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

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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 to four times that following conventional policy changes prior to the 2007–08 financial crisis.

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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

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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 0 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 came 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 Galí 1994; Eichenbaum and Evans 1995; 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 with 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 and the Maturity Extension Program. 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 target federal funds rate 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 Gürkaynak, 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 Eurodollar futures rate, which we label "short-term path surprises." Third, we construct an additional measure of policy path surprises, which 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 (see Wright 2012).

Since the pre-crisis period was dominated by the use of changes in the level and path of the target federal funds 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 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 100 basis point (bps) surprise easing leads to a total decline of 2.4 percent 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

[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.

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 100 basis point surprise easing in unconventional policy leads to a total decline of 8.8 percent in the value of the dollar within sixty minutes, a magnitude roughly four 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, Krishnamurthy and Vissing-Jorgensen (2011), D'Amico et al. (2012), Glick and Leduc (2012), Li and Wei (2012), Hamilton and Wu (2015), and Neely (2015).

By emphasizing the effects on the U.S. exchange rate, our work is related to that of Wright (2012) and Neely (2015), 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 with 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's 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 twenty-eight observations extends to September 2011 to encompass the second round, but not the third round.[2]

[2]See also Rogers, Scotti, and Wright (2014), who examine the effects of unconventional policies by the Federal Reserve, the European Central Bank (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.

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 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 with those following policy surprises when the target federal funds rate 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 pursued 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 by controlling for several important announcements between the end of October and December 16, 2008.

Thus, our sample period for conventional monetary policy actions extends from March 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.

[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 and 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 these FOMC announcements focused on providing details about liquidity policies (for instance, about the Term Auction Facility or discount window lending) or communicated awareness of ongoing economic events and did not announce policy changes.

For the conventional policy period, given that monetary policy is partly 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 ten minutes before a policy announcement to twenty minutes after.[5] This strategy provides a good measure of monetary policy shocks if possible interest risk premiums 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, Sack, and Swanson (2005), we 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

[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.

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

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

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 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 thirty-minute window, from ten minutes before an announcement to twenty minutes after (see Wright 2012)[7,8]. We examine the effect of long-term path surprises during the conventional as well as the unconventional period since, despite the absence of LSAPs, 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 (i) the short-term path surprises with respect to the target surprises, and (ii) 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 and defined such that surprises with a positive sign indicate monetary easing, while surprises with a negative sign indicate monetary tightening.

[7]We use the nearest-date futures contracts on Treasury securities from Tick Data. The surprises were constructed from changes in the returns 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 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 fifteen minutes before a given Federal Reserve announcement until one hour and forty-five 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.

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 information about the federal funds target (see table A1 in the appendix).[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, particularly those suggesting modifications to the Federal Reserve intentions to buy long-term assets. Major announcements that refer to large-scale asset purchases as well as forward guidance news are listed in table 1.[10] 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 fifty-six observations.[11]

Our sample encompasses announcements used in other studies on the effects of large-scale asset purchases and forward guidance. 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 (2015). Similarly, the five announcements for the

[9]The unscheduled meetings included in our measure are April 18, 1994; January 3, 2001; April 18, 2001; January 22, 2008; and October 8, 2008. See footnote 3 for more details. We also analyze the impact of omitting these observations in section 4.4.

[10]We make use of the comprehensive lists of major announcements in Rogers, Scotti, and Wright (2014), whose sample ends in mid-2013, and Hattori, Schrimpf, and Sushko (2016), whose sample ends in April 2014, but make several adjustments. See the notes to table 1 for details.

[11]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 Federal Reserve was considering all of its options, though he was not explicit about additional policy actions. Rogers, Scotti, and Wright (2014) treat it as an LSAP-related event; we do not, and consequently do not list it in table 1. 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.

Table 1. Federal Reserve Major LSAP and Forward Guidance Announcements

Date	Time EST	FG	Event	Description
11/25/2008	8:15 a.m.	N	LSAP1	Intend purchases up to $100 billion in GSE agency debt and $500 billion in MBS
12/1/2008	1:40 p.m.	N	LSAP1	Bernanke speech (Austin, Texas): open to purchase of long-term Treasury securities
12/16/2008	2:15 p.m.	Y	LSAP1	Target federal funds rate lowered to 0–25 bps; low rate warranted for "some time"; may purchase long-term Treasury securities
1/28/2009	2:15 p.m.	N	LSAP1	Ready to expand purchases of agency debt and MBS, and purchase long-term Treasury securities
3/18/2009	2:15 p.m.	Y	LSAP1	Purchase additional $750 billion in agency MBS and $100 billion in agency debt, and up to $300 billion in long-term Treasury securities; low funds rate for "an extended period"
8/10/2010	2:15 p.m.	N	LSAP2	Reinvest MBS principal into Treasury securities as they mature
8/27/2010	10:00 a.m.	N	LSAP2	Bernanke speech (Jackson Hole): FOMC likely to buy more longer-term securities
9/21/2010	2:15 p.m.	N	LSAP2	Maintain reinvestment policy and prepare to provide additional accommodation if needed
10/15/2010	8:15 a.m.	N	LSAP2	Bernanke speech (Federal Reserve Bank of Boston): easing to be continued
11/3/2010	2:15 p.m.	N	LSAP2	Purchase $600 billion more in longer-term Treasury securities by end of 2011:Q2
8/9/2011	2:15 p.m.	Y		Low rates at least until mid-2013
9/21/2011	2:15 p.m.	N	MEP	Buy $400 billion of long-term and sell equal amount of short-term securities by June 2012
1/25/2012	2:15 p.m.	Y		Low rates at least until late 2014
6/20/2012	2:15 p.m.	N	MEP	MEP extended until end 2012

(continued)

Table 1. (Continued)

Date	Time EST	FG	Event	Description
8/31/2012	10:00 a.m.	N	LSAP3	Bernanke speech (Jackson Hole): announces intention for further action
9/13/2012	12:30 pm.	Y	LSAP3	Purchase additional agency MBS at pace of $40 billion per month; low federal funds rate likely "at least through mid-2015"
12/12/2012	12:30 p.m.	Y	LSAP3	Purchase longer-term Treasury securities at monthly rate of $45 billion; low rates if unemployment above 6.5 percent and inflation no more than 2.5 percent
5/22/2013	10:30 a.m.	N	Taper Tantrum	Bernanke testimony: FOMC likely to slow asset purchases later in 2013 if economy and job market continue to improve
9/18/2013	2:15 p.m.	N	Exit	Will relate pace of asset purchases to assessment of costs and benefits as well as economic outlook
12/18/2013	2:15 p.m.	Y	Exit	Taper monthly purchases of MBS to $30 billion and Treasury securities to $35 billion; will reduce pace further in "measured steps"; abandoned threshold of 6.5 percent unemployment to keep rates low
3/19/2014	2:15 p.m.	Y	Exit	Will keep funds rate low for a "considerable time" after asset purchase program ends
10/29/2014	2:15 p.m.	Y	Exit	Asset purchase program ended; funds rate may remain below normal long-run level for some time after reaching employment and inflation targets
12/17/2014	2:15 p.m.	Y	Exit	Will be patient in beginning to normalize policy

Notes: FG denotes forward-guidance-related events. The table relies on the list of major announcements in Rogers, Scotti, and Wright (2014, table 1), whose sample ends in mid-2013, augmented by Hattori, Schrimpf, and Sushko (2016, table 1), whose sample ends in April 2014. To that list, we make several adjustments. In particular, we (i) follow the former in designating MEP events as announcements involving new information about the composition and duration of the program (September 21, 2011 and June 20, 2012) and omit August 1, 2012, though designated by Hattori, Schrimpf, and Sushko as an MEP event, since it yielded no new information about asset purchases or forward guidance; (ii) treat September 18, 2013 as an LSAP-related announcement, since it did provide new information about conditions for exiting from the asset purchase program; (iii) omit June 29, 2013; January 29, 2014; and April 30, 2014, though designated by Hattori, Schrimpf, and Sushko as exit events, since they did not affect the expected rate of tapering during the LSAP exit phase; and (iv) add October 29, 2014 and December 17, 2014 as forward-guidance-related exit announcements that occurred after their sample period ends.

second round of asset purchases (LSAP2) from August 10 to November 3, 2010 are similar to those used by Krishnamurthy and Vissing-Jorgensen (2011), Glick and Leduc (2012), and Wright (2012). In addition, our analysis encompasses two major announcements associated with the Maturity Extension Program (MEP) involving the sale of short-term Treasury securities to purchase longer-term assets for the Federal Reserve's balance sheet, as well as 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. Finally, we follow Hattori, Schrimpf, and Sushko (2016) in our designation of events associated with adjustments in forward guidance (FG) about the path of the federal funds rate.

2.2 Intraday Exchange Rate Movements

We conduct our analysis using intraday data on currency futures prices from Tick Data 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, the Canadian dollar, the euro, and the yen.[12] In 2010, these four currencies accounted for over 70 percent of all spot dollar transactions[13] and over 60 percent of all swap and futures dollar transactions (Bank for International Settlements 2010, Table D.1), 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

[12]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.

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

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. (2014) found that the use of interday data masks the significant effects that the ECB's interventions had on sovereign yields that only could be detected using higher-frequency intraday data.

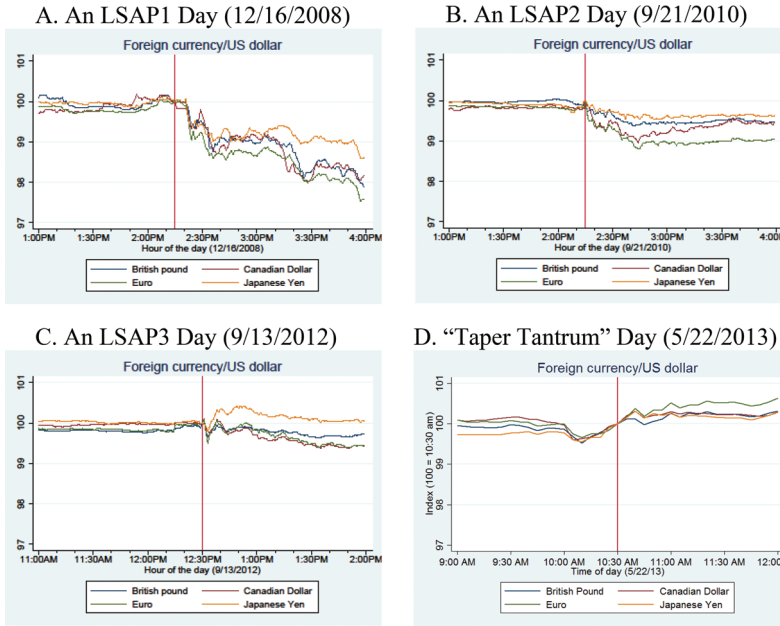
Consequently, we look at movements in the value of the U.S. dollar against foreign currencies in relatively narrow time intervals. Consistent with our identification of monetary policy surprises, we use response windows around monetary policy announcements of thirty minutes (ten minutes before, until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

3. Results

3.1 Changes in Value of the Dollar during LSAP Rounds, MEP, and Taper Tantrum

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 2:15 p.m. FOMC announcement about the details of LSAP1. The dollar depreciation was smaller following

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



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, the Canadian dollar, the euro, and the yen in response to the major announcements during the three LSAP rounds, the MEP, and the taper tantrum episode identified in table 1. The response windows start ten minutes before announcements and end twenty minutes after. Observe that the dollar depreciated against these currencies in response to announcements during all three LSAP rounds, and it appreciated during the taper tantrum episode. The appreciation of the dollar against the yen during LSAP3 is an exception, likely because of the yen's strong appreciation in the week before the September 13, 2012 FOMC meeting and market talk about possible

Table 2. Average Intraday Change in Exchange Rates

	LSAP1	LSAP2	MEP	LSAP3	Tantrum
British Pound/$	−66.48	−19.40	36.74	−13.10	27.17
Canadian Dollar/$	−61.72	−26.75	24.70	−16.70	44.32
Euro/$	−69.49	−24.57	35.43	−17.25	57.95
Japanese Yen/$	−41.91	−12.98	21.08	6.15	59.84
Intraday Trade-Weighted $	−61.91	−23.37	28.83	−13.14	50.13
No. Obs.	5	5	2	3	1
Memo: Interday Trade-Weighted $	−132.24	−19.51	145.87	−46.75	63.17

Notes: Mean values are in basis points. The intraday exchange rate response windows are measured from ten minutes before to twenty minutes after announcements. Negative values indicate depreciation of the dollar against foreign exchange. LSAP and MEP round observations are given in table 1; tantrum day is May 22, 2013.

Bank of Japan intervention. In addition, the dollar tended to appreciate following MEP announcements, suggesting that the impact of policy tightening at the short end of the yield curve outweighed the effect of policy loosening at longer maturities.

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 LSAP3, respectively.[14] The relatively small effect under LSAP3 does not necessarily imply that the Federal Reserve'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 50 bps. Similarly, the trade-weighted dollar

[14]We construct trade weights from the International Monetary Fund's Direction of Trade Statistics data in 2011 on U.S. bilateral exports and imports with the United Kingdom, Canada, the euro zone, and Japan, with calculated weights of 0.07, 0.41, 0.39, and 0.13, respectively. Results from taking simple averages are comparable.

appreciated on average by 29 bps following MEP announcements, consistent with an average surprise tightening of the short-term path measure, as we document in the next section.

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 twenty-four-hour period from the end of floor trading on the day prior to each announcement (usually 2:30 p.m. EST) and the end of floor trading on the announcement day.[15] 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 Summary Statistics of Monetary Policy Surprises

We begin our formal empirical analysis by reporting summary statistics for our monetary policy surprise measures, which are reported in table 3.[16] Observe that during the conventional period target surprises are on average positive, implying unanticipated policy easing, while short-term path surprises are slightly negative. The latter are similarly small during the unconventional period, though slightly positive, on average. Note that the standard deviations of the short-term path surprises during the two periods are of comparable magnitude. Similarly, long-term path surprises are roughly zero, on average, in both periods, although their standard deviation during the unconventional period is larger than that during the conventional one.

A further breakdown of the surprises during the three LSAP rounds and the MEP indicates that this greater variation during the unconventional period is primarily attributable to LSAP1 announcements. Table 3 also shows that the short-term and long-term path surprises were on average positive during the first round of asset purchases, indicating surprise easing, while the taper tantrum episode was associated with surprise tightening. We also note that policy announcements during the MEP resulted in surprise easing, on

[15]Note that all of the LSAP events reported in table 3 occurred before the end of trading on the day of announcement.

[16]Recall that short-term surprises are orthogonalized against target surprises, and long-term surprises are orthogonalized against short-term and target surprises, implying that their means over the full period are zero by construction.

Table 3. Monetary Policy Surprises, Summary Statistics

	Full Sample	**Conventional**	**Unconventional**	**LSAP1**	**LSAP2**	**MEP**	**LSAP3**	**Tantrum**
Target Surprise	N/A	1.55	N/A	N/A	N/A	N/A	N/A	N/A
		(9.00)						
Short-Term Path	0	−0.16	0.35	7.18	0.68	−4.80	−0.69	−2.54
	(6.34)	(6.95)	(4.76)	(6.09)	(1.94)	(3.20)	(1.61)	
Long-Term Path	0	0.002	−0.004	7.43	−1.23	6.24	−3.45	−10.29
	(5.41)	(4.15)	(7.54)	(20.18)	(4.51)	(1.68)	(6.63)	
No. Obs.	180	124	56	5	5	2	3	1

Notes: Mean values are in basis points, with standard deviation in parentheses. Monetary policy surprises are measured from ten minutes before to twenty minutes after announcements. Positive values indicate monetary easing. LSAP and MEP round observations are given in table 1; tantrum day is May 22, 2013.

average, in the long term, consistent with the Federal Reserve purchases of long-term Treasury securities, and surprise tightening in the short term, as the Fed sold short-term Treasury securities. Overall, we find these summary statistics to be intuitive and consistent with a standard financial reading of the direction of monetary policy during these episodes.

In principle, the yields underlying our policy surprises reflect market reactions to information regarding both LSAPs and the future path of monetary policy, i.e., forward guidance. In their analysis of Fed communication during the conventional period, Gürkaynak, Sack, and Swanson (2005) argue that short-term path surprises primarily capture Fed communication about forward guidance. This evidence combined with the fact that the large-scale asset purchases conducted by the Federal Reserve during the unconventional period mostly targeted long-term assets—particularly ten-year Treasury bonds—suggests that our short-term path surprises mostly represent forward guidance announcements, while the long-term path surprises mostly represent LSAP announcements.

To assess this conjecture about what our surprise measures during the unconventional period may be capturing, we regress short-term and long-term path surprises (PS_t^{ST}, PS_t^{LT}, respectively) on separate 0–1 dummies for event days involving news about forward guidance and major asset purchases, using the classification in table 1.[17] Because we are interested in seeing what type of announcements affect the surprises and not whether market participants were surprised on the upside or downside, we use the absolute value of surprises to make the effects independent of the sign.

As shown in table 4, asset purchase announcements have a significant effect only on long-term path surprises. This is intuitive since LSAPs were conducted mostly to lower long-term bond

[17]As listed in table 1, we classify ten announcements as containing forward guidance information. We designate asset purchase events as the sixteen announcements related to the three rounds of LSAPs, MEP, the taper tantrum day (May 22, 2013), and the first LSAP exit day (December 18, 2013), excluding those dates also conveying forward guidance information, with the three exceptions of December 16, 2008; March 18, 2009; and December 18, 2013, given their importance during the early phase and end of the unconventional period. The gist of the results goes through if we eliminate these three overlapping announcements from the asset purchase dummy, though the estimated effects are somewhat less significant.

Table 4. Effects of Forward Guidance and Major Asset Purchase Announcements on Monetary Surprises during Unconventional Period

	Short-Term Surprises (PS^{ST})	**Long-Term Surprises (PS^{LT})**
Forward Guidance	3.76***	4.69**
	(1.19)	(1.91)
Major Asset Purchases	0.60	4.74***
	(1.01)	(1.62)
R^2	0.16	0.22

Notes: Dependent variable is in absolute value terms. Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Designation of forward guidance events is given in table 1. Major asset purchase events include LSAP1, LSAP2, LSAP3, MEP days, tantrum day (May 22, 2013), and the first LSAP3 taper day (December 18, 2013) in table 1, excluding those days with some forward guidance, with exceptions of December 16, 2008; March 18, 2009; and December 18, 2013. Constant is included but not reported. Sample period is November 25, 2008 to December 17, 2014.

yields. In addition, the results indicate that the short-term path surprises respond to announcements about forward guidance during the unconventional period, in line with the results of Gürkaynak, Sack, and Swanson (2005) for the conventional period. Table 4 also reports that news about forward guidance affects long-term path surprises as well. Thus, our long-term path surprise measure could reflect a combination of both asset purchase and forward guidance announcements during the unconventional policy period.

Fully separating out the "pure" effects of forward guidance and asset purchases on our long-term surprise measure is challenging in light of the relatively short sample of observations for the unconventional period. However, Swanson (2016), who adapts the methodology of Gürkaynak, Sack, and Swanson (2005) to decompose monetary policy announcements into forward guidance and LSAP components, obtains results similar to ours. Specifically, he finds that while forward guidance and LSAPs both have significant effects on medium-term (two-, five-, and ten-year maturity) Treasury rates, only forward guidance has a significant effect on short-term (i.e., less than one year maturity) Treasury securities and Eurodollar rates.

In the following analysis we offer some additional evidence that long-term path surprises mostly reflect LSAPs. In particular, we show that while long-term path surprises have a substantial and significant impact on the dollar during the unconventional period, their effect on the dollar was negligible during the conventional period prior to the financial crisis, when they were not used by the Federal Reserve as a policy instrument.

3.3 Pooled Exchange Rate Effects of Monetary Policy Surprises

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

$$\begin{aligned}\Delta S_{i,t,w} = a_{1,i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} \\ + D_t^u \left(a_{2,i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT}\right) + \varepsilon_{i,t}, \qquad (1)\end{aligned}$$

where $\Delta S_{i,t,w}$ is the (log) change in the exchange between currency i and the U.S. dollar at time t during a response time window w. TS_t is the target federal funds rate surprise, PS_t^{ST} is the short-term path surprise, $PS_t^{LT}$is the long-term path surprise, a_i are currency fixed effects, 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 period compared with 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 $(\gamma_1 + \gamma_2)$, respectively. Note that we assume that there are no target surprises during the unconventional period after the target for the federal funds rate was set at its effective lower bound.[18]

[18]We explicitly abstract from target surprises altogether during the unconventional policy period by including target surprises through December 16, 2008—when the target rate reached its effective lower bound—in the conventional period

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 separately. To convey the information compactly, we trade-weight the dollar exchange rates against the four currencies included in our analysis—the British pound, the Canadian dollar, the euro, and the 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) is 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 5 reports coefficient estimates of equation (1), using response windows of lengths ranging from ten minutes before the announcement to $w =$ twenty minutes, one hour, and twenty-four hours after.

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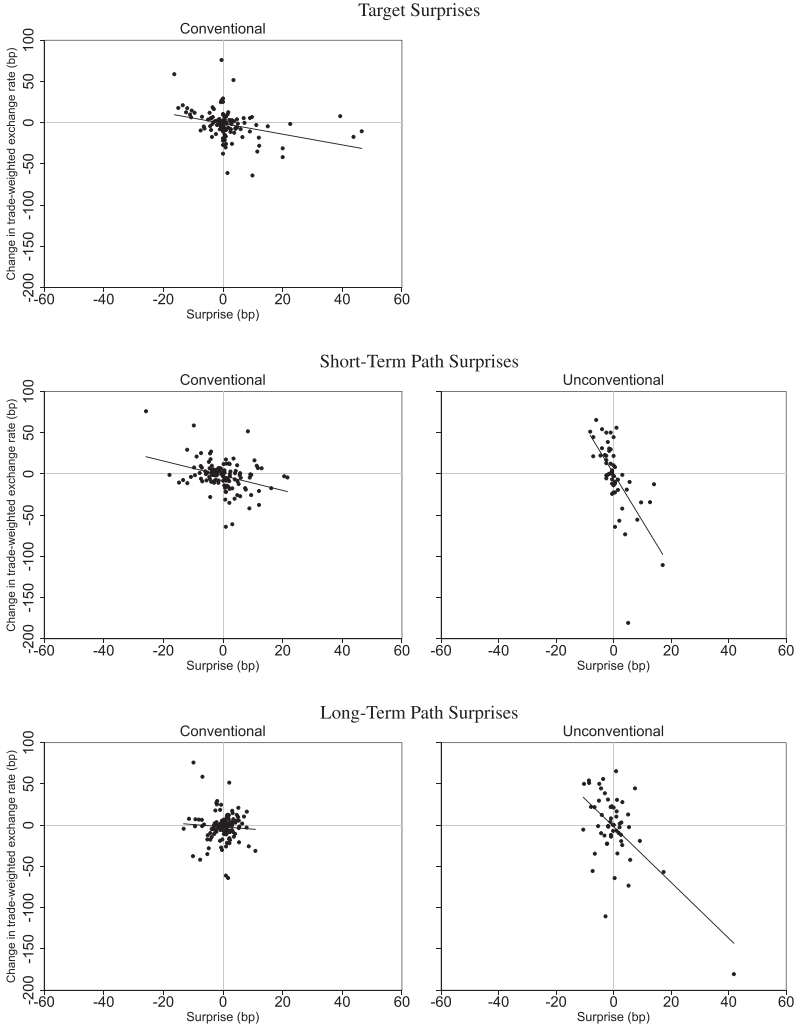
of our sample. We effectively exclude them from the rest of the sample, since federal funds rate futures were thinly traded during most of the unconventional period in our sample. Moreover, their movements more than likely did not represent expectations of future policy changes, since given the amount of excess reserves held by banks the federal funds rate ceased to be an effective monetary policy tool. In section 4.3 we conduct a sensitivity analysis that controls for announcements between the end of October and December 16, 2008.

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



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

Table 5. Monetary Policy Surprises and the Exchange Rate

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

	+20m	**+1h**	**+24h**
TS	-0.63^{***}	-0.79^{***}	-0.82^{**}
	(0.09)	(0.07)	(0.39)
PS^{ST}	-0.97^{***}	-1.35^{***}	-2.02^{***}
	(0.11)	(0.24)	(0.09)
PS^{LT}	-0.45^{*}	-0.30	0.13
	(0.26)	(0.37)	(0.50)
$D^u * PS^{ST}$	-4.06^{***}	-3.72^{***}	-5.23^{***}
	(0.33)	(0.48)	(1.09)
$D^u * PS^{LT}$	-2.82^{***}	-3.43^{***}	-4.31^{***}
	(0.30)	(0.18)	(1.03)
Memo:			
1. $\beta_1 + \beta_2$	-5.03^{***}	-5.07^{***}	-7.25^{***}
	(0.36)	(0.59)	(1.02)
2. $\gamma_1 + \gamma_2$	-3.27^{***}	-3.73^{***}	-4.18^{***}
	(0.52)	(0.47)	(0.55)
3. $\alpha_1 + \beta_1 + \gamma_1$	-2.05^{***}	-2.43^{***}	-2.71^{***}
	(0.38)	(0.64)	(0.67)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-8.30^{***}	-8.79^{***}	-11.43^{***}
	(0.60)	(0.56)	(1.32)
5. Line 4 / Line 3	4.05	3.61	4.22
R^2	0.48	0.37	0.15
No. Obs.	720	683	699

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to twenty minutes after announcements. Exchange rate response windows w for currency i are measured from ten minutes before to w = twenty minutes, one hour, and twenty-four hours after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is February 4, 1994 to December 17, 2014.

Constants are included in the regressions but are not reported in the table for brevity.[19]

We first concentrate on the effect of policy surprises on the dollar during the conventional period. Table 5 indicates that the dollar is affected via two channels. First, a surprise easing of 100 bps in the target federal funds rate leads to a 0.79 percent (i.e., 79 bps) decline in the value of the dollar one hour after a policy announcement and a 0.82 percent decline a day after. However, the dollar is also affected by surprise information about the future path of monetary policy. Specifically, we find that a 100 bps easing in the short-term path surprise during the conventional period leads the dollar to depreciate 1.35 percent one hour following announcements and 2.02 percent one day after. These effects are statistically significant at the 1 percent level or lower. In contrast, long-term path surprises did not have much impact on the exchange rate during the conventional period, as the estimated magnitude of γ_1 is small and barely significant at the 10 percent level only in the first twenty minutes.

These results are comparable to other findings in the literature for the conventional period. For example, Hausman and Wongswan (2011) also found that during the pre-crisis period the dollar typically responded more to surprise announcements about the future path of policy than to target surprises.[20] We augment their 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.

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 path surprises both being significantly larger than during the conventional period. More specifically, as table 5 indicates upon summing the coefficient estimates β_1 and β_2, a 100 bps short-term path surprise leads to a 5.07 percent

[19]The number of observations in the panel is less than the maximum of (180 events × 4 individual bilateral exchange rates =) 720 for some response windows when currency futures data are unavailable because the market was closed.

[20]Hausman and Wongswan (2011) examine the effects of U.S. target and short-term path monetary policy surprises on daily exchange rate changes for a panel of advanced and emerging economies during the conventional rate period from 1994 to 2005. They report that a 100 bps path surprise leads on average to a 1.6 percent depreciation of the dollar, comparable to our finding.

(7.25 percent) depreciation one hour (twenty-four 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 similar in magnitude to the effects of short-term path surprises during the unconventional policy period. Summing the coefficient estimates γ_1 and γ_2 implies that, in response to a 100 bps long-term path surprise, the dollar depreciates by 3.73 percent (4.18 percent) one hour (twenty-four hours) after announcement.

The finding that the dollar responds significantly to long-term path surprises as well as to short-term path surprises during the unconventional period is consistent with the Federal Reserve's objective of lowering long-term interest rates by purchasing long-term assets in large amounts. 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.

Overall, the interpretation of our results that we favor is that forward guidance operates largely through the short-term surprises, while LSAPs operate mostly through long-term path surprises. As mentioned above, table 4 presents evidence that short-term path surprises during the unconventional period react only to forward guidance announcements. In addition, the unresponsiveness of the exchange rate to long-term path surprises during the conventional period when LSAPs were not used provides additional evidence suggesting that LSAPs operate mostly through long-term path surprises.

Our finding that long-term path surprises significantly affect the value of the dollar during the unconventional period is broadly in line with the results reported in Wright (2012) and Rogers, Scotti, and Wright (2014).[21] 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

[21] Bowman, Londono, and Sapriza (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 two-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.

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 2.43 percent dollar depreciation, one hour after announcement (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 β_1, β_2, γ_1, and γ_2). In this case, we find that the dollar depreciated by 8.79 percent one hour following a surprise easing announcement, an effect which is more than three and half 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.[22] Thus, our results suggest that monetary policy remained effective in affecting the exchange rate even after reaching the zero lower bound, 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.[23]

[22]In Glick and Leduc (2013) we reported that the effects 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. Thus, to compare the effects on the dollar across periods in that work, 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 target federal funds rate 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 non-nested samples.

[23]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.

The findings from our panel regressions also hold for the individual currencies underlying our panel results. Table 6 presents individual results for the U.S. dollar exchange rate against the British pound, the Canadian dollar, the euro, and the yen. For brevity, we report only the effects with the one-hour 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 value against these individual currencies, while the effects from the long-term path surprises are insignificant (except for the yen). During the unconventional period, for all four currencies considered, the dollar depreciates by a magnitude several times larger than during the conventional period. In addition, during the unconventional period, the effect of short-term path surprises on the dollar exchange rate exceeds that of long-term surprises for all currencies, except the yen, though these differences are not statistically significant. In comparison, Swanson (2016) similarly finds that his measures of forward guidance and LSAP surprises have a comparable effect on the euro during the unconventional period, though forward guidance has a larger impact than do LSAP announcements on the yen.

3.4 Disaggregating LSAP Surprises

Given that financial markets were substantially impaired during the end of 2008 and early part of 2009, the unconventional monetary policy decisions made 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. In this section, we first examine the extent to which our results are driven by LSAP1 announcements, by rerunning our baseline regression with the use of dummy variables to distinguish between the effects following LSAP1 and all other announcements:

$$\Delta S_{i,t,w} = a_{1,i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} + \sum_k D_t^k \left(a_{2,i}^k + \beta_2^k PS_t^{ST} + \gamma_2^k PS_t^{LT}\right) + \varepsilon_{i,t}, \quad (2)$$

where k = LSAP1, Other.

Note that, as before, the coefficients α_1, β_1, and γ_1 reflect the effects of target, short-term path, and long-term path surprises,

Table 6. Monetary Policy Surprises and Individual Currency Values

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

	British Pound	Canadian Dollar	DM/Euro	Japanese Yen
TS	−0.79**	−0.62***	−1.00*	−0.79**
	(0.39)	(0.23)	(0.59)	(0.34)
PS^{ST}	−1.24***	−1.01***	−2.19***	−1.12***
	(0.39)	(0.34)	(0.63)	(0.36)
PS^{LT}	0.07	0.47	−1.21	−0.76
	(0.65)	(0.58)	(1.06)	(0.64)
$D^u * PS^{ST}$	−3.98**	−4.45**	−3.98*	−2.31**
	(2.03)	(2.11)	(2.03)	(1.05)
$D^u * PS^{LT}$	−3.54***	−3.01**	−3.02*	−3.90***
	(1.27)	(1.29)	(1.59)	(0.80)
Memo:				
1. $\beta_1 + \beta_2$	−5.22***	−5.46***	−6.17***	−3.43***
	(1.99)	(2.08)	(1.94)	(0.98)
2. $\gamma_1 + \gamma_2$	−3.47***	−2.54**	−4.23***	−4.67***
	(1.09)	(1.15)	(1.19)	(0.47)
3. $\alpha_1 + \beta_1 + \gamma_1$	−1.96**	−1.16	−4.41***	−2.67***
	(0.88)	(0.72)	(1.24)	(0.92)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	−9.48***	−8.62***	−11.40***	−8.88***
	(1.80)	(1.89)	(1.97)	(0.98)
5. Line 4 / Line 3	4.84	7.43	2.59	3.33
R^2	0.36	0.32	0.41	0.45
No. Obs.	180	180	143	180

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to twenty minutes after announcements. Exchange rate responses for currency i are measured from ten minutes before to w = sixty minutes after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is February 4, 1994 to December 17, 2014.

respectively, during the conventional period, while β_2^k and γ_2^k reflect the additional effects of short-term and long-term path surprises during LSAP1 and the other phases of the unconventional period. Table 7 shows that the effects on the dollar are larger and more persistent following policy surprises during the first round of asset purchases. In particular, unconventional policies during LSAP1 had about six times the impact on the dollar compared with the conventional period. Nevertheless, table 7 also indicates that, although the effects are attenuated and less persistent, the dollar still responded significantly to policy surprises outside of the LSAP1 period. In this case, the impact of unconventional policy on the dollar one hour following announcements is roughly two and a half times that during the conventional period. 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; Krishnamurthy and Vissing-Jorgensen 2011, among others), our results indicate that significant effects occurred during subsequent programs as well, when financial markets were operating more normally.

In table 8, we further distinguish between all three different rounds of asset purchases and the MEP. In terms of the regression above, we now let k = LSAP1, LSAP2, LSAP3, MEP, Other. The main message of this exercise is that the effects vary much more across the later rounds of asset purchases and the MEP program, likely reflecting the relatively low number of observations under each program as well as the more normal functioning of financial markets during LSAP2, LSAP3, and the MEP. For instance, while we continue to find large significant effects for the MEP program one hour following announcement, these effects do not persist to one day after. Similarly, the effects of long-term path surprises following LSAP2 announcements are significant only twenty minutes following announcements, and overall do not appear to affect the dollar during LSAP3.

3.5 Distinguishing between Positive and Negative Surprises

The introduction of unconventional policies during the financial crisis and following economic recovery led to significant policy easing. Our results show that these policies translated into large dollar

Table 7. Disaggregating LSAP1

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

	+20m	+1h	+24h
TS	-0.63^{***}	-0.79^{***}	-0.82^{**}
	(0.09)	(0.07)	(0.39)
PS^{ST}	-0.97^{***}	-1.35^{***}	-2.02^{***}
	(0.11)	(0.25)	(0.09)
PS^{LT}	-0.45^{*}	-0.30	0.13
	(0.26)	(0.37)	(0.50)
$D^{Other} * PS^{ST}$	-3.38^{***}	-1.82^{***}	-1.41^{*}
	(0.27)	(0.16)	(0.75)
$D^{Other} * PS^{LT}$	-2.01^{***}	-3.00^{***}	0.55
	(0.20)	(0.25)	(1.21)
$D^{LSAP1} * PS^{ST}$	-9.16^{***}	-10.58^{***}	-19.09^{***}
	(1.02)	(1.92)	(6.27)
$D^{LSAP1} * PS^{LT}$	-3.84^{***}	-3.92^{***}	-7.73^{***}
	(0.54)	(0.24)	(1.15)
Memo:			
1. $\alpha_1 + \beta_1 + \gamma_1$	-2.05^{***}	-2.43^{***}	-2.71^{***}
	(0.38)	(0.64)	(0.67)
2. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-6.80^{***}	-6.47^{***}	-2.75^{**}
	(0.75)	(0.65)	(1.27)
3. $\beta_1 + \gamma_1 + \beta_3 + \gamma_3$	-14.42^{***}	-16.14^{***}	-28.71^{***}
	(1.14)	(1.78)	(6.86)
4. Line 2 / Line 1	3.32	2.66	1.01
5. Line 3 / Line 1	7.04	6.63	10.59
R^2	0.51	0.41	0.23
No. Obs.	720	683	699

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to twenty minutes after announcements. Exchange rate response windows w for currency i are measured from ten minutes before to w = twenty minutes, one hour, and twenty-four hours after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point 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 8. Disaggregating LSAP and MEP Surprises

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

$$k = Other,\ LSAP1,\ LSAP2,\ LSAP3,\ MEP$$

	+20m	**+1h**	**+24h**
TS	-0.63^{***}	-0.79^{***}	-0.82^{**}
	(0.09)	(0.07)	(0.40)
PS^{ST}	-0.97^{***}	-1.35^{***}	-2.02^{***}
	(0.12)	(0.25)	(0.09)
PS^{LT}	-0.45^{*}	-0.30	0.13
	(0.26)	(0.37)	(0.50)
$D^{Other} * PS^{ST}$	-2.79^{***}	-1.14^{***}	0.06
	(0.27)	(0.18)	(0.99)
$D^{Other} * PS^{LT}$	-2.49^{***}	-4.57^{***}	-3.11^{**}
	(0.15)	(0.08)	(1.37)
$D^{LSAP1} * PS^{ST}$	-9.16^{***}	-10.58^{***}	-19.09^{***}
	(1.02)	(1.93)	(6.31)
$D^{LSAP1} * PS^{LT}$	-3.84^{***}	-3.92^{***}	-7.73^{***}
	(0.54)	(0.24)	(1.15)
$D^{LSAP2} * PS^{ST}$	-0.24	-11.08^{***}	50.70^{*}
	(3.28)	(2.41)	(30.13)
$D^{LSAP2} * PS^{LT}$	-7.95^{***}	0.72	-3.13
	(1.40)	(0.65)	(7.66)
$D^{LSAP3} * PS^{ST}$	-16.13^{**}	5.35	
	(7.78)	(12.20)	
$D^{LSAP3} * PS^{LT}$	3.29	1.15	9.46^{*}
	(2.32)	(3.88)	(5.64)
$D^{MEP} * PS^{ST}$	-7.06^{***}	-16.08^{***}	-19.25
	(1.72)	(3.04)	(20.10)
$D^{MEP} * PS^{LT}$	-0.86	-8.44^{***}	5.87
	(1.05)	(2.35)	(10.05)
R^2	0.57	0.46	0.29
No. Obs.	720	683	699

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to twenty minutes after announcements. Exchange rate response windows w for currency i are measured from ten minutes before to w = twenty minutes, one hour, and twenty-four hours after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is February 4, 1994 to December 17, 2014.

depreciations. An interesting question is whether the effects will be of similar magnitude as the Federal Reserve shrinks the size of its balance sheet in the years ahead, leading to possible surprise policy tightening. We investigate this issue by differentiating between positive and negative surprises using dummy variables.

Table 9 reports the results. We find evidence of asymmetric effects, particularly for the conventional period, with surprise target and short-term path tightening having substantially larger effects than surprise policy easing on the dollar, a result in line with the findings of Wang, Yang, and Simpson (2008). As before, note that long-term path surprises do not have a significant effect on the exchange rate during the pre-crisis period.

The results are more mixed for the unconventional period. Table 9 suggests the presence of asymmetric effects following long-term path surprises, with surprise easing having substantially larger impact on the dollar than tightening.[24] In contrast, short-term path surprise easing and tightening have roughly the same impact on the dollar twenty minutes and one hour following announcement.

3.6 Discussion

Our results suggest that monetary policy remains quite effective at the zero lower bound, at least through its effect on the foreign value of domestic currency. While determining the precise theoretical channels underlying this finding is outside the scope of this paper, we note that our finding may be consistent with standard theory linking the real exchange rate between two countries to the differential in the paths of expected future (real) short-term interest rates or, alternatively, in the long-term (real) interest rate differential. Even with short-term interest rates at their effective lower bound, this relationship would predict that unconventional policies could still affect the real exchange rate by affecting expected future policy rates

[24]Rogers, Scotti, and Wright (2014) also find that the dollar responded more to Federal Reserve's surprise policy tightening than to policy easing. They find more mixed results following announcements by the Bank of England, the ECB, and the Bank of Japan. In addition, they find evidence of asymmetric effects on stock prices following Federal Reserve announcements. However, note that in contrast to our exercise, they do not differentiate between short-term and long-term path surprises when examining possible asymmetric effects.

Table 9. Distinguishing Positive vs. Negative Surprises

$$\Delta S_{i,t,w} = \sum_{k=+,-} (a^k_{1,i} + a^k_1 TS^k_t + \beta^k_1 PS^{ST,k}_t + \gamma^k_1 PS^{LT,k}_t) + D^u_t \sum_{k=+,-} (a^k_{2,i} + \beta^k_2 PS^{ST,k}_t + \gamma^k_2 PS^{LT,k}_t) + \varepsilon_{i,t}$$

	+20m	**+1h**	**+24h**
TS^+	-0.44^{***}	-0.41^{***}	-1.00^{*}
	(0.10)	(0.10)	(0.54)
TS^-	-1.71^{***}	-2.55^{***}	-1.72^{***}
	(0.38)	(0.51)	(0.60)
PS^{ST+}	-0.06	-0.37	0.47
	(0.20)	(0.28)	(0.89)
PS^{ST-}	-1.86^{***}	-2.19^{***}	-4.85^{***}
	(0.20)	(0.34)	(0.83)
PS^{LT+}	0.05	0.10	2.26
	(0.25)	(0.38)	(1.59)
PS^{LT-}	-0.18	0.20	-0.00
	(0.36)	(0.44)	(1.27)
$D^U * PS^{ST+}$	-4.37^{***}	-3.47^{***}	-4.55^{**}
	(0.44)	(0.64)	(2.21)
$D^U * PS^{ST-}$	-4.45^{***}	-5.48^{***}	-9.19^{***}
	(0.34)	(0.55)	(2.14)
$D^U * PS^{LT+}$	-3.83^{***}	-5.00^{***}	-9.41^{***}
	(0.28)	(0.36)	(1.71)
$D^U * PS^{LT-}$	-1.33^{***}	0.06	6.10^{***}
	(0.42)	(0.97)	(1.44)
R^2	0.52	0.42	0.22
No. Obs.	720	683	699

Notes: $k = +(-)$ indicates positive (negative) surprises; i.e., monetary policy easing (tightening). Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to twenty minutes after announcements. Exchange rate response windows w for currency i are measured from ten minutes before to w = twenty minutes, one hour, and twenty-four hours after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is February 4, 1994 to December 17, 2014.

(see, for instance, Swanson and Williams 2014). In turn, the nominal exchange rate would inherit the properties of the real exchange rate in the presence of nominal rigidities in the short run. Thus, to the extent that unconventional policies reduced domestic long-term interest rates relatively more than conventional policies, theory would predict larger exchange rate depreciation. Similarly, this relationship also underlies the predicted effects of asset purchases on the exchange rate through the portfolio balance channel, where yields of assets bought by the central bank, and those with similar characteristics, are reduced through declines in term premiums (Neely 2015).

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 and the role of specific announcements, the exclusion of unscheduled meeting announcements, and non-nested 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 ten minutes before announcements until sixty (rather than twenty) minutes after. The results are given in table 10. Given this wider window for surprises, we report the exchange rate effects only for the sixty-minute and the twenty-four-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 with those reported in table 5 with the narrow window. This mitigates the difference between the exchange rate effect of monetary policy across periods. Overall, monetary easing

Table 10. Robustness: Wider Surprise Windows

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

	+1h	**+24h**
TS	-0.84^{***}	-1.19^{***}
	(0.13)	(0.40)
PS^{ST}	-1.76^{***}	-2.52^{***}
	(0.34)	(0.42)
PS^{LT}	-0.82^{*}	-0.39
	(0.50)	(0.36)
$D^u * PS^{ST}$	-3.47^{***}	-6.19^{***}
	(0.56)	(1.16)
$D^u * PS^{LT}$	-1.73^{***}	-2.10^{***}
	(0.18)	(0.61)
Memo:		
1. $\beta_1 + \beta_2$	-5.23^{***}	-8.71^{***}
	(0.50)	(1.13)
2. $\gamma_1 + \gamma_2$	-2.56^{***}	-2.49^{***}
	(0.34)	(0.39)
3. $\alpha_1 + \beta_1 + \gamma_1$	-3.43^{***}	-4.10^{***}
	(0.87)	(0.15)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-7.79^{***}	-11.20^{***}
	(0.45)	(1.38)
5. Line 4 / Line 3	2.27	2.73
R^2	0.49	0.27
No. Obs.	488	468

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to sixty minutes after announcements. Exchange rate response windows w for currency i are measured from ten minutes before to w = one hour and twenty-four hours after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is February 4, 1994 to December 17, 2014.

during the unconventional period leads to a depreciation of the dollar after sixty 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 four times difference with the narrow window results reported in table 5.

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., Gürkaynak, 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 partly via long-term asset purchases. 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 still very substantial, roughly three times larger during the unconventional than the conventional period, as shown in table 11. A conventional-period monetary policy announcement that included a 100 bps decline in both the target and short-term path surprises leads to a 2.1 percent decline in the value of the dollar one hour following announcement, whereas during the unconventional period a 100 bps fall in the short-term path surprise generates a dollar depreciation of 5.8 percent. Thus, our main finding is robust to the more typical measurement of policy surprises.

4.3 Controlling for Specific Announcements during Transition to Unconventional Period

As discussed earlier, the transition between the conventional and unconventional periods is difficult to pin down precisely. In our

Table 11. Robustness: Excluding Long-Term Path Surprises

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

	+20m	**+1h**	**+24h**
TS	-0.63^{***}	-0.79^{***}	-0.82^{**}
	(0.09)	(0.07)	(0.39)
PS^{ST}	-0.95^{***}	-1.33^{***}	-2.03^{***}
	(0.10)	(0.23)	(0.08)
$D^u * PS^{ST}$	-4.71^{***}	-4.45^{***}	-6.01^{***}
	(0.30)	(0.41)	(1.11)
Memo:			
1. $\alpha_1 + \beta_1$	-1.58^{***}	-2.12^{***}	-2.85^{***}
	(0.15)	(0.30)	(0.37)
2. $\beta_1 + \beta_2$	-5.65^{***}	-5.78^{***}	-8.04^{***}
	(0.36)	(0.55)	(1.06)
3. Line 2 / Line 1	3.57	2.72	2.82
R^2	0.29	0.21	0.10
No. Obs.	720	683	699

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to twenty minutes after announcements. Exchange rate response windows w for currency i are measured from ten minutes before to w = twenty minutes, one hour, and twenty-four hours after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is February 4, 1994 to December 17, 2014.

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 was later announced on December 16 of that year. As such, two announcements in our sample contained information regarding asset purchases and forward guidance, as well as information on the target surprise since the federal funds rate wasn't yet at its effective lower bound: November 25, 2008 and December 16, 2008. Thus, it is likely that the announcements' effects on the dollar on these two days

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 dummy variables for the November 25, 2008 and December 16, 2008 announcements. As can be noted from panel A of figure 1, the movement in the dollar was large following the December 16 FOMC meeting, implying that its inclusion in the conventional period of our baseline specification may affect the comparison of policy effectiveness across regimes.

Table 12 examines the robustness of our results when we control for these two specific announcements. The table indicates that our results are largely unchanged. While we find that the November 25, 2008 and December 16, 2008 announcements indeed each had very large impacts on the exchange rate, the essence of our results go through under this alternative specification. In particular, we still find that the dollar depreciated by roughly two to three times more following surprise easing during the unconventional period as compared with 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.[25] 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 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

[25]These results are available upon request.

Table 12. Robustness: Separating Out Selected Announcements

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

	+20m	**+1h**	**+24h**
TS	-0.63^{***}	-0.79^{***}	-0.82^{**}
	(0.09)	(0.07)	(0.39)
PS^{ST}	-0.97^{***}	-1.35^{***}	-2.02^{***}
	(0.11)	(0.25)	(0.09)
PS^{LT}	-0.45^{*}	-0.30	0.13
	(0.26)	(0.37)	(0.50)
$D^u * PS^{ST}$	-3.23^{***}	-1.55^{***}	-1.50^{**}
	(0.24)	(0.19)	(0.63)
$D^u * PS^{LT}$	-2.99^{***}	-4.05^{***}	-5.09^{***}
	(0.19)	(0.12)	(1.10)
$D^{11/25/08}$	-26.86	-165.08^{***}	-128.54^{***}
	(33.85)	(63.39)	(29.77)
$D^{12/16/08}$	-46.95^{***}	-75.43^{***}	-207.33^{***}
	(10.51)	(17.11)	(56.81)
Memo:			
1. $\beta_1 + \beta_2$	-4.20^{***}	-2.90^{***}	-3.52^{***}
	(0.36)	(0.31)	(0.54)
2. $\gamma_1 + \gamma_2$	-3.44^{***}	-4.35^{***}	-4.96^{***}
	(0.43)	(0.32)	(0.61)
3. $\alpha_1 + \beta_1 + \gamma_1$	-2.05^{***}	-2.43^{***}	-2.71^{***}
	(0.38)	(0.64)	(0.67)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-7.64^{***}	-7.24^{***}	-8.48^{***}
	(0.75)	(0.63)	(0.87)
5. Line 4 / Line 3	3.73	2.97	3.13
R^2	0.49	0.46	0.18
No. Obs.	720	683	699

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to twenty minutes after announcements. Exchange rate response windows w for currency i are measured from ten minutes before to w = twenty minutes, one hour, and twenty-four hours after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point surprise on the exchange rate in basis points. A negative coefficient indicates dollar depreciation. Sample period is February 4, 1994 to December 17, 2014.

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 13. As expected, removing the unscheduled meetings implies a greater impact of the target surprises on the dollar, which now depreciates by about 1.5 percent one hour following announcement compared with roughly 0.8 percent for our benchmark case in table 5. However, the effects of the short-term path surprises are now somewhat smaller. Taking these two effects into account, table 13 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:

$$\Delta S_{i,t,w} = a_i + \alpha TS_t + \beta PS_t^{ST} + \gamma PS_t^{LT} + \varepsilon_{i,t}, \tag{3a}$$

while the specification for the unconventional period is

$$\Delta S_{i,t,w} = a_i^u + \beta^u PS_t^{ST} + \gamma^u PS_t^{LT} + \varepsilon_{i,t}, \tag{3b}$$

Table 13. Robustness: Omitting Unscheduled Meetings

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

	+20m	**+1h**	**+24h**
TS	-1.15^{***}	-1.53^{***}	-0.73^{**}
	(0.20)	(0.21)	(0.33)
PS^{ST}	-0.89^{***}	-1.14^{***}	-1.84^{***}
	(0.12)	(0.19)	(0.07)
PS^{LT}	-0.24	0.11	0.67
	(0.21)	(0.31)	(0.51)
$D^u * PS^{ST}$	-4.13^{***}	-3.93^{***}	-5.41^{***}
	(0.32)	(0.51)	(1.04)
$D^u * PS^{LT}$	-3.03^{***}	-3.84^{***}	-4.85^{***}
	(0.35)	(0.24)	(1.05)
Memo:			
1. $\beta_1 + \beta_2$	-5.03^{***}	-5.07^{***}	-7.25^{***}
	(0.36)	(0.59)	(1.02)
2. $\gamma_1 + \gamma_2$	-3.27^{***}	-3.73^{***}	-4.18^{***}
	(0.52)	(0.47)	(0.55)
3. $\alpha_1 + \beta_1 + \gamma_1$	-2.28^{***}	-2.56^{***}	-1.90^{**}
	(0.39)	(0.54)	(0.76)
4. $\beta_1 + \gamma_1 + \beta_2 + \gamma_2$	-8.30^{***}	-8.79^{***}	-11.43^{***}
	(0.60)	(0.56)	(1.32)
5. Line 4 / Line 3	3.64	3.44	6.02
R^2	0.50	0.39	0.15
No. Obs.	700	663	679

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to twenty minutes after announcements. Exchange rate response windows w for currency i are measured from ten minutes before to w = twenty minutes, one hour, and twenty-four hours after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point 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 14. Robustness: Non-nested Regressions

A. Conventional Period $\Delta S_{i,t,w} = a_{1i} + \alpha_1 TS_t + \beta_1 PS_t^{ST} + \gamma_1 PS_t^{LT} + \varepsilon_{i,t}$			
	+20m	**+1h**	**+24h**
TS	−0.61***	−0.75***	−0.76*
	(0.09)	(0.07)	(0.39)
PS^{ST}	−0.95***	−1.34***	−2.03***
	(0.10)	(0.23)	(0.09)
PS^{LT}	−0.45*	−0.29	0.13
	(0.26)	(0.36)	(0.50)
Memo: $\alpha_1 + \beta_1 + \gamma_1$	−2.00***	−2.38***	−2.66***
	(0.37)	(0.61)	(0.65)
R^2	0.16	0.18	0.06
No. Obs.	496	459	491
B. Unconventional Period $\Delta S_{i,t,w} = a_{2i} + \beta_2 PS_t^{ST} + \gamma_2 PS_t^{LT} + \varepsilon_{i,t}$			
	+20m	**+1h**	**+24h**
PS^{ST}	−5.08***	−5.35***	−7.72***
	(0.34)	(0.57)	(1.09)
PS^{LT}	−3.28***	−3.66***	−4.04***
	(0.53)	(0.48)	(0.53)
Memo: $\beta_2 + \gamma_2$	−8.36***	−9.01***	−11.76***
	(0.62)	(0.56)	(1.38)
R^2	0.67	0.47	0.25
No. Obs.	224	224	208

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Surprise windows are defined as ten minutes before to twenty minutes after announcements. Exchange rate response windows w for currency i are measured from ten minutes before to twenty minutes, one hour, and twenty-four hours after announcement. Exchange rate changes and surprises are in basis point units, so the figures in the table can be interpreted as the effect of a 1 basis point 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.

where ζ is an error term and other variables are defined as before. We report the results in table 14. 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.[26]

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 target federal funds rate 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.

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

Appendix. Policy Announcements

Table A1. Policy Announcements

Date	Time	Sched.	Unsched.	Speech
2/4/1994	11:05	1		
3/22/1994	14:20	1		
4/18/1994	10:05		1	
5/17/1994	14:25	1		
7/16/1994	14:20	1		
8/16/1994	13:20	1		
9/27/1994	14:20	1		
11/15/1994	14:20	1		
12/20/1994	14:15	1		
2/1/1995	14:15	1		
3/28/1995	14:15	1		
5/23/1995	14:15	1		
7/6/1995	14:15	1		
8/22/1995	14:15	1		
9/26/1995	14:15	1		
11/15/1995	14:15	1		
12/19/1995	14:15	1		
1/31/1996	14:15	1		
3/26/1996	11:40	1		
5/21/1996	14:15	1		
7/3/1996	14:15	1		
8/20/1996	14:15	1		
9/24/1996	14:15	1		
11/13/1996	14:15	1		
12/17/1996	14:15	1		
2/5/1997	14:15	1		
3/25/1997	14:15	1		
5/20/1997	14:15	1		
7/2/1997	14:15	1		
8/19/1997	14:15	1		
9/30/1997	14:15	1		
11/12/1997	14:15	1		
12/16/1997	14:15	1		
2/4/1998	14:10	1		
3/31/1998	14:15	1		
5/19/1998	14:15	1		
7/1/1998	14:15	1		
8/18/1998	14:15	1		
9/29/1998	14:15	1		
11/17/1998	14:15	1		
12/22/1998	14:15	1		
2/3/1999	14:10	1		
3/30/1999	14:10	1		
5/18/1999	14:10	1		
6/30/1999	14:15	1		

(continued)

Table A1. (Continued)

Date	Time	Sched.	Unsched.	Speech
8/24/1999	14:15	1		
10/5/1999	14:10	1		
11/16/1999	14:15	1		
12/21/1999	14:15	1		
2/2/2000	14:15	1		
3/21/2000	14:15	1		
5/16/2000	14:15	1		
6/28/2000	14:15	1		
8/22/2000	14:15	1		
10/3/2000	14:10	1		
11/15/2000	14:10	1		
12/19/2000	14:15	1		
1/3/2001	13:15		1	
1/31/2001	14:15	1		
3/20/2001	14:15	1		
4/18/2001	10:55		1	
5/15/2001	14:15	1		
6/27/2001	14:10	1		
8/21/2001	14:15	1		
10/2/2001	14:15	1		
11/6/2001	14:20	1		
12/11/2001	14:15	1		
1/30/2002	14:15	1		
3/19/2002	14:15	1		
5/7/2002	14:15	1		
6/26/2002	14:15	1		
8/13/2002	14:15	1		
9/24/2002	14:15	1		
11/6/2002	14:15	1		
12/10/2002	14:15	1		
1/29/2003	14:15	1		
3/18/2003	14:15	1		
5/6/2003	14:15	1		
6/25/2003	14:15	1		
8/12/2003	14:15	1		
9/16/2003	14:15	1		
10/28/2003	14:15	1		
12/9/2003	14:15	1		
1/28/2004	14:15	1		
3/16/2004	14:15	1		
5/4/2004	14:15	1		
6/30/2004	14:15	1		
8/10/2004	14:15	1		
9/21/2004	14:15	1		
11/10/2004	14:15	1		

(continued)

Table A1. (Continued)

Date	Time	Sched.	Unsched.	Speech
12/14/2004	14:15	1		
2/2/2005	14:15	1		
3/22/2005	14:15	1		
5/3/2005	14:15	1		
6/30/2005	14:15	1		
8/9/2005	14:15	1		
9/20/2005	14:15	1		
11/1/2005	14:15	1		
12/13/2005	14:15	1		
1/31/2006	14:15	1		
3/28/2006	14:15	1		
5/10/2006	14:15	1		
6/29/2006	14:15	1		
8/8/2006	14:15	1		
9/20/2006	14:15	1		
10/25/2006	14:15	1		
12/12/2006	14:15	1		
1/31/2007	14:15	1		
3/21/2007	14:15	1		
5/9/2007	14:15	1		
6/28/2007	14:15	1		
8/7/2007	14:15	1		
9/18/2007	14:15	1		
10/31/2007	14:15	1		
12/11/2007	14:15	1		
1/22/2008	8:30		1	
1/30/2008	14:15	1		
3/18/2008	14:15	1		
4/30/2008	14:15	1		
6/25/2008	14:15	1		
8/5/2008	14:15	1		
9/16/2008	14:15	1		
10/8/2008	7:00		1	
10/29/2008	14:15	1		
11/25/2008	8:15		1	
12/1/2008	13:40			1
12/16/2008	14:15	1		
1/28/2009	14:15	1		
3/18/2009	14:15	1		
4/29/2009	14:15	1		
6/24/2009	14:15	1		
8/12/2009	14:15	1		
9/23/2009	14:15	1		
11/4/2009	14:15	1		
12/16/2009	14:15	1		

(continued)

Table A1. (Continued)

Date	Time	Sched.	Unsched.	Speech
1/27/2010	14:15	1		
3/16/2010	14:15	1		
4/28/2010	14:15	1		
6/23/2010	14:15	1		
8/10/2010	14:15	1		
8/27/2010	10:00			1
9/21/2010	14:15	1		
10/15/2010	8:15			1
11/3/2010	14:15	1		
12/14/2010	14:15	1		
1/26/2011	14:15	1		
3/15/2011	14:15	1		
4/27/2011	12:30	1		
6/22/2011	12:30	1		
8/9/2011	14:15	1		
8/26/2011	10:00		1	
9/21/2011	14:15	1		
11/2/2011	12:30	1		
12/13/2011	14:15	1		
1/25/2012	12:30	1		
3/13/2012	14:15	1		
4/25/2012	12:30	1		
6/20/2012	12:30	1		
8/1/2012	14:15	1		
8/31/2012	10:00			1
9/13/2012	12:30	1		
10/24/2012	14:15	1		
12/12/2012	12:30	1		
1/30/2013	14:15	1		
3/20/2013	14:00	1		
5/1/2013	14:00	1		
5/22/2013	10:30		1	
6/19/2013	14:00	1		
7/31/2013	14:00	1		
9/18/2013	14:00	1		
10/30/2013	14:00	1		
12/18/2013	14:00	1		
1/29/2014	14:00	1		
3/19/2014	14:00	1		
4/30/2014	14:00	1		
6/18/2014	14:00	1		
7/30/2014	14:00	1		
9/17/2014	14:00	1		
10/29/2014	14:00	1		
12/17/2014	14:00	1		

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