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Unconventional Monetary Policy and the Dollar: Conventional Signs, Unconventional Magnitudes

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Abstract

We examine the effects of unconventional monetary policy surprises on the value of the dollar using high-frequency intraday data and contrast them with the effects of conventional policy tools. Identifying monetary policy surprises from changes in interest rate future prices in narrow windows around policy announcements, we find that monetary policy surprises since the Federal Reserve lowered its policy rate to the effective lower bound have had larger effects on the value of the dollar. In particular, we document that the impact on the dollar has been roughly three times that following conventional policy changes prior to the 2007-08 financial crisis.

JEL classification: E5, E43, F31

Keywords: monetary policy, large scale asset purchases; quantitative easing, dollar, exchange rate

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1. Introduction

During the 2007-08 financial crisis and its aftermath, the Federal Reserve introduced new monetary policy measures to stabilize financial markets and mitigate the effects of the crisis on economic activity. These so-called unconventional policy tools have been necessary both because of the extraordinary nature of the financial crisis and because the federal funds policy rate was quickly dropped to its effective lower bound of near zero percent by the end of 2008. As a result, the Federal Reserve turned to large-scale asset purchases (LSAPs)—also commonly called quantitative easing—and to greater forward guidance about the future path of monetary policy to achieve its dual mandate of price stability and maximum employment.

These new policy tools come with a significant amount of uncertainty regarding their effectiveness, particularly whether the standard transmission channels of monetary policy through financial asset markets work as well as they did in the past. An important channel through which changes in monetary policy affect the economy, particularly when the policy rate is near its lower bound, is the value of domestic currency. There is much empirical evidence, for instance, documenting that the dollar typically depreciated following declines in the federal funds rate in the pre-crisis period (see, for instance, Clarida and Galì, 1994; Eichenbaum and Evans, 1996; Faust and Rogers, 2003; Scholl and Uhlig, 2008; and Bouakez and Normandin, 2010).

In this paper, we examine how the U.S. dollar has reacted to changes in unconventional monetary policy since the federal funds rate reached its zero lower bound in December 2008 and how this effect compares to those following changes in monetary policy in the period before then. In particular, we analyze the impact of monetary policy announcements between 1994 and 2014, thus capturing the effects of the three waves of quantitative easing. We use high-frequency intraday data in panel regressions to study the dollar's movements against the currencies of

major U.S. trading partners in time intervals immediately following monetary policy announcements by the Federal Reserve. The use of intraday data enables us to better isolate the response of the dollar to monetary announcements from other possible determinants. To control for the likelihood that market participants anticipate policy changes, we construct surprise changes in monetary policy using changes in short-term and long-term interest rate futures around the time of policy announcements.

We compute three types of monetary policy surprises. We first use changes in federal funds rate futures around Federal Open Market Committee (FOMC) announcements about the federal funds rate target to measure surprises in the policy target, termed "target surprises" by Kuttner (2001).[1] Clearly, target surprises are only relevant during the pre-crisis period when the federal funds rate was above the zero lower bound. Second, as emphasized by Gürkayrkanak, Sack, and Swanson (2005), FOMC announcements not only contain information about the policy target, but also include communication about the future path of monetary policy. As a result, we follow their approach to isolate the surprise movements in the expected path of the federal funds rate, as measured by the change in the one-year ahead euro-dollar futures rate, which we label "short-term path surprises." Third, we construct an additional measure of policy path surprises, that we term "long-term path surprises," using long-term Treasury futures rates. The idea is that these surprises may capture the Federal Reserve's attempts to directly influence long-term Treasury rates via LSAPs and long-term forward guidance (see Wright, 2012).

Since the pre-crisis period was dominated by the use of changes in the level and path of the federal funds target rate as the main tool of monetary policy, we refer to this period as the "conventional policy period." Correspondingly, we denote the crisis and post-crisis period when

[1] See also Bernanke and Kuttner (2005), Fleming and Piazzesi (2005), Faust et al. (2007), and D'Amico and Farka (2011) for other analyses of the effects of monetary policy target surprises during the period before the financial crisis.

LSAPs and related policies were the main tools of monetary policy as the "unconventional policy period." Our results show that the exchange rate channel of the transmission of monetary policy is highly effective during both the conventional and unconventional policy periods, but that the effects are significantly larger in the latter period.

In particular, we first document that during the conventional period the U.S. dollar depreciated significantly in response to both target and short-term path surprises, though not in response to long-term surprises. Specifically, we find that a one standard deviation surprise easing leads to a total decline of 17 basis points in the value of the dollar in the hour after announcements. In comparison, during the unconventional policy period, the U.S. dollar depreciated significantly in response to both short-term and long-term path surprises, with target surprises no longer a feasible tool of monetary policy as long as the federal funds rate was expected to remain at its effective lower bound. Since the end of 2008, we find that a one standard deviation surprise easing in unconventional policy leads to a total decline of 51 basis points in the value of the dollar within 60 minutes, a magnitude roughly three times that during the conventional period.

Our paper adds to a growing and active literature on the effects of unconventional monetary policy. Starting with Gagnon et al. (2011), several papers have attempted to analyze the effectiveness of recent monetary policy actions with event studies of Federal Reserve announcements; see, for instance, Neely (2010), Krishnamurthy and Vissing-Jorgensen (2011), D'Amico et al. (2012), Glick and Leduc (2012), Hamilton and Wu (2012), and Li and Wei (2012).

By emphasizing the effects on the U.S. exchange rate, our work related to that of Neely (2010) and Wright (2012) who look at the impact of announcements of large-scale asset purchases and other announcements by the Federal Reserve on the dollar. However, our focus is

different, as we seek to compare the effect of surprise changes in unconventional policy, including both short-term and long-term path surprises, on the exchange rate to those during the conventional period. While our approach partly follows Wright's methodology in constructing monetary policy path surprises, we also make an additional distinction between short-term and long-term path surprises. In addition, our work differs from Neely in that it controls for market expectations of possible changes in monetary policy, which is important to precisely identify the surprise component of policy announcements. We also have the benefit of working with a longer sample that includes policy announcements during the first, second, and third rounds of large-scale asset purchases between 2008 and 2014. Neely's sample covers only the first round of LSAPs between November 2008 and November 2009, while Wright's sample of 28 observations extends to September 2011 to encompass the second round, but not the third round.[2]

Finally, our approach here differs from that followed in previous work of ours (Glick and Leduc, 2013) which abstracted from the transmission of monetary policy via path surprises during the conventional period. Taking these surprises into account alters the comparison of the effects of monetary surprises on the dollar across regimes, which we now find to be substantially larger during the unconventional period. In addition, our methodological approach differs in that in this paper we employ a pooled panel that includes observations from both the conventional and unconventional periods. This enables nested tests to directly compare the effectiveness of policies across periods.

The paper is organized as follows. In Section 2 we describe our data and measures of monetary surprises. Section 3 presents the benchmark empirical results for the effects of

[2] See also Rogers, Scotti, and Wright (2014) who examine the effects of unconventional policies by the Federal Reserve, the ECB, the Bank of England, and the Bank of Japan on bond yields and stock prices, in addition to those on exchange rates. Bowman, Londono, and Sapriza (2014) examine the effects of unconventional U.S. monetary policies on asset prices in emerging markets, including exchange rates.

unconventional and conventional monetary policy on the value of the dollar. Robustness exercises are reported in Section 4. Section 5 concludes.

2. Identification of Monetary Policy Events and Surprises

2.1 Identifying monetary policy surprises

We examine the effects of monetary policy surprises on the value of the U.S. dollar during the recent period when policymakers relied heavily on unconventional policy tools, such as large-scale asset purchases and communications about future policy actions – the "unconventional policy period," and contrast these effects to those following policy surprises when the federal funds rate target was above the zero lower bound – the "conventional policy period." The transition between these two periods is somewhat blurred since conventional policy actions were still being employed while the Federal Reserve's intentions to adopt unconventional measures were being signaled. For instance, while the FOMC lowered the federal funds rate to its effective lower bound on December 16, 2008, the future use of unconventional policy tools had already been indicated by Chairman Bernanke in speeches in November and early December that year. In our benchmark specification, we assume that the conventional period ends in October 2008. As a result, these speeches, which provided important information to market participants about the type of unconventional policies that might be pursed in the future, are included in the set of policy announcements during the unconventional period. One advantage of using this sample split is that it makes our sample of unconventional policy announcements more comparable to that typically used in the literature, as we discuss below. Nevertheless, we also conduct sensitivity analysis to alternative sample breaks.

Thus, our sample period for conventional monetary policy actions extends from February 1994, when the FOMC began issuing a press release after every meeting and every change in

policy, until October 2008. The period characterized by unconventional monetary policy actions spans the period from November 2008 to the end of our sample in December 2014.[3]

The extent to which an announcement affects the currency when it is released to the public depends on how much market participants expect the announcement. If market participants fully anticipate the content of an announcement, then no additional information is revealed at the time of the announcement's release and the value of the dollar should not move as a result. Therefore, controlling for market participants' expectations is crucial for our analysis. To identify surprise changes in monetary policy, we use changes in interest rate futures in a tight time interval around monetary policy news.

For the conventional policy period, given that monetary policy is conducted via changes in the target for the federal funds rate, we follow the approach proposed in Kuttner (2001), and use the change in federal funds rate futures constructed by D'Amico and Farka (2011) to identify monetary policy surprises in the target for the federal funds rate.[4] We refer to them as "target surprises." To better isolate the influence of changes in monetary policy, the procedure uses intraday tick data to measure the change in federal funds rate futures from 10 minutes before a

[3]Our benchmark sample includes unscheduled intermeeting announcements on April 18, 1994, January 3, 2001, April 18, 2001, January 22, 2008, and October 8, 2008, and excludes unscheduled announcements made on October 15, 1998, September 17, 2001, as well as those on August 10, 2007, August 17, 2007, and March 11, 2008. The October 15, 1998 event followed the Russian ruble devaluation and the near collapse of Long-Term Capital Management, and government securities markets were closed at the time of the FOMC announcement that day. The September 17, 2001 event was excluded as well, on the grounds that asset market responses at that time reflect not just the effects of the FOMC announcement but also the fact that it was the first day that the federal funds rate market was open after the September 11 terrorist attack. Bernanke and Kuttner (2005) and D'Amico and Farka (2011) also exclude October, 15, 1998 and September 17, 2001. The unscheduled meetings of August 10, 2007, August 17, 2007, and March 11, 2008 are excluded because the FOMC merely communicated awareness of events after these meetings and did not announce policy changes.

[4] Following Kuttner (2001), we assume that the federal funds futures rate can be expressed as a weighted average of the rate prevailing so far in the month and the expected rate for the rest of the month, plus a risk premium. Assuming a constant risk premium implies that our monetary surprise measure can be defined as the change in the futures rate, adjusted by the scale factor, $D/(D-d)$, where D is the number of days in the month and d is the day in the month of the monetary policy announcement. We use this definition as long as the announcement occurs earlier than the last seven days of the month. If the announcement falls in the last seven days, the surprise is computed as the unadjusted change in the next-month federal funds futures contract to avoid unduly large adjustment factors.

policy announcement to 20 minutes after.[5] This strategy provides a good measure of monetary policy shocks if possible interest risk premia remain relatively constant around policy announcements.

However, as Gürkaynak, Sack, and Swanson (2005) have highlighted, FOMC announcements during the conventional policy period not only contain information about the current target for the federal funds rate, but also include information about the future path of monetary policy. Following Gürkaynak etal, w define the "short-term path surprises" as the change in the one-year eurodollar futures rate around the time of policy announcements that are orthogonal to the target surprises.[6]

For the post-crisis period, identifying monetary policy surprises with the changes in federal funds rate futures is not a feasible empirical strategy as long as the federal funds rate is expected to remain at its effective lower bound and monetary policy is conducted through unconventional means. However, path surprises of the kind suggested by Gürkaynak, Sack, and Swanson (2005) can be used to identify policy surprises associated with forward guidance or LSAPs during the unconventional policy period. In addition, given the Federal Reserve's emphasis on directly lowering long-term interest rates through unconventional means, we differentiate between short-term and a long-term path surprises by also examining the change in longer-term futures rates around policy announcements. More specifically, we define long-term path surprises as the change in the principal component of the two-, five-, ten, and thirty-year Treasury rate futures, again measured during a 30-minute window, from 10 minutes before an announcement to 20 minutes after (see Wright, 2012)).[7,8] We examine the effect of long-term

[5] This window represents the "narrow" window in D'Amico and Farka (2011). They also considered wider windows, extending to 60 minutes after announcements. We use the wider 60 minute windows as a robustness check.

[6] Specifically, we use transaction prices for the eurodollar contract with maturity closest to one year.

[7] We use the nearest date futures contracts on Treasuries from Tickdata. The surprises were constructed from changes in the returns on the on the two-, five-, ten-, and thirty-year bond futures contracts, divided by the duration of the cheapest-to-deliver security in the futures basket, as gathered from Bloomberg. In our principal components

path surprises during the conventional as well as the unconventional periods since policy announcements during the conventional period may also contain information about the future path of policy that is not captured by the short-term path surprises.

For the conventional period, we isolate the separate effects of target, short-term path, and long-term path surprises by orthogonalizing (1) the short-term path surprises with respect to the target surprises, and (2) the long-term path surprises with respect to both the target surprises and the short-term path surprises. For the unconventional period, we orthogonalize the long-term path surprises with respect to the short-term path surprises.. All policy surprises are demeaned, scaled to have a standard deviation of 1, and defined such that surprises with a positive sign indicate monetary easing, while surprises with a negative sign indicate monetary tightening.

Overall, the news events in the conventional policy period consist of 124 FOMC announcements, 119 following scheduled meetings and 5 following unscheduled intermeeting communications. The series includes unscheduled meetings during this period only if the announcements included a change in the federal funds target. For instance, the measure excludes the unscheduled meetings in 2007 because the Federal Reserve did not announce a change in the federal funds rate at those meetings.[9]

For the period characterized by unconventional monetary policy, we use all FOMC announcements between December 2008 and December 2014—including both regularly scheduled and some unscheduled meetings. We also include selected speeches and testimonies given by Board of Governors' Chairman Bernanke in which he signaled possible policy changes,

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analysis of these duration-adjusted yield changes, we take the eigenvector corresponding to the largest eigenvalue, i.e., the first principal component, and multiply each yield change by its respective eigenvector component. It should be noted that the bulk of Federal Reserve asset purchases during the third LSAP round involved mortgage-backed securities. However, we do not have intraday data on these securities since they typically are traded over the counter.

[8] Wright (2012) uses a baseline surprise window from 15 minutes before a given Federal Reserve announcement until 1 hour and 45 minutes after. Our surprise window (-10, +20) was chosen to match that of the narrow measure of D'Amico and Farka (2011) for federal fund surprises employed below. A wider surprise window is considered as a robustness exercise.

[9] The unscheduled meetings included in the measure are April 18, 1994, January 3, 2001, April 18, 2001, January 22, 2008, and October 8, 2008. See footnote 3 for more details.

particularly those suggesting modifications to the Federal Reserve intentions to buy long-term assets. The major announcements that refer to large-scale asset purchases and forward guidance news are listed in Table 1. The complete sample for the unconventional policy period, which includes these LSAP announcements as well as other announcements following FOMC meetings, consists of a total of 56 observations.[10] Our sample thus encompasses announcements used in other studies on the effects of large-scale asset purchases. For instance, our announcements associated with the first round of large-scale asset purchases (LSAP1) between December 16, 2008, and March 18, 2009, largely overlap with those used by Gagnon et al. (2011) and Neely (2010). Similarly, the five announcements for the second round of asset purchases (LSAP2) from August 10 to November 3, 2010, are similar to those used by Wright (2012), Krishnamurthy and Vissing-Jorgensen (2011), and Glick and Leduc (2012). In addition, our analysis encompasses several major announcements associated with the third round of asset purchases (LSAP3), which was initiated in September 2012 and ended in October 2014. This round of announcements also includes the Congressional testimony of Chairman Bernanke on May 22, 2013, which led to the so-called "taper tantrum."

2.2 Intraday exchange rate movements

We conduct our analysis using intraday data on currency futures prices from Tickdata for the days in our announcement sample. The data set contains minute-by-minute tick transaction prices on foreign exchange contracts involving the U.S. dollar with several currencies, including the, British pound, Canadian dollar, euro, and yen.[11] In 2010, these four currencies accounted

[10] In addition to the LSAP-related speeches by Chairman Bernanke cited in Table 1, our sample also includes a speech on August 26, 2011, when the Chairman stated the Fed was considering all of its options, though he was not explicit about additional policy actions. We do not separately break out FOMC announcements related to the Maturity Extension Program involving the sale of short-term Treasuries to purchase longer-term assets for the Federal Reserve's balance sheet. For the Bernanke speeches on November 25, 2008 and December 1, 2008, we imputed values of 0 for the target surprise measure, since there were no announcements regarding the policy target.
[11] These data are based on contracts traded on the Chicago Board of Trade. We use the price of the nearest, most heavily traded futures contract on each announcement day. In the case of the euro, we use the deutschmark before the euro's introduction in 1999.

for over 70 percent of all spot dollar transactions[12] and over 60 percent of all swap and futures dollar transactions (BIS, 2010), while the countries issuing these currencies accounted for about 40 percent of U.S. bilateral trade transactions.

One advantage of using intraday data that is particularly relevant for monetary policy announcements is that it enables us to better isolate their effects. For instance, many studies of large-scale asset purchases by the Federal Reserve since 2008 have relied on daily data to assess the effect of unconventional monetary policy on the price of financial assets (see, for instance, Gagnon et al., 2011)). This approach assumes that the market effects from a monetary announcement will dominate effects from any other information released that day. However, this assumption may be particularly troublesome for asset prices such as exchange rates, which react naturally to news from around the world. Hence, it is more difficult to precisely uncover potential links between monetary policy announcements and movements in currency values using daily data, as the effects of other news events on the U.S. dollar are likely to confound those from monetary policy. For instance, studying the effects of the European Central Bank (ECB) Securities Market Programme on sovereign yields, Ghysels et al. (2013) found that the use of inter-day data masks the significant effects that the ECB's interventions had on sovereign yields that only could be detected using higher frequency intra-day data.

Consequently, we look at movements in the value of the U.S. dollar against foreign currencies in relatively narrow time intervals. Consistent with our identification of monetary policy surprises, we use response windows around monetary policy announcements of 30 minutes (10 minutes before, until 20 minutes after) and 70 minutes (10 minutes before, until 60 minutes after). Using tight time intervals helps us isolate the effects of the monetary announcements from other possible determinants of currency values, assuming these

[12] The euro, yen, pound, and Canadian dollar accounted for 39, 15, 12, and 7 percent of spot transactions, respectively.

announcements rapidly influence the views of market participants and are quickly reflected in the value of the dollar. For comparison, we also report results extending the response surprise windows to 1440 minutes, i.e., 24 hour, after announcements.

3. Results

3.1 Changes in value of the dollar during LSAP rounds

We begin our analysis by reporting the raw, i.e., actual, changes in the value of the dollar during the three rounds of LSAPs. Figure 1 illustrates the intraday behavior of bilateral exchange rates on selected LSAP announcement days. As shown in panel A, the dollar depreciated sharply against all four currencies on December 16, 2008, immediately after the 2:15pm FOMC announcement about the details of LSAP1. The dollar depreciation was smaller following the selected FOMC announcements about LSAP2 and LSAP3. In contrast, the dollar appreciated sharply during the "taper tantrum" following Chairman Bernanke's congressional testimony on May 22, 2013, as markets evidently interpreted his discussion about the future liftoff of the federal funds rate as a surprise monetary tightening.

Table 2 reports changes in the value of the dollar vis-à-vis the pound, Canadian dollar, euro, and yen in response to the major announcements during the three LSAP rounds identified in Table 1, with the latter round separated into subsamples associated with the ramp-up of asset purchases, the taper tantrum episode and subsequent announcements related to tapering of these purchases. The response windows start 10 minutes before announcements and end 20 minutes after. Observe that the dollar depreciated against these currencies in response to announcements during all three LSAP rounds, and appreciated during the taper tantrum episode, and subsequent taper-related announcements. (The appreciation of the dollar against the yen during early phase of LSAP3 is an exception, possibly because of the yen's strong appreciation in the week before

the September 13, 2012, FOMC meeting and market talk about possible Bank of Japan intervention.)

On a trade-weighted basis, the dollar depreciated by an average of 62, 23, and 13 basis points (bps) after announcements about LSAP1, LSAP2, and the ramp up of LSAP3, respectively.[13] The relatively small effect under LSAP3 does not necessarily imply that the Fed's LSAP3 monetary policy actions were ineffective, since the markets may have anticipated these announcements and incorporated them into asset prices. This motivates the need to control for the extent to which the announcements were surprises to the market. During the taper tantrum episode, when markets inferred a greater likelihood of Federal Reserve tightening in the near term, the dollar appreciated by 60 bps. The dollar also appreciated in subsequent pre-taper-related announcements by an average of 1.3 bps, though there is a fair degree of variability across currencies.

For comparison, the table also shows total changes in the *inter*day value of the dollar against major currencies, as calculated by the Board of Governors over the 24-hour period from the end of floor trading on the day prior to each announcement (usually 2:30pm EST) and the end of floor trading on the announcement day. [14] Note that the interday changes have the same signs but are generally larger than the intraday changes measured over the event window periods.

3.2 Pooled Effects of conventional and unconventional monetary policy surprises

We estimate the effects of surprise monetary policy announcements on the value of the dollar against the British pound, Canadian dollar, the DM/euro, and the yen using the following panel specification:

$$\Delta S_{i,t,w} = a_{1,i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma PS_t^{LT} + D_t^u \left(a_{2,i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT}\right) + \varepsilon_{i,t} \qquad (1)$$

[13] We construct trade weights from IMF *Direction of Trade* data in 2011 on U.S. bilateral exports and imports with the U.K., Canada, Eurozone, and Japan, with calculated weights of 0.07, 0.41, 0.39, and 0.13, respectively. Results from taking simple averages are comparable.

[14] Note that all of the LSAP events reported in Table 2 occurred before the end of trading on the day of announcement.

where $\Delta S_{i,t,w}$ is the (log) change in the exchange between currency *i* and the United States at time *t* during a time window *w*. TS_t is the federal funds rate target surprise, PS_t^{ST} is the short-term path surprise, PS_t^{LT} is the long-term path surprise, a_i is a currency fixed effect, and ε_t is an error term. D_t^u is a dummy variable that is equal to one for the unconventional period and is zero otherwise. The parameters α_1, β_1, and γ_1 represent the effects of target surprises, short-term path surprises, and long-term path surprises on the dollar during the conventional period, respectively. Shifts in the impact of the short- and long-term path surprises on the dollar during the unconventional compared to the conventional one are captured by the parameters β_2 and γ_2. The effects of the short- and long-term path surprises on the dollar during the unconventional period are thus given by ($\beta_1 + \beta_2$) and ($\gamma_1 + \gamma_2$). Note that we assume that there are no target surprises during the unconventional period, since the target for the federal funds rates was at its effective lower bound.[15]

As discussed in Section 2, positive values of the monetary policy surprises are defined to indicate monetary easing surprises, while the exchange rate is defined as units of foreign exchange per U.S. dollar, so that a *decrease* in *S* indicates a *depreciation* of the dollar. Hence, negative coefficient estimates are consistent with the finding that monetary policy easing leads to a depreciation of the dollar.

To illustrate the relationship between the change in the exchange rate and the different monetary surprises, Figure 2 reports scatter plots of the change in the value of the dollar against target surprises, short-term path surprises, and long-term path surprises for the conventional and unconventional periods. To convey the information compactly, we trade-weight the dollar

[15] Federal funds rate futures were thinly traded during this period. Their movements more than likely did not represent expectations of future policy changes, since given the amount of excess reserves held by banks, the federal funds rate ceased to be an effective monetary policy tool. Therefore, we abstract from target surprises altogether during the unconventional policy period.

exchange rates against the four currencies included in our analysis – the British pound, Canadian dollar, euro, and yen.

First, observe that the sample includes both negative, i.e., unexpected tightening, as well as positive, i.e., unexpected easing, monetary surprises. The scatters indicate a clear negative relationship between the dollar and monetary surprises, particularly for the target and the short-term path surprises during the conventional period and for the short- and long-term path surprises during the unconventional period. Thus, surprise monetary loosening (tightening) are associated with dollar depreciation (appreciation), the more so the greater the surprise. In addition, we note that the dollar appeared to move substantially more in response to monetary surprises during the unconventional period than during the conventional period.

A more formal empirical analysis confirms this assessment. Table 3 reports coefficient estimates of equation (1) from regressions of changes in the value of the dollar on our measure of policy surprises, using response windows of lengths ranging from 10 minutes before the announcement to w = 20, 60, 1440 minutes (i.e., 24 hours) after. Constants are included in the regressions, but are not reported in the table for brevity.

We first concentrate on the effect of policy surprises on the dollar during the conventional period. Table 3 indicates that the dollar is affected via two channels. First, a one standard deviation surprise easing in the federal funds rate target leads to a 6.96 basis point decline in the value of the dollar 60 minutes after a policy announcement and 8.32 basis points a day after. However, the dollar is also impacted by surprise information about the future path of monetary policy. Specifically, we find that a one standard deviation easing in the short-term path surprise during the conventional period leads the dollar to depreciate 8.58 basis points 60 minutes following announcements and 12.95 basis points one day after. These effects are statistically significant at 1% or lower. In contrast, long-term path surprises did not much impact

the exchange rate during the conventional period, as the estimated magnitude of γ_1 is small and barely significant at the 10% level only in the first 20 minutes.

The transmission of monetary policy to the exchange rate operates differently during the unconventional policy period, with the effects of long-term as well as short-term surprises both being significantly larger than during the conventional period. More specifically, as Table 3 indicates upon summing the coefficient estimates β_1 and β_2 , a one standard deviation short-term path surprise leads to a 30.69 (44.27) basis points depreciation 60 minutes (24 hours) after an announcement, an effect far larger than during the conventional policy period. In addition, we find that long-term path surprises have effects of a similar magnitude as the short-term path surprises during the unconventional policy period: summing the coefficients estimates γ_1 and γ_2 implies that, in response to a one standard deviation in the long-term path surprise, the dollar depreciates by 20.39 (22.89) basis points, 60 minutes (24 hours) after announcement.

Converting our results into basis point terms, a target surprise of one percentage point (100 bp) causes an estimated 0.87 percent decline in the value of the dollar within 60 minutes. Similarly, a one percentage point short-term (long-term) path surprise during the conventional period leads the dollar to depreciate by 1.3 percent, while a long-term path surprise leads to a negligible depreciation of 0.4 percent. During the unconventional period, a one percentage point short-term path surprise causes a 4.6 percent dollar depreciation; a long-term path surprise leads to a depreciation of comparable magnitude, of 3.8 percent.[16]

Table 3 indicates notable and intuitive differences between the different channels through which monetary policy announcements can affect the exchange rate in the conventional and unconventional periods. Our results are comparable to other findings in the literature. For example, Hausman and Wongswan (2011) also found that during the pre-crisis period the dollar

[16] The conversion into basis points changes utilizes the fact that the standard deviations over the sample period of short-term and long-term path surprises are 6.34 bps and 5.41 bps, respectively, and that the standard deviation of target surprises is 7.75 bps.

is affected not only by target surprise announcements, but also by surprise announcements about the future path of policy.[17] We augment this finding with the result that this forward-guidance-type channel during the conventional policy period is captured solely by short-term path surprises, as the dollar barely reacts to long-term path surprises.

In contrast, during the unconventional period the dollar responds significantly to long-term path surprises as well as to short-term path surprises. This is consistent with the Federal Reserve's objective of lowering long-term interest rates by purchasing long-term assets in large amounts.[18] In turn, the absence of such a program during the conventional period is consistent with our finding that the dollar did not react significantly to long-term path surprises before the crisis. Our finding that long-term path surprises matter significantly during the unconventional period is broadly in line with the results reported in Wright (2012) and Rogers, Scotti, and Wright (2014) for the pound, the euro, the yen, and the Canadian dollar.[19] To compare the magnitude of the effects of policy surprises during the conventional and unconventional periods, we assume that a typical FOMC announcement during both periods includes information about the target for the federal funds rate and also language about the future path of monetary policy. Thus, to calculate the effects of monetary policy surprises between 1994 and 2008, we sum the coefficient estimates on the target surprise and short-term and long-term path surprises ($\alpha_1 + \beta_1 + \gamma_1$), which implies a 17.16 basis point dollar depreciation, 60 minutes after

[17] As noted above, we find that the dollar depreciated on average by 1.3 percent in response to a 100bps short-term path surprise. Hausman and Wongswan (2011) examine the effects of U.S. target and short-term path surprises on daily exchange rate changes for a panel of advanced and emerging economies during the conventional rate period from 1994 to 2005. Like us, they find foreign currency values typically respond more to path than to target surprises and report that a 100bps path surprise leads on average to a 1.6 percent depreciation of the dollar, comparable to our finding.

[18] Of course, the long-term path surprise could be due to the Fed's forward guidance in addition to its large-scale asset purchases. Our approach does not allow us to distinguish between these two channels.

[19] Bowman et al (2014) analyze the effects of U.S. long-term path surprises on asset markets prices, including exchange rates, in emerging markets, during the unconventional period. In an event study they find evidence that emerging market currencies responded over 2 day windows around U.S. monetary policy announcements. In a panel study they find that these effects are smaller (and not statistically significant) after controlling for country-specific characteristics that affect vulnerability to changes in U.S. monetary policy.

announcements (note that we include the effect of the long-term path surprises even though they are not statistically significant in most cases). For the unconventional period, we assume that a typical surprise announcement is composed of both short-term and long-term path surprises (by summing $\beta_1, \beta_2, \gamma_1$, and γ_2). In this case, we find that the dollar depreciated 51.08 basis points 60 minutes following a surprise easing announcement, an effect which is about three times larger than its effect following a conventional policy surprise easing. The relatively greater impact of unconventional policy surprises still remains one day after announcements.[20] Thus, our results suggest that monetary policy remained effective in affecting the exchange rate even after reaching the zero lower bound, which is in line with the finding of Swanson and Williams (2014). However, while they find that the sensitivity of the pound/dollar and euro/dollar exchange rates to economic news remained about the same before and after the zero lower bound was reached, our analysis shows that the dollar responded by more following unconventional policy surprises.[21]

The findings from our panel regressions also hold for the individual currencies underlying our panel results. Table 4 presents individual results for the U.S. dollar exchange rate against the British pound, Canadian dollar, euro, and yen. For brevity, we report only the effects with the 60-minute response window after policy announcements. As for the pooled results during the conventional period, both the target and short-term path surprises affect the dollar's

[20] In Glick and Leduc (2013) we reported that the impact of policy surprises on the dollar during the conventional and unconventional periods were of similar magnitudes. This difference in results is due to the fact that our previous work abstracted from the presence of both short-term and long-term path surprises in addition to the target surprises during the conventional period. To compare the effects on the dollar across periods, we converted the effects of (long-term) path surprises during the unconventional period into equivalent target surprise effects during the conventional period, using an estimate of their correlation between 1994 and 2008. Our current approach differs since we include (orthogonalized) path surprises along with federal funds rate target surprises. In addition, here we employ a panel that pools observations from both the conventional and unconventional periods. This enables nested tests to directly compare the effectiveness of policies across periods. In a later robustness result we show that the difference in coefficients still remains when working with nonnested samples.

[21] The difference between our results and those of Swanson and Williams (2014) may be due to the different news measures considered. We focus on news in the form of surprise policy announcements, while they examine the effects of news in the form of macroeconomic data releases.

value against these individual currencies, while the effects from the long-term path surprises are insignificant (except for the yen). During the unconventional period, both short- and long-term path surprises affect the dollar exchange rate to a similar extent for all currencies.[22] In addition, for the four currencies considered, the dollar depreciates by a magnitude several times larger during the unconventional monetary policy period than during the conventional period.

3.2 LSAP1 and the taper period

Given that financial markets were substantially impaired during the end of 2008 and early part of 2009, the unconventional monetary policy decisions taken during that time could have had effects on the value of dollar that differed quite substantially from those during less turbulent times in the post-crisis period. Similarly, large movements in asset prices also occurred during the tapering period as the FOMC signaled and then initiated a gradual decline in Treasury and mortgage-backed securities purchases that ultimately ended the LSAP3 program. In particular, Chairman Bernanke's remarks on May 22, 2013 appear to have caught market participants off guard and led to substantial fluctuations in bond, equity, and currency markets worldwide.

In this section, we examine the extent to which our results are driven by the key announcements during LSAP1 and the tapering period of LSAP3 (i.e., from May 22, 2013 to the end of the program on October 29, 2014) by adding dummy variables (D^{LSAP1} , D^{Taper}) to equation (1) that isolate the effects of these two periods of interest. Specifically, we run the following regression:

$$\begin{aligned}\Delta S_{i,t,w} = {} & a_{1,i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} + D_t^u \left(a_{2,i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT} \right) \\ & + D_t^{LSAP1} \left(a_{3,i} + \beta_3 PS_t^{ST} + \gamma_3 PS_t^{LT} \right) + D_t^{Taper} \left(a_{4,i} + \beta_4 PS_t^{ST} + \gamma_4 PS_t^{LT} \right) + \varepsilon_{i,t}\end{aligned} \quad (2)$$

[22] Wright (2012) reports that the Canadian dollar, pound, and euro appreciate interday by 0.56, 0.73. and 1.09 percent, respectively, in response to a standardized long-term monetary surprise, implying a similar rank response order as we report in Table 4. We cannot make a direct numerical comparison to our results for individual currencies, since we do not have the information to convert his surprise measure into bp terms.

Table 5 reports the results. Note that the coefficients α_1 , β_1, γ_1 reflect the effects of target, short-term path, and long-term path surprises during the conventional period, while β_2, γ_2 reflect the additional effects of short-term and long-term path surprises in the unconventional period, while excluding the effects of surprises during the LSAP1 and taper periods; the latter effects are captured by the coefficients β_3, γ_3 and β_4, γ_4 , respectively. The main message is that the short- and long-term path surprises had larger effects during LSAP1 and the tapering period, with those following LSAP1 announcements being particularly persistent during the 24 hour response window. While the large effects of unconventional monetary policy during LSAP1 when financial markets were impaired has been addressed by others (e.g., Gagnon et al. 2011) and Krishnamurthy and Vissing-Jorgensen 2011, among others), our results indicate that large effects occurred during the tapering period as well, when financial markets were operating more normally.[23] Nevertheless, Table 5 also indicates that, although the effects are attenuated and less persistent, the dollar still responded significantly to policy surprises outside of the LSAP1 and tapering periods.

In particular , during these other phases of the Federal Reserve's purchasing programs during the unconventional period the dollar depreciated on average by 15.17 bps in the 60 minutes following short-term path surprises, while the long-term path surprises led to a decline in the dollar's value of 6.44 bps. Thus, abstracting from the LSAP1 and tapering periods, the dollar depreciated about 1.3 times more in the 60 minutes following a monetary easing during the unconventional period than during the conventional period.

[23] It should be noted that the policy surprises are typically negatively signed during the taper period, indicating monetary tightening. Hence the negative coefficients on the variables $D^{Taper} * PS^{ST}$, $D^{Taper} * PS^{LT}$ are consistent with positive effects on the exchange rate, i.e., an appreciation of the dollar.

4. Robustness Analysis

In this section we subject our benchmark results to several robustness checks. In particular, we assess the role of the window size used to construct our monetary surprise measures, the exclusion of long-term path surprises, alternative break dates between the conventional and unconventional periods, the exclusion of unscheduled meeting announcements, and nonnested regressions for the conventional and unconventional periods.

4.1 Wider surprise windows

We first consider the implications of using a wider window to construct the conventional and unconventional policy surprises, going from 10 minutes before announcements until 60 (rather than 20) minutes after. The results are given in Table 6. Given this wider window for surprises, we report the exchange rate effects only for +60 minute and +24 hour response windows.

Overall, we find that our results are broadly robust to this alternative measure of policy surprises, as the effects of the short- and long-term path surprises still are much larger during the unconventional period than during the conventional period. Looking more closely, it should be noted that the short-term path surprises during the conventional period tend to have a much stronger impact on the exchange rate compared to those reported in Table 3 with the narrow window. This narrows the difference between the exchange rate effect of monetary policy across periods. Overall, monetary easing during the unconventional period leads to a depreciation of the dollar after 60 minutes that is about two and a quarter times as large as that during the conventional monetary period (where the latter includes the effect of target surprises); this is lower than the roughly three times difference with the narrow window results reported in Table 3.

4.2 Exclusion of long-term path surprises

For the conventional period, the literature has generally emphasized two types of monetary policy surprises, those associated with unexpected changes in the policy rate – target surprises -- and those capturing the influence of FOMC communication on the future path of relatively short-term interest rates, such as the one-year eurodollar rate – what we term short-term path surprises (see, e.g. Gürkayrkanak, Sack, and Swanson, 2005; Hausman and Wongswan, 2011). , By including long-term path surprises in our benchmark specification we allow for the possibility that policymakers can directly influence longer-term interest rates either via long-term asset purchases or via forward guidance. However, given that policymakers have less direct control over long-term interest rates, the identification of policy surprises via this channel is possibly more uncertain.

We now assess the robustness of our main finding by removing the long-term path surprises from the benchmark model altogether. Interestingly, we still find that monetary policy's impact on the dollar is two to three times larger during the unconventional than conventional period, as shown in Table 7. A conventional-period monetary announcement that included a one standard deviation decline in both the target and short-term path surprises leads to a 15.02 basis point decline in the value of the dollar one hour following announcement, whereas during the unconventional period a one standard deviation fall in the short-term path surprise generates a dollar depreciation of 35.35 basis points. Thus, our main finding is robust to the more typical measurement of policy surprises.

4.3 The December 16, 2008 announcement

As discussed earlier, the transition between the conventional and unconventional periods is difficult to pin down precisely. In our benchmark specification, we treated October 2008 as the end of the conventional period, before the FOMC's decision to fully lower the federal funds rate

to its effective lower bound as it announced on December 16 later that year. As such, the December 16, 2008 FOMC statement is somewhat special as it contained information on forward guidance and on the FOMC's intentions to buy long-term assets, in addition to its decision to bring the federal funds rate down to its effective lower bound. Thus, it is likely that the announcement's effects on the dollar reflect the use of conventional as well as unconventional policies. As a robustness check, we continue to end the conventional period in October 2008, but add a dummy variable for the December 16, 2008 announcement. As can be noted from panel A of Figure 1, the movement in the dollar was large that day, implying that its inclusion in the conventional period of our baseline specification may affect the comparison of policy effectiveness across regimes.

Our results in Table 8, however, indicate that this is largely not the case. While we find that the December 2008 FOMC statement indeed had a very large impact on the exchange rate, the gist of our results go through under this alternative specification. In particular, we still find that the dollar depreciated by roughly three times more following surprise easing during the unconventional period as compared to the conventional period. We have also examined the robustness of our results to starting the unconventional period in January 2009, thus eliminating the announcements regarding unconventional policy in November and December 2008 and found similar results as with our baseline specification.[24] All told, while the exact break between the conventional and unconventional periods is not clear cut, reasonable variations leave our results essentially unchanged.

4.4 Unscheduled FOMC meetings

Examining the effects of the target surprises on the dollar in the top panel scatters of Figure 2, it is apparent that there are several large positive surprises, roughly 40 basis points in magnitude, which had a much more muted impact on the exchange rate. These announcements

[24] These results are available upon request.

can be traced to three unscheduled FOMC meetings that occurred on January 3, 2001, April 18, 2001, and January 22, 2008.

The differential effects of intermeeting announcements on asset markets have been noted in other studies. Fleming and Piazzesi (2005), for example, analyze monetary policy effects over the period February 1994 to December 2004 using a sample that includes three of the episodes we examine—April 18, 1994, January 3, 2001, and April 18, 2001—as well as September 17, 2001, and October 15, 2008. They find that Treasury rates responded particularly slowly to the announcements on these days. They suggest several reasons why intermeeting moves might be important in explaining the market's weak response: intermeeting target rate easing surprises tend to occur in relatively uncertain environments, tend to be larger, and may have a larger "signaling" component than other announcements about economic weakness, thereby dampening bond demand and the easing of long-term rates, or alternatively they may take a longer time to be digested and processed by markets. Consequently, the effect of policy surprises on the dollar during the conventional period, and hence our comparison with the effects during the unconventional period, may be affected by FOMC announcements following unscheduled meetings.

Therefore, as another robustness exercise, we remove the unscheduled meetings from the conventional period sample and report the results in Table 9. As expected, removing the unscheduled meetings implies a greater impact of the target surprises on the dollar, which now depreciates by about 14 basis points in the 60 minutes following announcements compared to roughly 7 basis points for our benchmark case in Table 3. However, the effects of the short-term path surprises are now somewhat smaller. Taking these two effects into account, Table 9 indicates that the impact of a typical monetary easing on the dollar during the unconventional period still remains several times larger than that during the conventional period.

4.5 Non-nested regressions

The analysis above involved estimation of pooled panels for the entire set of observations during the conventional and unconventional periods. As a final exercise, we examine the robustness of our results to estimating the effects of the policy surprises for the conventional and unconventional periods separately. More specifically, we estimate the following regression for the conventional period

$$\Delta S_{i,t,w} = a_i + \alpha TS_t + \beta PS_t^{ST} + \gamma PS_t^{LT} + \zeta_{i,t}, \quad (3a)$$

while the specification for the unconventional period is

$$\Delta S_{i,t,w} = a_i^u + \beta^u PS_t^{ST} + \gamma^u PS_t^{LT} + \zeta_{i,t}, \quad (3b)$$

where ζ is an error term and other variables are defined as before. We report the results in Tables 10, Even without any formal statistical testing, we find that our benchmark results are little affected by this change in specification. For instance, comparing the effects of a surprise easing on the value of the U.S. dollar across periods, we continue to find that the dollar depreciated substantially more during the unconventional period than during the conventional period.[25]

5. Conclusion

Using intraday data, we examine the effects of recent unconventional monetary policy on the value of the U.S. dollar against other major currencies. To assess the relative effectiveness of unconventional monetary policy on the dollar, we contrast the impact of policy surprises following policy announcements during the unconventional period since the end of 2008 with that during the pre-crisis period when the federal funds rate was the main tool of monetary policy. We use high frequency data on futures prices to measure market surprises regarding the

[25] In this exercise, the surprise measures are calculated separately for each period, i.e. they are orthogonalized, demeaned, and standardized separately for the conventional and unconventional periods.

federal funds rate target and the future path of monetary policy, arising from forward guidance and/or large-scale asset purchases by the Federal Reserve.

Our results indicate that the exchange rate effect of the recent policies has been substantial and much greater than that of monetary policy in the pre-crisis period when the Federal Reserve could rely on changes in the federal funds rate to conduct monetary policy. In particular, we find that monetary policy now has roughly three times the bang per policy surprise on the value of the dollar as previously.

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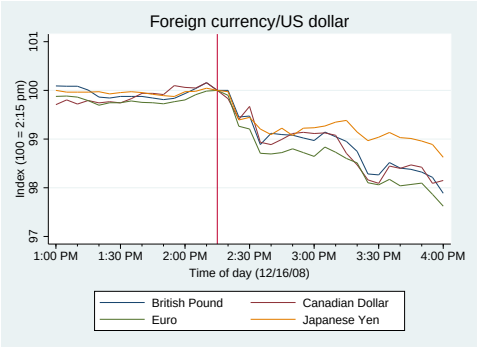
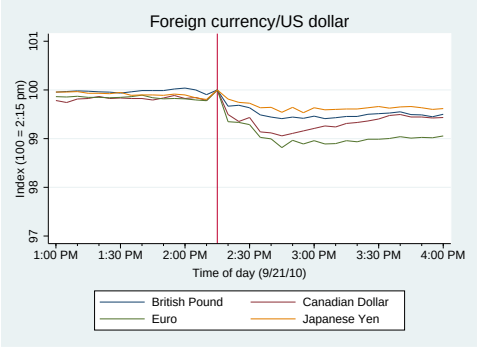
Figure 1: Intraday Response of Foreign Currency Value of Dollar, Selected LSAP Days

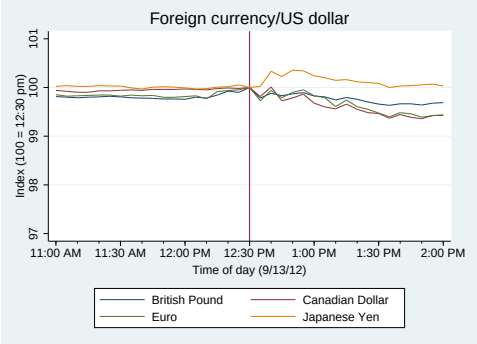
(a) An LSAP1 Day (12/16/2008)



(b) An LSAP2 Day (9/21/2010)



(c) An LSAP3 Day (9/13/2012)



(d) "Taper Tantrum" Day (5/22/2013)

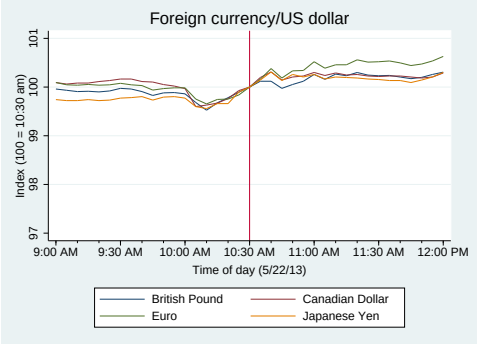
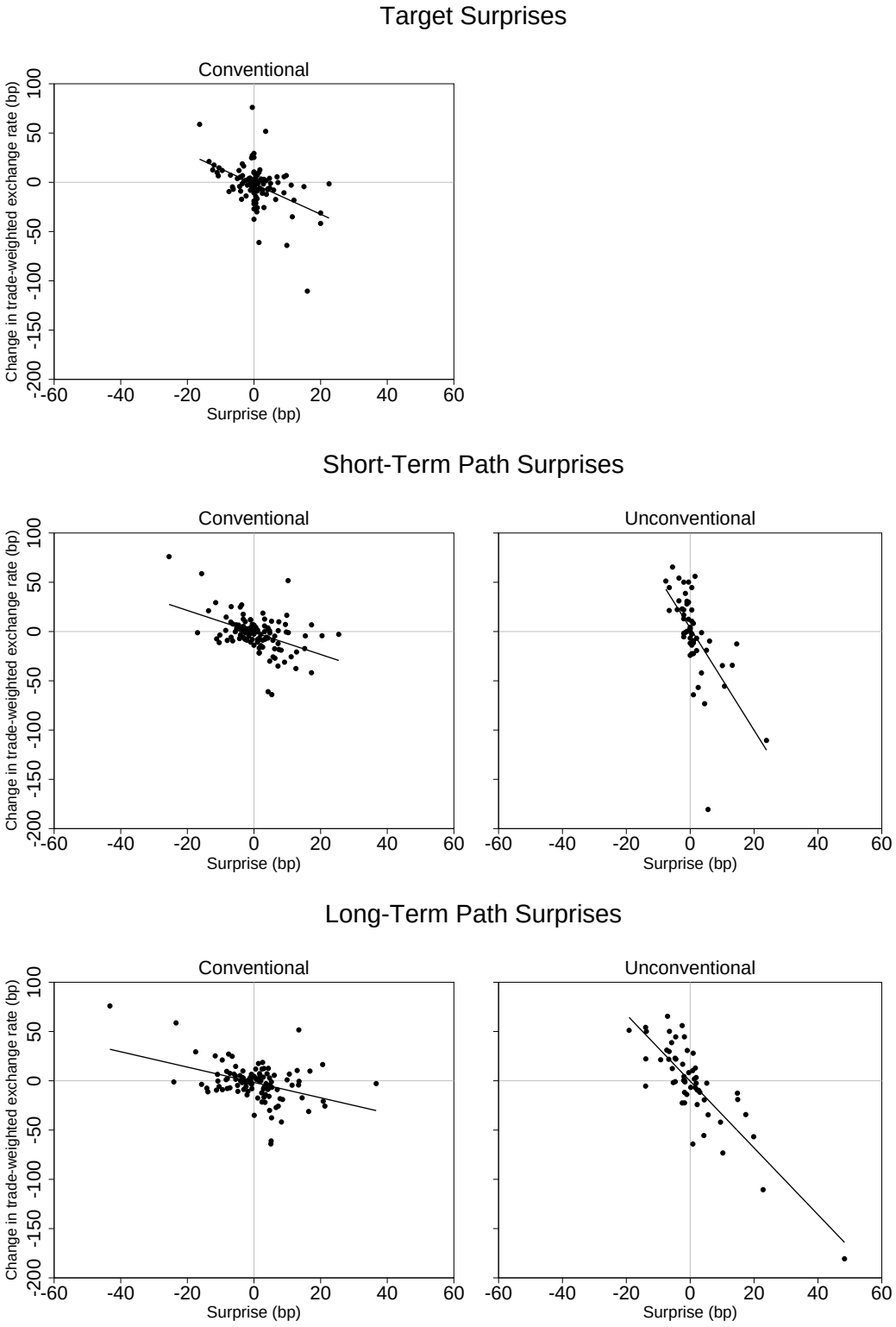


Figure 2: Monetary Policy Surprises and Exchange Rate Responses, +20 Minute Windows



Note: Positive monetary surprises indicate easing. The intraday exchange rate response windows are measured from 10 minutes before to 20 minutes after announcements. Negative exchange rate responses indicate depreciation of the dollar against foreign exchange.

Table 1: Federal Reserve Major LSAP and Forward Guidance Announcements

Date	Time (ET)	Round	Event	Description
11/25/2008	8:15am	1	Initial LSAP1 announcement	FOMC announces intended purchases of $100 billion in GSE debt and up to $500 billion in MBS.
12/1/2008	1:40pm	1	Bernanke Speech in Austin, Texas	Chairman Bernanke says that the Fed could purchase long-term Treasuries.
12/16/2008	2:15pm	1	FOMC Statement	FOMC first mentions possible purchase of long-term Treasuries and that conditions will warrant low federal funds rate for "some time."
1/28/2009	2:15pm	1	FOMC Statement	FOMC says that it is ready to expand agency debt and MBS purchases, as well as purchase long-term Treasuries.
3/18/2009	2:15pm	1	FOMC Statement	FOMC says it will purchase an additional $750 billion in agency MBS, increase its purchases of agency debt by up to $100 billion, and buy up to $300 billion in long-term Treasuries. Also states conditions warrant low funds rate for "an extended period."
8/10/2010	2:15pm	2	FOMC Statement	FOMC states that it will continue to roll over the Federal Reserve holdings of Treasury securities as they mature.

8/27/2010	10:00am	2	Bernanke Speech at Jackson Hole	Chairman Bernanke suggests that the FOMC is likely to buy longer-term securities.
9/21/2010	2:15pm	2	FOMC Statement	FOMC states that the Federal Reserve will continue to roll over its holdings of Treasury securities as they mature and is prepared to provide additional accommodation if needed.
10/15/2010	8:15am	2	Bernanke Speech at Boston Fed	Chairman Bernanke indicates easing is to be continued.
11/3/2010	2:15pm	2	FOMC Statement	FOMC states its intention to purchase $600 billion more in longer-term Treasury securities by the end of the second quarter of 2011.
8/31/2012	10:00am	3	Bernanke Speech at Jackson Hole	Chairman Bernanke announces intention for further action.
9/13/2012	12:30pm	3	FOMC Statement	FOMC says it will purchase additional agency mortgage-backed securities at a pace of $40 billion per month and low federal funds rate likely “at least through mid-2015.”
12/12/2012	12:30pm	3	FOMC Statement	FOMC extends longer-term Treasury security purchases and announces numerical threshold targets for continued monetary accommodation.

5/22/2013	10:30am	3	Testimony to Congress Statement	Chairman Bernanke remarks that the Federal Reserve will likely start slowing its asset purchases later in 2013 if the economy and job market continue to improve.
6/19/2013	2:15pm	3	FOMC Statement	FOMC relates pace of asset purchases to inflation as well as employment outlook.
9/18/2013	2:15pm	3	FOMC Statement	FOMC relates pace of asset purchases assessment of costs and benefits as well as the economic outlook.
12/18/2013	2:15pm	3	FOMC Statement	FOMC announces plan to reduce pace of asset purchases and that the low funds rate will be maintained past the time unemployment rate reaches its numerical threshold.

Table 2: Average Intraday Change in Exchange Rates (in Basis Points)

	LSAP1	LSAP2	LSAP3		
			Ramp-up	Tantrum	Pre-Taper
	11/25/08 - 3/18/09	8/10/10 - 11/3/10	8/31/12 - 12/12/12	5/22/13	6/19/13 - 12/18/13
British pound/$	-66.48	-19.40	-13.10	27.17	-3.79
Canadian dollar/$	-61.72	-26.75	-16.70	44.32	6.71
Euro/$	-69.49	-24.57	-17.25	57.95	-10.08
Japanese yen/$	-41.91	-12.98	6.15	59.84	15.27
Intraday trade-weighted $	-61.91	-23.37	-13.14	50.13	1.30
No. obs.	5	5	3	1	3
Memo: Interday trade-weighted $	-132.24	-19.51	-46.75	63.17	54.82

Note: The intraday exchange rate response windows are measured from 10 minutes before to 20 minutes after announcements. Negative values indicate depreciation of the dollar against foreign exchange.

Table 3: Monetary Policy Surprises and the Exchange Rate

$$\Delta S_{i,t,w} = a_{1i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} + D_t^u(a_{2i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT}) + \epsilon_{i,t}$$

	+20m	+1h	+24h
TS	-5.25***	-6.96***	-8.32**
	(0.79)	(0.59)	(3.36)
PS^{ST}	-6.14***	-8.58***	-12.95***
	(0.72)	(1.56)	(0.57)
PS^{LT}	-2.43*	-1.61	0.67
	(1.39)	(2.00)	(2.69)
$D^u * PS^{ST}$	-24.65***	-22.11***	-31.31***
	(1.92)	(3.01)	(6.49)
$D^u * PS^{LT}$	-15.45***	-18.77***	-23.55***
	(1.58)	(0.99)	(5.54)
Memo:			
1. $\beta_1 + \beta_2$	-30.79***	-30.69***	-44.27***
	(2.12)	(3.64)	(6.01)
2. $\gamma_1 + \gamma_2$	-17.88***	-20.39***	-22.89***
	(2.82)	(2.54)	(2.93)
3. $\alpha_1 + \beta_1 + \gamma_1$	-13.82***	-17.16***	-20.61***
	(2.14)	(3.77)	(4.24)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-48.67***	-51.08***	-67.15***
	(3.38)	(3.31)	(7.78)
5. Line 4 / Line 3	3.52	2.98	3.26
R^2	0.49	0.37	0.15
No. obs.	720	683	699

Note: Robust standard errors in parentheses. *,**,*** denote significance at 10%, 5%, 1% levels, respectively. Surprise windows defined as 10 minutes before to 20 minutes after announcements. Exchange rate response windows are measured from 10 minutes before to 20 minutes, 1 hour, and 24 hours after announcement. Exchange rate changes are in basis point units and surprises are in standardized units, so the figures in the table can be interpreted as effect of a one standard deviation surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is March 22, 1994 to December 17, 2014.

Table 4: Impact of Policy Surprises on Individual Currencies

$$\Delta S_{i,t,w} = a_{1i} + \alpha_{1i} TS_t + \beta_{1i} PS_t^{ST} + \gamma_{1i} PS_t^{LT} + D_t^u (a_{2i} + \beta_{2i} PS_t^{ST} + \gamma_{2i} PS_t^{LT}) + \epsilon_{i,t}$$

	British Pound	Canadian Dollar	DM/Euro	Japanese Yen
TS	-7.09**	-6.08***	-8.89*	-6.18**
	(3.17)	(2.07)	(4.63)	(2.62)
PS^{ST}	-7.90***	-6.44***	-13.96***	-7.09***
	(2.51)	(2.18)	(4.00)	(2.26)
PS^{LT}	0.40	2.56	-6.61	-4.13
	(3.59)	(3.19)	(5.86)	(3.47)
$D^u * PS^{ST}$	-23.73*	-26.89**	-23.32*	-13.35**
	(12.43)	(12.95)	(12.29)	(6.47)
$D^u * PS^{LT}$	-19.41***	-16.51**	-16.55*	-21.31***
	(6.86)	(6.96)	(8.71)	(4.32)
Memo:				
1. $\beta_1 + \beta_2$	-31.63***	-33.34***	-37.28***	-20.44***
	(12.19)	(12.78)	(11.74)	(6.03)
2. $\gamma_1 + \gamma_2$	-19.00***	-13.95**	-23.16***	-25.45***
	(5.83)	(6.19)	(6.36)	(2.55)
3. $\alpha_1 + \beta_1 + \gamma_1$	-14.59***	-9.96**	-29.45***	-17.40***
	(5.26)	(4.25)	(6.92)	(5.50)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-50.63***	-47.28***	-60.44***	-45.89***
	(10.79)	(11.48)	(11.23)	(5.62)
5. Line 4 / Line 3	3.47	4.75	2.05	2.64
R^2	0.37	0.33	0.42	0.45
No. obs.	180	180	143	180

Note: Robust standard errors in parentheses. *,** ,*** denote significance at 10%, 5%, 1% levels, respectively. Surprise windows defined as 10 minutes before to 20 minutes after announcements. Exchange rate responses are measured from 10 minutes before to 60 minutes after announcements. Exchange rate changes are in basis point units and surprises are in standardized units, so the figures in the table can be interpreted as effect of a one standard deviation surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is February 4, 1994 to December 17, 2014.

Table 5: Robustness: Importance of LSAP1 and Taper

$$\Delta S_{i,t,w} = a_{1i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} + D_t^u(a_{2i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT}) + D_t^{LSAP1}(a_{3i} + \beta_3 PS_t^{ST} + \gamma_3 PS_t^{LT}) + D_t^{Taper}(a_{4i} + \beta_4 PS_t^{ST} + \gamma_4 PS_t^{LT}) + \epsilon_{i,t}$$

	+20m	+1h	+24h
TS	-4.88***	-5.97***	-6.40**
	(0.67)	(0.58)	(3.04)
PS^{ST}	-6.13***	-8.55***	-12.83***
	(0.73)	(1.56)	(0.59)
PS^{LT}	-2.44*	-1.62	0.71
	(1.39)	(1.99)	(2.72)
$D^u * PS^{ST}$	-18.10***	-6.62***	-2.80
	(2.10)	(1.43)	(5.06)
$D^u * PS^{LT}$	-7.47***	-4.82*	19.43
	(1.72)	(2.50)	(17.71)
$D^{LSAP1} * PS^{ST}$	-35.85***	-55.38***	-112.79***
	(6.43)	(13.63)	(36.38)
$D^{LSAP1} * PS^{LT}$	-13.52***	-16.64***	-61.55***
	(2.20)	(2.02)	(18.53)
$D^{Taper} * PS^{ST}$	-26.07***	-29.30***	-16.60
	(5.54)	(4.36)	(11.07)
$D^{Taper} * PS^{LT}$	-4.23***	-20.54***	-32.84
	(1.14)	(2.35)	(26.51)
Memo:			
1. $\beta_1 + \beta_2$	-24.22***	-15.17***	-15.63***
	(2.82)	(1.98)	(4.54)
2. $\gamma_1 + \gamma_2$	-9.91***	-6.44*	20.14
	(2.89)	(3.48)	(16.59)
3. $\alpha_1 + \beta_1 + \gamma_1$	-13.44***	-16.14***	-18.52***
	(2.24)	(3.84)	(4.25)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-34.13***	-21.61***	4.51
	(5.47)	(5.06)	(19.36)
5. Line 4 / Line 3	2.54	1.34	-0.24
R^2	0.53	0.44	0.25
No. obs.	720	683	699

Note: Robust standard errors in parentheses. *,** ,*** denote significance at 10%, 5%, 1% levels, respectively. Surprise windows defined as 10 minutes before to 20 minutes after announcements. Exchange rate response windows are measured from 10 minutes before to 20 minutes, 1 hour, and 24 hours after announcement. Exchange rate changes are in basis point units and surprises are in standardized units, so the figures in the table can be interpreted as effect of a one standard deviation surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is March 22, 1994 to December 17, 2014.

Table 6: Robustness: Wider Surprise Windows

$$\Delta S_{i,t,w} = a_{1i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} + D_t^u(a_{2i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT}) + \epsilon_{i,t}$$

	+1h	+24h
TS	-6.50***	-9.16***
	(1.00)	(3.06)
PS^{ST}	-14.34***	-20.51***
	(2.80)	(3.46)
PS^{LT}	-6.26*	-2.97
	(3.80)	(2.72)
$D^u * PS^{ST}$	-28.29***	-50.46***
	(4.57)	(9.43)
$D^u * PS^{LT}$	-13.15***	-15.91***
	(1.34)	(4.62)
Memo:		
1. $\beta_1 + \beta_2$	-42.63***	-70.97***
	(4.04)	(9.18)
2. $\gamma_1 + \gamma_2$	-19.41***	-18.88***
	(2.60)	(2.95)
3. $\alpha_1 + \beta_1 + \gamma_1$	-27.10***	-32.64***
	(6.82)	(1.31)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-62.04***	-89.86***
	(3.61)	(11.11)
5. Line 4 / Line 3	2.29	2.75
R^2	0.49	0.27
No. obs.	488	468

Note: Robust standard errors in parentheses. *,**,*** denote significance at 10%, 5%, 1% levels, respectively. Surprise windows defined as 10 minutes before to 60 minutes after announcements. Exchange rate response windows are measured from 10 minutes before to 1 hour and 24 hours after announcement. Exchange rate changes are in basis point units and surprises are in standardized units, so the figures in the table can be interpreted as effect of a one standard deviation surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is April 18, 1994 to December 17, 2014.

Table 7: Robustness: Excluding Long-Term Path Surprises
$\Delta S_{i,t,w} = a_{1i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + D_t^u(a_{2i} + \beta_2 PS_t^{ST}) + \epsilon_{i,t}$

	+20m	+1h	+24h
TS	-4.92***	-6.54***	-7.86**
	(0.82)	(0.55)	(3.38)
PS^{ST}	-6.02***	-8.47***	-12.97***
	(0.66)	(1.46)	(0.53)
$D^u * PS^{ST}$	-28.86***	-26.88***	-36.47***
	(1.77)	(2.53)	(6.67)
Memo:			
1. $\beta_1 + \beta_2$	-34.87***	-35.35***	-49.43***
	(2.16)	(3.41)	(6.32)
3. $\alpha_1 + \beta_1$	-10.93***	-15.02***	-20.82***
	(1.06)	(2.00)	(3.25)
4. $\beta_1 + \beta_2$	-34.87***	-35.35***	-49.43***
	(2.16)	(3.41)	(6.32)
5. Line 4 / Line 3	3.19	2.35	2.37
R^2	0.29	0.22	0.10
No. obs.	720	683	699

Note: Robust standard errors in parentheses. *,**,*** denote significance at 10%, 5%, 1% levels, respectively. Surprise windows defined as 10 minutes before to 20 minutes after announcements. Exchange rate response windows are measured from 10 minutes before to 20 minutes, 1 hour, and 24 hours after announcement. Exchange rate changes are in basis point units and surprises are in standardized units, so the figures in the table can be interpreted as effect of a one standard deviation surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is March 22, 1994 to December 17, 2014.

Table 8: Robustness: The December 16, 2008 Announcment

$$\Delta S_{i,t,w} = a_{1i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} + D_t^u(a_{2i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT}) + D_t^{Dec.08}(a_{D08i}) + \epsilon_{i,t}$$

	+20m	+1h	+24h
TS	-4.97***	-6.68***	-6.81**
	(0.80)	(0.59)	(3.00)
PS^{ST}	-6.13***	-8.57***	-12.86***
	(0.72)	(1.56)	(0.60)
PS^{LT}	-2.43*	-1.62	0.70
	(1.39)	(2.00)	(2.71)
$D^u * PS^{ST}$	-21.90***	-19.44***	-16.91***
	(1.96)	(2.61)	(2.55)
$D^u * PS^{LT}$	-15.78***	-19.09***	-25.34***
	(1.56)	(0.92)	(5.85)
$D^{Dec.08}$	-32.23***	-31.36***	-169.78***
	(4.89)	(6.19)	(54.91)
Memo:			
1. $\beta_1 + \beta_2$	-28.03***	-28.01***	-29.76***
	(2.27)	(3.32)	(2.00)
2. $\gamma_1 + \gamma_2$	-18.21***	-20.71***	-24.64***
	(2.79)	(2.49)	(3.17)
3. $\alpha_1 + \beta_1 + \gamma_1$	-13.54***	-16.87***	-18.96***
	(2.18)	(3.78)	(4.21)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-46.25***	-48.72***	-54.40***
	(3.65)	(3.30)	(4.71)
5. Line 4 / Line 3	3.42	2.89	2.87
R^2	0.49	0.38	0.17
No. obs.	720	683	699

Note: Robust standard errors in parentheses. *,**,*** denote significance at 10%, 5%, 1% levels, respectively. Surprise windows defined as 10 minutes before to 20 minutes after announcements. Exchange rate response windows are measured from 10 minutes before to 20 minutes, 1 hour, and 24 hours after announcement. Exchange rate changes are in basis point units and surprises are in standardized units, so the figures in the table can be interpreted as effect of a one standard deviation surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is March 22, 1994 to December 17, 2014.

Table 9: Robustness: Omitting Unscheduled Meetings

$$\Delta S_{i,t,w} = a_{1i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} + D_t^u(a_{2i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT}) + \epsilon_{i,t}$$

	+20m	+1h	+24h
TS	-9.58***	-13.68***	-10.40***
	(1.69)	(1.76)	(3.17)
PS^{ST}	-5.61***	-7.09***	-11.46***
	(0.81)	(1.15)	(0.45)
PS^{LT}	-1.20	0.84	4.10
	(1.16)	(1.74)	(2.81)
$D^u * PS^{ST}$	-24.28***	-22.20***	-32.37***
	(1.73)	(3.16)	(6.29)
$D^u * PS^{LT}$	-16.82***	-21.44***	-27.05***
	(1.85)	(1.29)	(5.65)
Memo:			
1. $\beta_1 + \beta_2$	-29.89***	-29.29***	-43.83***
	(1.95)	(3.52)	(6.10)
2. $\gamma_1 + \gamma_2$	-18.02***	-20.60***	-22.95***
	(2.82)	(2.55)	(2.93)
3. $\alpha_1 + \beta_1 + \gamma_1$	-16.39***	-19.94***	-17.76***
	(2.42)	(3.32)	(4.92)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-47.90***	-49.89***	-66.79***
	(3.28)	(3.16)	(7.85)
5. Line 4 / Line 3	2.92	2.50	3.76
R^2	0.51	0.40	0.15
No. obs.	700	663	679

Note: Robust standard errors in parentheses. *,**,*** denote significance at 10%, 5%, 1% levels, respectively. Surprise windows defined as 10 minutes before to 20 minutes after announcements. Exchange rate response windows are measured from 10 minutes before to 20 minutes, 1 hour, and 24 hours after announcement. Exchange rate changes are in basis point units and surprises are in standardized units, so the figures in the table can be interpreted as effect of a one standard deviation surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is March 22, 1994 to December 17, 2014.

Table 10: Robustness: Non-Nested Regressions

Panel A: Conventional Period

$\Delta S_{i,t,w} = a_{1i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} + \epsilon_{i,t}$

	+20m	+1h	+24h
TS	-5.58***	-6.91***	-7.01*
	(0.83)	(0.64)	(3.62)
PS^{ST}	-6.59***	-9.28***	-14.08***
	(0.73)	(1.63)	(0.60)
PS^{LT}	-1.85*	-1.22	0.54
	(1.06)	(1.49)	(2.06)
Memo: $\alpha_1 + \beta_1 + \gamma_1$	-14.02***	-17.41***	-20.56***
	(1.97)	(3.47)	(4.19)
R^2	0.16	0.18	0.06
No. obs.	496	459	491

Panel B: Unconventional Period

$\Delta S_{i,t,w} = a_{2i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT} + \epsilon_{i,t}$

	+20m	+1h	+24h
PS^{ST}	-26.84***	-28.22***	-40.76***
	(1.79)	(3.03)	(5.76)
PS^{LT}	-25.00***	-27.97***	-30.85***
	(4.05)	(3.68)	(4.06)
Memo: $\beta_2 + \gamma_2$	-51.84***	-56.19***	-71.60***
	(4.38)	(3.59)	(8.16)
R^2	0.67	0.47	0.25
No. obs.	224	224	208

Note: Robust standard errors in parentheses. *,** ,*** denote significance at 10%, 5%, 1% levels, respectively. Surprise windows defined as 10 minutes before to 20 minutes after announcements. Exchange rate response windows are measured from 10 minutes before to 20 minutes, 1 hour, and 24 hours after announcement. Exchange rate changes are in basis point units and surprises are in standardized units, so the figures in the table can be interpreted as effect of a one standard deviation surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. The conventional sample period is March 22, 1994 to October 29, 2008. The unconventional sample period is November 25, 2008 to December 17, 2014.