-Value	(0.03)	(0.00)	(0.00)	(0.87)
β_{exp}^{ZLB}	3.73	11.14	3.04	2.36
P-Value	(0.00)	(0.00)	(0.11)	(0.01)
β_{tp}^{ZLB}	0.41	-0.76	-4.42	-5.00
P-Value	(0.69)	(0.72)	(0.08)	(0.49)
R^2	0.56	0.41	0.48	0.69

Notes: Estimated coefficients of Equation. Coefficients describe the impact on the exchange rate (in basis points) of a 1 basis point “target” or “path” monetary policy shock. ZLB is a dummy that takes value of 1 if the economy is at the zero lower bound. The estimation pools all types of monetary policy events. The path shock is computed using the 2 or 10 year bond yield.