The Effects of Unconventional and Conventional U.S. Monetary Policy: The Role of Expected Inflation*

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Abstract

This paper converts unconventional monetary policy measures into equivalent conventional monetary policy measures — federal funds rate surprises and expected inflation surprises — and compares the effects of unconventional and conventional monetary policy announcements on the value of the dollar through these two channels. I find that the impact of the federal funds rate surprises on the dollar value has not changed much since the crisis began, although this channel has become irrelevant because the zero lower bound (ZLB) has eliminated all federal funds rate surprises. The impact of the expected inflation surprises on the dollar value, however, has weakened dramatically compared to the pre-crisis period.

JEL classification: E4, F3, G1

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1 Introduction

Researchers have long sought to understand how monetary policy announcements affect exchange rates, especially when the Federal Reserve introduced new monetary policy tools. Since 1982, the Fed has targeted the federal funds rate as the primary instrument of monetary policy. But since the late 2008, the federal funds rate has been effectively zero, so that lowering it further to stimulate the economy has become infeasible. Consequently, the Fed started the unconventional policy tools such as large-scale asset purchases (LSAPs) and forward guidance to affect the long-term interest rates and influence the economy. The latest unconventional policy actions taken by the Fed has led to a burgeoning literature that investigates the announcement effect of (unconventional) monetary policies on U.S. dollar exchange rate. See, for instance, Glick and Leduc (2011), Fratzscher et al. (2012), Neely (2015).

A related major challenge has been to compare the effect of unconventional monetary policy announcements with that of the conventional monetary policy announcements. Glick and Leduc (2013) examine how the U.S. dollar has reacted to changes in unconventional monetary policy since the federal funds rate reached its ZLB in December 2008, and are the first to compare this effect to those following changes in conventional monetary policy in the preceding period. Their pioneering work converts the unconventional monetary policy surprises into equivalent federal funds rate surprises, and enables the comparison of unconventional and conventional monetary policy effects. They find that unconventional monetary policy has the same "bang" per unit of surprise as the federal funds rate previously had and that the exchange channel of monetary policy is still working effectively.

One concern arises: The federal funds rate surprises contain only current monetary policy information, while the unconventional monetary policy surprises — measured by the long-term rate surprises — contain both the current federal funds rate information, and the expected future federal funds rate information. After December 2008, since the spot federal funds rate is effectively zero, the non-zero unconventional monetary policy surprises can only be triggered by expected future federal funds rate surprises. Thus, it is an open question whether one can convert the unconventional monetary policy surprises into “equivalent (current) federal funds rate surprises”.

This article addresses this question and decomposes the long-term rate surprises into federal funds rate surprises and expected future federal funds rate surprises. Based on the market interpretation that a lower expected future federal funds rate leads to higher inflation expectations, I suggest that a surprise in expected future federal funds rate can be quantified and well approximated by a linear expression of the expected future inflation surprises. Thus, both conventional and unconventional monetary policy surprises can be expressed and contrasted in comparable measures: federal funds rate surprises that measure the current federal funds rate surprises, and expected inflation surprises that measure the expected future federal funds rate surprises.

This paper is the first one to empirically examine the effects of monetary policy announcements on the value of the dollar through these two different channels. Moreover, it adds to a growing and active literature on the effects of unconventional monetary policy, especially those with event studies of the FOMC announcements; e.g., Gagnon el al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), D’Amico et al. (2012), Glick and Leduc (2012), Glick and Leduc (2013), Li and Wei (2013), Hamilton and Wu (2015), and Neely (2015).

My work is most closely related to Glick and Leduc (2013). I augment their model with an expected inflation surprise channel, and replicate their result in the augmented model that the federal funds rate surprise channel has remained intact since the crisis began. Nevertheless, because the ZLB has eliminated all federal funds rate surprises, the expected inflation surprise channel now plays the sole role at ZLB. Most importantly, I find the impact of the expected inflation surprise channel has weakened dramatically compared to the pre-crisis period.

I organize the paper as follows. Section 2 explains the underlying transmission mechanism of federal funds rate surprise channel and expected inflation surprise channel, and augments Glick and Leduc (2013)'s model with expected inflation surprises. Section 3 describes the data, and define measures of surprises and the exchange rate movement. Baseline results are provided in Section 4 and robustness tests are relegated to the appendix. Section 5 concludes.

2 Announcement Effect Transmission Mechanism

2.1 Transmission Mechanism

A monetary policy announcement affects the economy through two different channels: current federal funds rate surprises and expected future federal funds rate surprises. Every time the FOMC meets and announces a new federal funds rate target (or a QE program), not only do they announce the current federal funds rate, but they also reveal new information about the future federal funds rate path. As a result, the financial market will react to both pieces of information.

The current federal funds rate surprise is the unanticipated component of the federal funds rate. The Fed lowers the federal funds rate to provide more stimulus and raises it to slow economic activity and control inflation. The importance of federal funds rate surprise channel has long been established in the literature; e.g., Kuttner (2001) decomposes federal funds rate changes into anticipated and unanticipated components, and finds the response of the treasury bond yields to the unanticipated piece is large and significant, while the response to the anticipated piece is small and insignificant. Subsequent papers analyzing the federal funds rate surprise channel include Bernanke and Kuttner (2005), D'Amico and Farka (2011), and Glick and Leduc (2013).

The expected future federal funds rate surprise is the unanticipated component of the future federal funds rate path. Gürkaynak, Sack, and Swanson (2005a) show that the current federal funds rate surprise itself is inadequate to fully capture the effects of U.S. monetary policy announcements on asset prices. In addition to the "current federal funds rate target" factor (i.e. current federal funds rate surprises), a "future path of policy" factor must be added to explain the bond yields and stock prices movements, especially for the longer-term Treasury yields.

Both the current and expected future federal funds rates determine the Treasury bond rates and consequently determine the exchange rate movements. Current federal funds rate surprises capture the "current federal funds rate target" factor, but contain little information about the "future path of policy" factor. Hence if the Fed maintains current federal funds rate, but at the same time provide guidance about future federal funds rate, the exchange rate would react to this Fed announcement, but it would be impossible to explain the exchange rate movement using the current federal funds rate surprises.

The FOMC meeting held on June 16-17, 2015 is such an example, where the current federal funds rate surprises cannot be used to explain the exchange rate movement since the current federal funds rate target remains at zero. In the press conference following the meeting, Chair Yellen (2015) said:

> *The Committee continues to judge that the first increase in the federal funds rate will be appropriate when it has seen further improvement in the labor market and is reasonably confident that inflation will move back to its 2 percent objective over the medium term. . . . the Committee concluded that these conditions have not yet been achieved. . . . the Committee will determine the timing of the initial increase in the federal funds rate on a meeting-by-meeting basis, depending on its assessment of incoming economic information and its implications for the economic outlook.*

This speech was widely interpreted (e.g., Hilsenrath (2015), and Ramage (2015)) as a signal that the Fed would raise federal funds rate at a slower pace in coming years than the market projected. The market reacted to this speech instantaneously. The yield on the benchmark 10-year note decreased by 7.7 bps, down from 2.383% before the statement to 2.306% by the end of June 17, 2015. This reaction was spurred not by what the FOMC did, but rather by what it said: indeed, the decision to leave the current federal funds rate target unchanged was completely anticipated by the financial markets, but Yellen's speech was read by the financial markets as indicating that the FOMC would raise federal funds rate at a slower pace than expected, which led the dollar to depreciate by 78 basis points (bps) against the Euro, from 1.1250USD/EUR by the end of June 16, 2015 to 1.1338USD/EUR by the end of June 17, 2015. Hence, treating the monetary policy action on this date as a zero bp surprise change in the current federal funds rate would be missing the whole story.

2.2 A Decomposition of Long-Term Rate Surprises

Following Gürkaynak, Sack, and Swanson (2005a), I try to decompose the long-term rate surprise into a current federal funds rate surprise and a "future path of policy" factor, and I suggest using the expected inflation surprise as a natural proxy for the "future path of policy" factor.

Gürkaynak, Sack, and Swanson (2005b) provide theoretical and empirical evidence that the long-term interest rate responses to monetary announcements are largely driven by expected inflation variation. In addition, I am inspired by an off-the-shelf open-economy New Keynesian model. In Appendix A, I show that the expected future federal funds rate surprises can be quantified and well approximated by a linear expression of expected future inflation surprises. Then according to the expectations theory of the term structure, I can decompose the long-term rate surprises into a linear combination of current federal funds rate surprises and expected inflation surprises; i.e.,

$$LongRate\_surp = \gamma_0 + \gamma_1 FedFund\_surp + \gamma_2 ExpInfl\_surp \tag{1}$$

The intuition behind (1) is straightforward: When the federal funds rate is above zero, the federal funds rate reacts to inflation following the Taylor rule. Moreover, the reaction coefficient with respect to inflation is greater than one, indicating that whenever the Fed sees a high inflation and raises the federal funds rate, it raises the real interest rate and consequently mitigate the inflation. Put it one step forward, whenever the market expects a future federal funds rate raise, their expected future inflation would decrease. This suggests a negative relationship between the expected future monetary policy and the expected inflation; i.e., I expect $\gamma_2 < 0$.

A similar pattern can be observed for the post-crisis period: whenever the Fed slows down its pace to raise the (future) federal funds rate, the markets would always adjust upward their inflation expectation, and vice versa. Take the FOMC June 17, 2015 announcement as an example, the markets interpreted the FOMC statement as a signal that the Fed would raise federal funds rate at a slower pace than expected. As a consequence, the 10-year expected inflation implied by inflation swaps increased from 2.112% by the end of June 16, 2015, to 2.127% by the end of June 17, 2015, implying a 1.5 bps 10-year expected annual inflation surprise.

The decomposition of the unconventional monetary policy surprises — i.e., the long-term rate surprises — into (current) federal funds rate surprises and expected inflation surprises enables me to compare the announcement effect of the unconventional monetary policy with that of the conventional monetary policy.

2.3 An Augmented Model

Since the federal funds rate reached its ZLB by the end of 2008, the Federal Reserve has employed unconventional tools — forward guidance and QE to achieve its dual mandate of price stability and maximum employment. It is important to compare how the U.S. dollar has reacted to changes in unconventional monetary policy and how this effect compares to those following changes in conventional monetary policy in the preceding period. In this chapter, I augment Glick and Leduc (2013)'s model with expected inflation surprises, convert the unconventional monetary policy into equivalent conventional monetary policy, and enable the comparison of the effect of the unconventional monetary policy with that of the conventional monetary policy through two different channels: federal funds rate surprise channel, and expected inflation surprise channel.

1. Conventional Monetary Policy Period (Before November, 2008)

   The Fed announces a new federal funds rate target and guides the market's expectation about future federal funds rate (approximated by expected future inflation) by issuing the FOMC statements, transcripts, and minutes. Hence the effect of conventional monetary policy announcement on dollar's value can be estimated by:

$$ExchRate\_Mov = \alpha_0 + \alpha_1 FedFund\_surp + \alpha_2 ExpInfl\_surp \tag{2}$$

   where $ExchRate\_Mov$ denotes the exchange rate movement, $FedFund\_surp$ the federal funds rate surprise, and $ExpInfl\_surp$ the expected inflation surprise on the policy announcement day. Figure 1 displays the transmission mechanism.

2. Unconventional Monetary Policy Period (Since November, 2008)

   During the unconventional monetary policy period, the Fed conducts LSAPs, and changes the long-term bond rate. Following Glick and Leduc (2013), the effect of unconventional monetary policy on dollar's value can be estimated by:

$$ExchRate\_Mov = \beta_0 + \beta_1 LongRate\_surp \tag{3}$$

where $LongRate\_surp$ denotes the long-term rate surprise[1] on the policy announcement day. Figure 2 displays the transmission mechanism.

3. Convert the unconventional monetary policy into equivalent conventional monetary policy (Full Sample[2])

   As analyzed in Section 2.2, the long-term rate surprises (unconventional monetary policy) can be converted into equivalent federal funds rate surprises and expected inflation surprises. Figure 3 displays the conversion mechanism.

$$LongRate\_surp = \gamma_0 + \gamma_1 FedFund\_surp + \gamma_2 ExpInfl\_surp \tag{4}$$

Equation (4) shows that 1 bp unexpected federal funds rate tightening leads to γ_1 bps increase of long-term rate surprise, and 1 bp unexpected future inflation surprise (indicating a lower expected future federal funds rate) leads to $-\gamma_2$ bps decrease of long-term rate surprise. I expect $\gamma_1 > 0$ and $\gamma_2 < 0$ since a higher expected inflation implies a lower expected future federal funds rate.

Equation (4) enables me to compare the unconventional monetary policy effect with the conventional monetary policy effect through two different channels: federal funds rate surprise channel, and expected inflation surprise channel. During the unconventional monetary policy period, a 1 bp long-term rate surprise is equivalent to $\frac{1}{\gamma_1}$ bps federal funds rate surprise if the long-term rate surprise solely comes from unexpected current federal funds rate tightening,

[1]In the following sections, the results with 5-year and 10-year horizon are reported.

[2]Section 4.3 shows that there is no structural break at the 2008 financial crisis.

and is equivalent to $\frac{1}{\gamma_2}$ bps unexpected inflation surprise if the long-term rate surprise solely comes from unexpected future federal funds rate tightening. Thus to compare effect of the unconventional monetary policy with that of the conventional monetary policy on the dollar value, I multiply the unconventional policy effect β_1 by the adjustment parameter γ_1 for the federal funds rate surprise channel, and multiply β_1 by the adjustment parameter γ_2 for the expected inflation surprise channel. This adjusted unconventional monetary policy effect $\beta_1\gamma_1$ and $\beta_1\gamma_2$ can be directly contrasted with the conventional monetary policy effect α_1 and α_2, where $\beta_1\gamma_1$ and α_1 both measure the effect through federal funds rate surprise channel; and $\beta_1\gamma_2$ and α_2 both measure the effect through expected inflation surprise channel. If the magnitude of $\beta_1\gamma_1$ and α_1 ($\beta_1\gamma_2$ and α_2) are comparable, I can assert the transmission mechanism of federal funds rate surprise channel (expected inflation surprise channel) is intact. If the magnitude of $\beta_1\gamma_1$ ($\beta_1\gamma_2$) is much smaller than α_1 (α_2), I can assert the impact of federal funds rate surprise channel (expected inflation surprise channel) on the dollar value has weakened.

The regression residuals of (4) will be attributed to the surprises in the term premium. According to Stavrakeva and Tang (2015), the effect of QE on exchange rates can be attributed mostly to QE changing expectations over future federal funds rates, and the effect of term premia is weak at best. Hence the endogeneity problem is not a concern.

3 Data Description and Surprise Identification

3.1 Monetary Policy Regime

My measure of monetary policy announcement dates largely follows Glick and Leduc (2013). The sample period for conventional monetary policy actions extends from January 2003, when the 5-year and 10-year Treasury Inflation-Protected Securities (TIPS) first became available, until October 2008, just before the federal funds target rate reached the ZLB with 49 observations; and the unconventional monetary policy period extends from November 2008 until September 2014 with 52 observations.

3.2 Federal Funds Rate Surprises: $FedFund\_surp$

Following Kuttner (2001), I construct the federal funds rate surprises $FedFund\_surp_t$ from the federal funds rate futures series $\{f^i_{s,t}\}$, the yields of i-month ahead federal funds rate futures contract on day t of month s.

$$FedFund\_surp_t = \begin{cases} \frac{m}{m-t+1}(f^0_{s,t} - f^0_{s,t-1}) & \text{if } 1 < t < m-6, \\ f^1_{s,t} - f^1_{s,t-1} & \text{if } t \geq m-6, \\ f^0_{s,1} - f^1_{s-1,m} & \text{if } t = 1. \end{cases} \tag{5}$$

where m is the number of days in the corresponding month.

3.3 Expected Inflation Surprises: $ExpInfl\_surp$

I first compute daily forward inflation expectation series $E_t\pi_{t,t+5y}$ and $E_t\pi_{t,t+10y}$ for 5- and 10-year horizon as the difference between daily Treasury yield curve rates and daily Treasury real yield curve rates of corresponding maturity[3]. Then the expected inflation surprises on day t is constructed as the interday change of forward inflation expectation:

$$ExpInfl\_surp_t = \begin{cases} E_t\pi_{t,t+5y} - E_{t-1d}\pi_{t,t-1d+5y} & \text{for 5-year horizon} \\ E_t\pi_{t,t+10y} - E_{t-1d}\pi_{t,t-1d+10y} & \text{for 10-year horizon} \end{cases} \tag{6}$$

[3]The data series are downloaded from U.S. Department of Treasury database: `http://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/default.aspx`

where the subscripts d and y denote "day" and "year", respectively.

3.4 Long-Term Rate Surprises: $LongRate\_surp$

Following Wright (2012), this paper takes the end-of-day quotes on the front contracts of 5- and 10-year bond futures trading on the Chicago Mercantile Exchange (CME) from Bloomberg, and compute the interday change of the futures prices[4]. The bond futures prices and the corresponding Treasury note spot rate are negatively correlated, a higher futures price accompanies a lower spot rate, and vice versa. To be consistent with my definition of federal funds rate surprises, I define the long-term rate surprises $LongRate\_surp_t$ as the inverse of the interday change of the futures prices, so that a negative federal funds rate surprise and long-term rate surprise both indicate an expansionary monetary policy.

$$LongRate\_surp_t = \begin{cases} -[P_t(5y) - P_{t-1}(5y)] & \text{for 5-year horizon} \\ -[P_t(10y) - P_{t-1}(10y)] & \text{for 10-year horizon} \end{cases} \tag{7}$$

where $P_t(5y)$ and $P_t(10y)$ are the 5-year and 10-year bond future price by the end of day t.

3.5 Exchange Rate Movements: $ExchRate\_Mov$

Similar to Glick and Leduc (2013), the exchange rate movements $ExchRate\_Mov_t$ in response to the announcement is defined as the interday changes in the log of the currency futures prices from Bloomberg[5].

$$ExchRate\_Mov_t = f_t - f_{t-1} \tag{8}$$

[4]In the appendix, I use the Treasury note spot rate to construct an alternative measure of long-term rate surprises as a robustness check.

[5]In the appendix, I use the spot exchange rate to construct an alternative measure of exchange rate movement as a robustness check.

where f_t is the log of the currency futures price by the end of day t.

These foreign exchange futures contracts involve the U.S. dollar with several currencies, including the euro, yen, pound, and Canadian dollar. A positive movement of the price implies a potential U.S. dollar depreciation.

4 Unconventional vs. Conventional Monetary Policy

In this section, I present the benchmark results estimated for the model in Section 2.3.

4.1 Conventional Monetary Policy (Before November, 2008)

During the conventional monetary policy period, the Fed announces a new federal funds rate target and guides the market's expectation about future federal funds rate (approximated by expected future inflation) by issuing the FOMC statements, transcripts, and minutes. Hence the effect of conventional monetary policy announcement on dollar's value can be estimated by:

$$ExchRate\_Mov = \alpha_0 + \alpha_1 FedFund\_surp + \alpha_2 ExpInfl\_surp \quad (9)$$

Table 1 and 2 reports the dollar response coefficients to surprise changes in the federal funds rate and expected inflation during the pre-crisis period of January 2003 to October 2008. As expected, the dollar appreciated in response to federal funds tightening surprise, with a 1 bp surprise tightening in the federal funds rate leading to an appreciation in the trade-weighted dollar of about 1 bp (1.031 bps for the regression with 5-year expected inflation, and 0.725 bps with 10-year expected inflation)[6], which is comparable to Glick and Leduc's

[6] I construct trade weights following Glick and Leduc (2013), from *Direction of Trade* data in 2011 on U.S. bilateral exports and imports with the U.K., Canada, Eurozone, and Japan, with calculated weights of 0.07, 0.41, 0.39, and 0.13, respectively. Results from taking simple averages are comparable.

interday response[7]. The responses of dollar exchange rate to the federal funds rate surprise are insignificant for all the currency pairs. However, according to Glick and Leduc (2013), if the time window is narrowed down from interday to 10-minute before, 20-minute after the announcement, I can get similar estimates with high significance.

The expected inflation serves as a proxy for future monetary policy. A higher expected inflation indicates a lower future federal funds rate, and consequently a lower long-term spot rate, leading to a weaker dollar. As expected, the dollar depreciated in response to expected inflation surprise, with a 1 bp 10-year (5-year) surprise in the expected annual inflation leading to a depreciation in the trade-weighted dollar of about 4.5 bps (3.9 bps). The coefficient of the expected inflation surprises is significant for most currency pairs, indicating that it takes time (a day or so) for the market to infer the future monetary policy from the announcement.

The R^2 of my conventional monetary policy analysis is approximately 0.12, much larger than Glick and Leduc (2013)'s 0.04, indicating that the expected inflation surprises play a large role in exchange rate movements.

4.2 Unconventional Monetary Policy (Since November, 2008)

During the unconventional monetary policy period, the Fed conducts LSAPs, and changes the long-term bond rate. Following Glick and Leduc (2013), the effect of unconventional monetary policy on dollar's value can be estimated by:

$$ExchRate\_Mov = \beta_0 + \beta_1 LongRate\_surp \tag{10}$$

Table 3 and 4 estimate the effects of unconventional monetary policy surprises on the

[7] Glick and Leduc (2013)'s result is reported as: one standard deviation surprise easing in the federal funds rate leads to 9.88 bps appreciation of U.S. dollar. To compare this result with mine, I divide it with the standard deviation of federal funds rate surprises 9.2 bps to get 1.074.

value of the dollar. I find that the dollar depreciates against all currencies in response to an unconventional policy easing, with a 1 unit surprise 10-year (5-year) rate easing leading to 0.4 bps (0.85 bps) depreciation. The slopes are significant for most currency pairs. This result appears different from Glick and Leduc (2013), who find that a 1 bp surprise easing in the unconventional monetary policy leads to a 4.83 bps dollar depreciation[8]. Recall that Glick and Leduc (2013) use the changes in the principal component of the 2-, 5-, 10-, and 30-year Treasury rate futures, while I use the inverse of the price changes in the 10-year (5-year) Treasury rate futures. In Section 4.4, once I convert the unconventional monetary policy into equivalent conventional monetary policy tools, I draw the same conclusion as Glick and Leduc (2013) that the federal funds rate surprise channel has remained intact since the crisis began, indicating that the difference between Glick and Leduc (2013) and mine is just a matter of different data unit.

The R^2 is 0.276 (0.339) for trade-weighted dollar movement with 10-year (5-year) rate surprises, comparable to Glick and Leduc (2013)'s 0.32.

4.3 Adjustment Parameter (Full Sample)

Section 2.2 and 2.3 show that the unconventional monetary policy surprises can be converted into equivalent federal funds rate surprises and expected inflation surprises, which enables me to compare unconventional and conventional monetary policy effects through different channels.

$$LongRate\_surp = \gamma_0 + \gamma_1 FedFund\_surp + \gamma_2 ExpInfl\_surp \tag{11}$$

[8]Glick and Leduc (2013)'s result is reported as: one standard deviation surprise easing in the unconventional monetary policy is associated with 58.43 bps depreciation in the dollar value. To compute its per bps response, I divide it by the standard deviation of unconventional monetary policy surprises 12.1 bps to get 4.83.

The estimated coefficients γ_1 and γ_2 capture how the unconventional monetary policy surprises (i.e., long-term rate surprises) relate to the federal funds rate surprises and the expected inflation surprises. I then use these parameters to re-scale the effect of long-term rate surprises. This conversion enables me to report the relative responses of the dollar to conventional and unconventional policy surprises in comparable terms.

In Table 5, I estimate γ_1 and γ_2 over the full sample period (January, 2003 - September, 2014), and obtain an estimated value of $\gamma_1 = 1.964$, and $\gamma_2 = -3.944$ for 10-year horizon, and $\gamma_1 = 1.663$, and $\gamma_2 = -0.551$ for 5-year horizon, implying that a 1 bp surprise increase in the federal funds rate is associated with a 1.964 bps (1.663 bps) rise in the 10-year (5-year) rate surprise, and a 1 bp surprise increase in the 10-year (5-year) expected inflation is associated with a 3.944 bps (0.551 bps) decrease in the 10-year (5-year) rate surprise measure. All slopes are significant. Observe that γ_2 is much larger for 10-year rate than for 5-year rate. This is consistent with Gürkaynak, Sack and Swanson (2005b) that at longer horizons, the expected inflation component tend to be more important in determining the interest rate with corresponding maturity.

Glick and Leduc (2013) estimate the adjustment parameter γ_1 between unconventional monetary policy surprises and federal funds rate surprises that a 1 bp surprise easing in the federal funds rate is associated with a 0.192 bps change in the unconventional monetary policy surprise[9]. I will show in Section 4.4 that the difference between Glick and Leduc (2013)'s result and mine is caused by different measurement of unconventional monetary policy surprises.

In addition, my R^2 (0.068 for 10-year and 0.12 for 5-year) is larger than Glick and Leduc (2013)'s 0.02, and my estimation shows that the coefficient for expected inflation surprises is highly significant, implying the important role of expected inflation surprise channel.

[9] Glick and Leduc (2013)'s result is reported as: one standard deviation surprise easing in the federal funds rate is associated with 0.146 unit change in the unconventional policy surprise measure. To compute its per bps response, I multiply it by the ratio of the standard deviation of unconventional vs. conventional federal funds rate surprises 12.1bps/9.2bps to get 0.192.

A remaining question is: When the federal funds rate is at ZLB, would the decomposition of *LongRate_surp* be different from the non-ZLB period? i.e., is there a structural break for γ_1 and γ_2 in November 2008?

For γ_1, it is straightforward to see that there is no structural break in November 2008, because at the ZLB phase, the federal funds rate surprise is stuck at zero. So the value of γ_1 before the crisis directly carries over to the ZLB phase.

For γ_2, I perform a Chow test in Table 6, which shows that there is no structural break when the federal funds rate reached its ZLB in November 2008. This justifies my regression of (11) over the full sample.

4.4 Federal Funds Rate Surprise Channel

This section compares the effect of the unconventional monetary policy vs. that of the conventional monetary policy through the federal funds rate surprise channel. In Section 2.3, I showed that the adjusted unconventional monetary policy effect $\beta_1\gamma_1$ can be directly contrasted with the conventional monetary policy effect α_1, where $\beta_1\gamma_1$ and α_1 both measure the effect through the federal funds rate surprise channel; i.e., the transmission mechanism initiated by the current federal funds rate surprises.

This comparison is a revisit of Glick and Leduc (2013) in a more generalized model. Recall that Glick and Leduc (2013) show the unconventional monetary policy has the same "bang" per unit of surprise as the federal funds rate previously had. Because the correlation between the federal funds rate surprises and expected inflation surprises is fairly low (0.072 for 10-year horizon and 0.057 for 5-year horizon), Glick and Leduc (2013)'s result should not be too biased despite the omission of expected inflation surprises. Thus I expect to replicate Glick and Leduc (2013)'s result that the values of $\beta_1\gamma_1$ and α_1 are about the same.

Table 7 and 8 report the estimated effects of adjusted unconventional monetary policy through the federal funds rate surprise channel during the unconventional monetary policy period, together with the estimated effects of conventional monetary policy through the federal funds rate surprise channel during the conventional monetary policy period, and the ratio of the two effects. It shows that 1 bp federal funds rate surprise easing leads to a 0.779 bps (1.414 bps) depreciation in the trade-weighted dollar during the unconventional monetary policy period. These magnitudes are comparable to those during conventional monetary policy period 0.725 bps (1.031 bps), with the ratios of unconventional to conventional period being 1.075 (1.371). This outcome is just as I expected, suggesting that during the unconventional monetary policy period, the federal funds rate surprise channel indeed has similar "bang" per unit of surprise as during the conventional monetary policy period.

That said, it would be hasty to conclude that the federal funds rate surprise channel is still effective. Given the fact that $\beta_1\gamma_1$ is approximately the same as α_1, the federal funds rate surprise channel is effective only when the Fed is still capable of freely adjusting the federal funds rate. However, during the unconventional monetary policy period, the federal funds rate is stuck at zero, so consequently there is almost no variation in the federal funds rate surprises (see Figure 4). Thus the federal funds rate surprise channel is irrelevant during this period, and the Fed can only affect the economy by manipulating the market's expectation about future federal funds rate, i.e., via expected inflation surprise channel.

4.5 Expected Inflation Surprise Channel

This section compares the effect of the unconventional monetary policy vs. that of the conventional monetary policy through the expected inflation surprise channel.

Analogous to Figure 4, Figure 5 shows that during the unconventional monetary policy period, the 10-year expected inflation surprises are still as volatile as they were during the conventional monetary policy period, indicating that the expected inflation surprise channel remains a feasible option for the Federal Reserve.

In Section 2.3, I showed that the adjusted unconventional monetary policy effect $\beta_1\gamma_2$ can be directly contrasted with the conventional monetary policy effect α_2, where $\beta_1\gamma_2$ and α_2 both measure the effect through the expected inflation surprise channel; i.e., the transmission mechanism initiated by the future federal funds rate surprises.

Table 9 and 10 report the estimated effects of adjusted unconventional monetary policy through the expected inflation surprise channel during the unconventional monetary policy period, together with the estimated effects of conventional monetary policy through the expected inflation surprise channel during the conventional monetary policy period, and the ratio of the two effects. It shows that 1 bp expected inflation surprise leads to a 1.565 bps (0.469 bps) depreciation in the trade-weighted dollar during the unconventional monetary policy period. These magnitudes are much smaller than those during conventional monetary policy period 4.502 bps (3.894 bps), with the ratios of unconventional to conventional period being 0.348 (0.120). This suggests that during the era of unconventional monetary policy, the expected inflation surprise channel is no longer as effective as during the conventional monetary policy period. That is, the relative importance of expected future federal funds rate in the determination of the exchange rate has weakened dramatically compared to the pre-crisis period.

5 Conclusion

Using the interday data, I converted unconventional monetary policy measures into equivalent conventional monetary policy measures — the federal funds rate surprises and expected inflation surprises — and compare the effects of unconventional and conventional monetary policy announcements on the value of the dollar through these two channels. My results suggest that the federal funds rate surprise channel has been as effective as it was when the Fed could rely on changes in the federal funds rate to conduct monetary policy. However, this channel is no longer a feasible option since the federal funds rate reached its ZLB, because there is no more federal funds rate variation. The expected inflation surprise channel, which captures the effect of expected future federal funds rate, is still working, but the impact has weakened dramatically compared to the pre-crisis period. How these findings should change when the ZLB no longer binds is an open question.

It is difficult to fully evaluate the net spill-over effect of U.S. unconventional monetary policy. Finance ministers of many countries criticize the easy policy stance in the U.S., saying it could be a modern-day equivalent of the "beggar-thy-neighbor" policies of the 1930s. For example, see Fontevecchia (2011). On the other hand, the expansionary policies bring the U.S. back to solid growth, and result in a positive spill-over effect (e.g., stronger demand) for the emerging markets (see Bernanke (2013)). This paper draws a bottom line. I show that the unconventional monetary policy is significantly less effective on the dollar value, as compared to the pre-crisis period; i.e., the unconventional monetary policy would not result in as much dollar depreciation as it would have under equivalent conventional monetary policies. Hence the appreciation pressure of emerging markets' currencies might not be as large as the finance ministers perceive.

A Appendix: Open-Economy New Keynesian Model

A standard open-economy New Keynesian model (e.g., see Engel and West (2006)) can be summarized[10] as:

$$E_t z_{t+1} = B z_t + w_t, \tag{12}$$

[10]For simplicity, I assume the foreign economic variables are constants and hence omitted.

where $z_t = \begin{bmatrix} \pi_t \\ q_t \\ i_t \end{bmatrix}$, $w_t = \begin{bmatrix} \mu_{ct} \\ \mu_{yt} \\ \mu_{mt} \end{bmatrix}$.

B is the coefficient matrix, π_t is the inflation, q_t is the real exchange rate, i_t the interest rate, μ_{ct} the cost shock, μ_{ct} the productivity shock, and μ_{mt} is the monetary surprise in the Taylor rule.

When the shocks follow AR(1) processes, (12) has a close-form solution, and all variables are linear in the current values of these shocks:

$$\pi_t = c_{pc}\mu_{ct} + c_{py}\mu_{yt} + c_{pm}\mu_{mt} \tag{13}$$

$$q_t = c_{qc}\mu_{ct} + c_{qy}\mu_{yt} + c_{qm}\mu_{mt} \tag{14}$$

$$i_t = c_{ic}\mu_{ct} + c_{iy}\mu_{yt} + c_{im}\mu_{mt} \tag{15}$$

To isolate the surprise component, I define the operator $\tilde{}$ as

$$\tilde{x} \equiv E_t x - E_{t-1d} x \tag{16}$$

where E_{t-1d} means expectation conditional on information available at t minus one day.

Moreover, I assume the Fed announcement only reveals information related to domestic monetary policy (i.e., series $\{\mu_{m,t+n}\}_{n=0}^{\infty}$). Thus I can apply the surprise component operator $\tilde{}$ to (13) and (15). For any $n > 0$, I have

$$\tilde{\pi}_{t+n} = c_{pm}\tilde{\mu}_{m,t+n} \tag{17}$$

$$\tilde{i}_{t+n} = c_{im}\tilde{\mu}_{m,t+n} \tag{18}$$

Equations (17) and (18) indicate: $\forall\ n$,

$$\tilde{i}_{t+n} = const \cdot \tilde{\pi}_{t+n} \tag{19}$$

and the coefficient could be negative (see Engel (2015)). Thus I have shown the expected future federal funds rate surprises can be quantified and well approximated by a linear expression of expected future inflation surprises.

B Appendix: Rubustness

In the benchmark analysis, I follow Glick and Leduc (2013), and use the exchange rate futures to measure the exchange rate movement. Also I use the inverse of changes in the long-term bond futures to measure the long-term rate surprises. In this section I assess the robustness of my results to alternative measures: I use spot exchange rate to measure the exchange rate movement, and the constant maturity bond yields to measure the long-term rate surprises.

B.1 Alternative Long-Term Rate Surprises

In Section 3.4, I defined the long-term rate surprises $LongRate\_surp$ as the inverse of the interday change of the futures prices, so that a negative long-term rate surprise indicates an expansionary monetary policy. In this section, I use the corresponding constant maturity bond rate to construct the long-term rate surprises. $LongRate\_surp$ is defined as the interday change of the spot rates, so a negative sign still indicates an expansionary monetary policy.

$$LongRate\_surp_t = \begin{cases} i_t(5y) - i_{t-1}(5y) & \text{for 5-year horizon} \\ i_t(10y) - i_{t-1}(10y) & \text{for 10-year horizon} \end{cases} \tag{20}$$

where $i_t(5y)$ and $i_t(10y)$ are the constant maturity bond rate with 5-year and 10-year maturity by the end of day t.

Figure 6 and 7 provide scatter plots of long term rate surprises constructed from spot rate versus from futures prices for 5-year and 10-year Treasury note, respectively. Obviously the two different measures for long-term rate surprises are highly positively correlated[11].

B.2 Alternative Exchange Rate Movements

In Section 3.5, the exchange rate movements $ExchRate\_Mov$ in response to the announcement is defined as the interday changes in the log of the currency futures prices following Glick and Leduc (2013). In this section, I use the spot exchange rate instead of the currency futures prices. $ExchRate\_Mov$ is defined as the interday change in the log of the spot exchange rate, so a negative sign still indicates a U.S. dollar appreciation.

$$ExchRate\_Mov_t = s_t - s_{t-1} \tag{21}$$

where s_t is the log of the spot exchange rate of U.S. dollar by the end of day t.

Figure 8 provides scatter plots of exchange rate movements constructed from spot rate versus from futures rate for U.S. dollar against British pound, Canadian dollar, Euro, and Japanese yen, respectively. The two different measures for exchange rate movements are highly positively correlated.

[11] Note that the units of the two measures are different. The surprise constructed from spot rate is measured in percentages, while the surprise constructed from futures prices is measured in U.S. dollars. This difference in measurement does not affect my conclusions, since the long-term rate surprise is a measure for the unconventional monetary policy surprise, and is eventually converted into equivalent federal funds rate surprises and expected inflation surprises, which are measured in bps.

B.3 Results with Alternative Measures

Table 11 and 12 report the results with alternative measures of long-term rate surprises and exchange rate movements for the response of the trade-weighted dollar. I find that the federal funds rate surprise channel is virtually the same during the unconventional monetary policy period as during the conventional monetary policy period, while expected inflation surprise channel is significantly less effective during the unconventional monetary policy period than during the conventional monetary policy period, largely consistent with the benchmark results.

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Figure 1: Conventional Monetary Policy

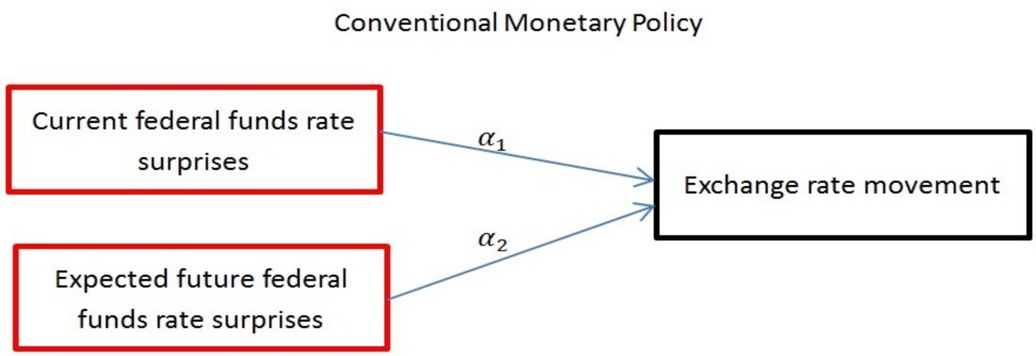


Figure 2: Unconventional Monetary Policy

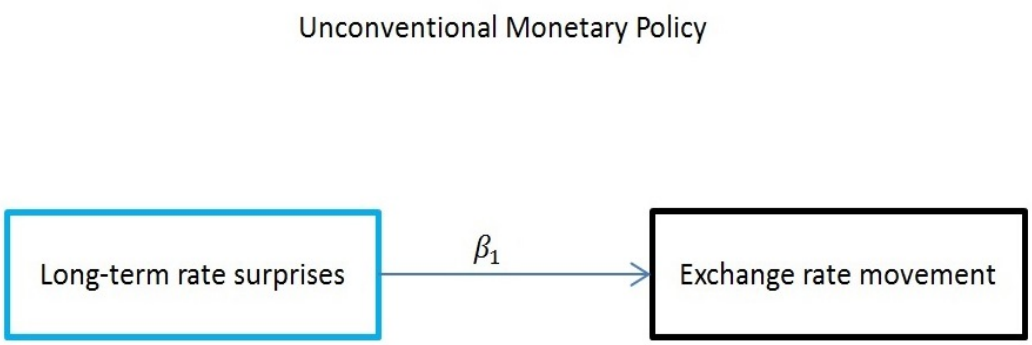


Figure 3: Convert Unconventional Monetary Policy into Equivalent Conventional Monetary Policy

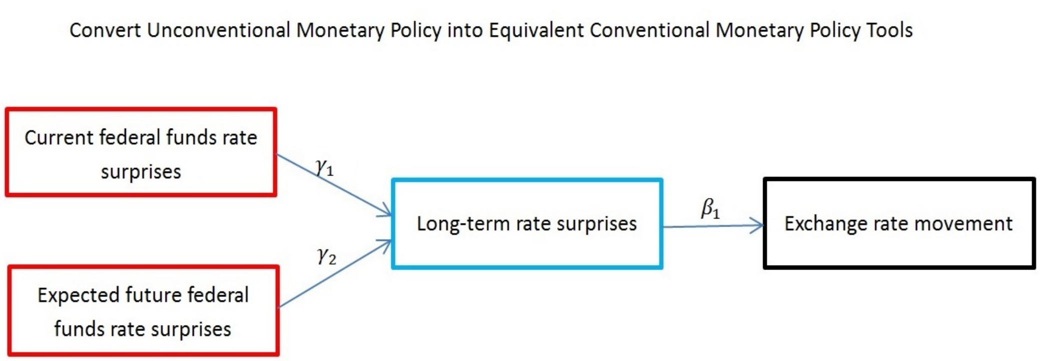
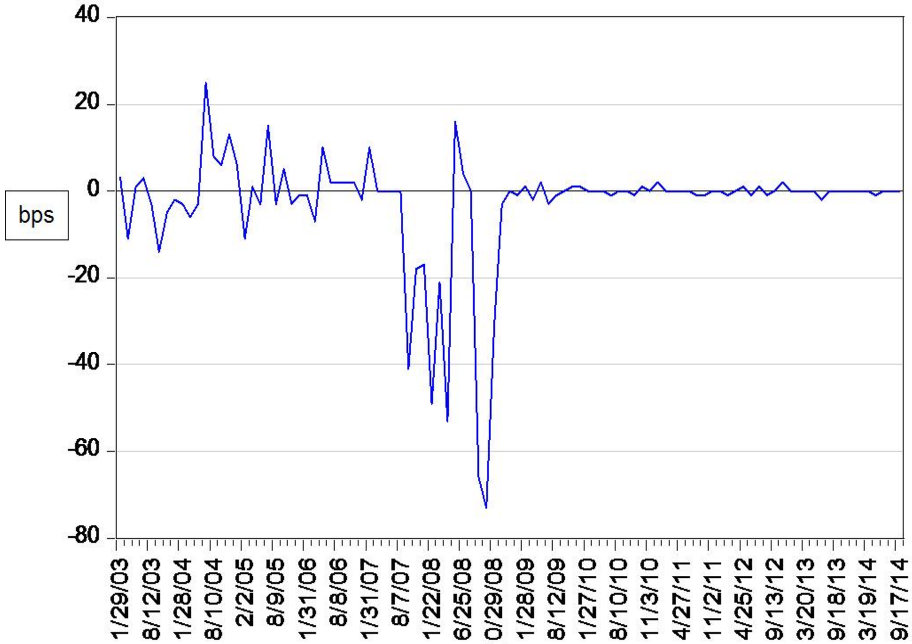
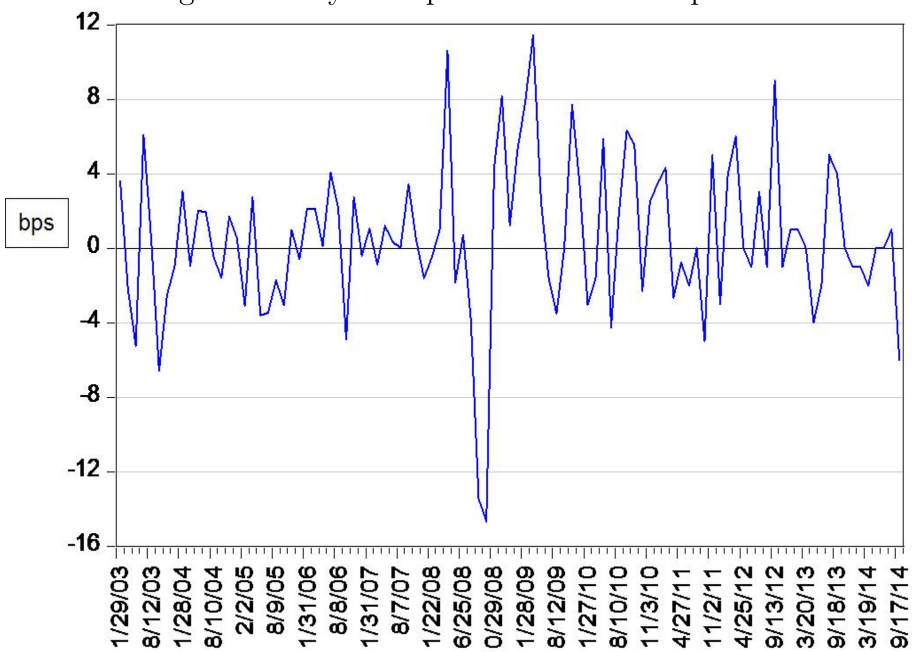


Figure 4: Effective federal funds rate interday changes



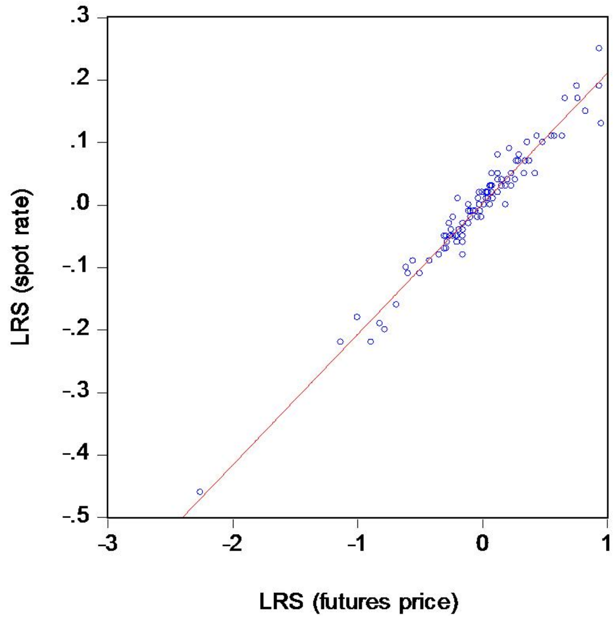
Sample: January 2003 - September 2014, 101 observations

Figure 5: 10-year expected inflation surprises



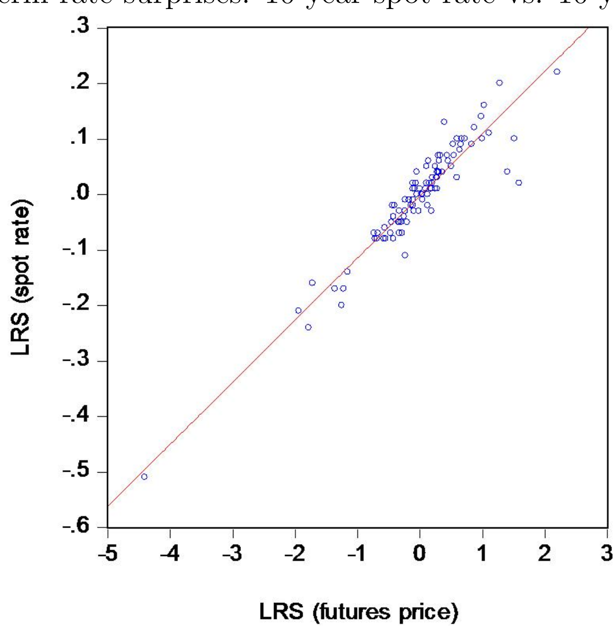
Sample: January 2003 - September 2014, 101 observations

Figure 6: Long-term rate surprises: 5-year spot rate vs. 5-year futures prices



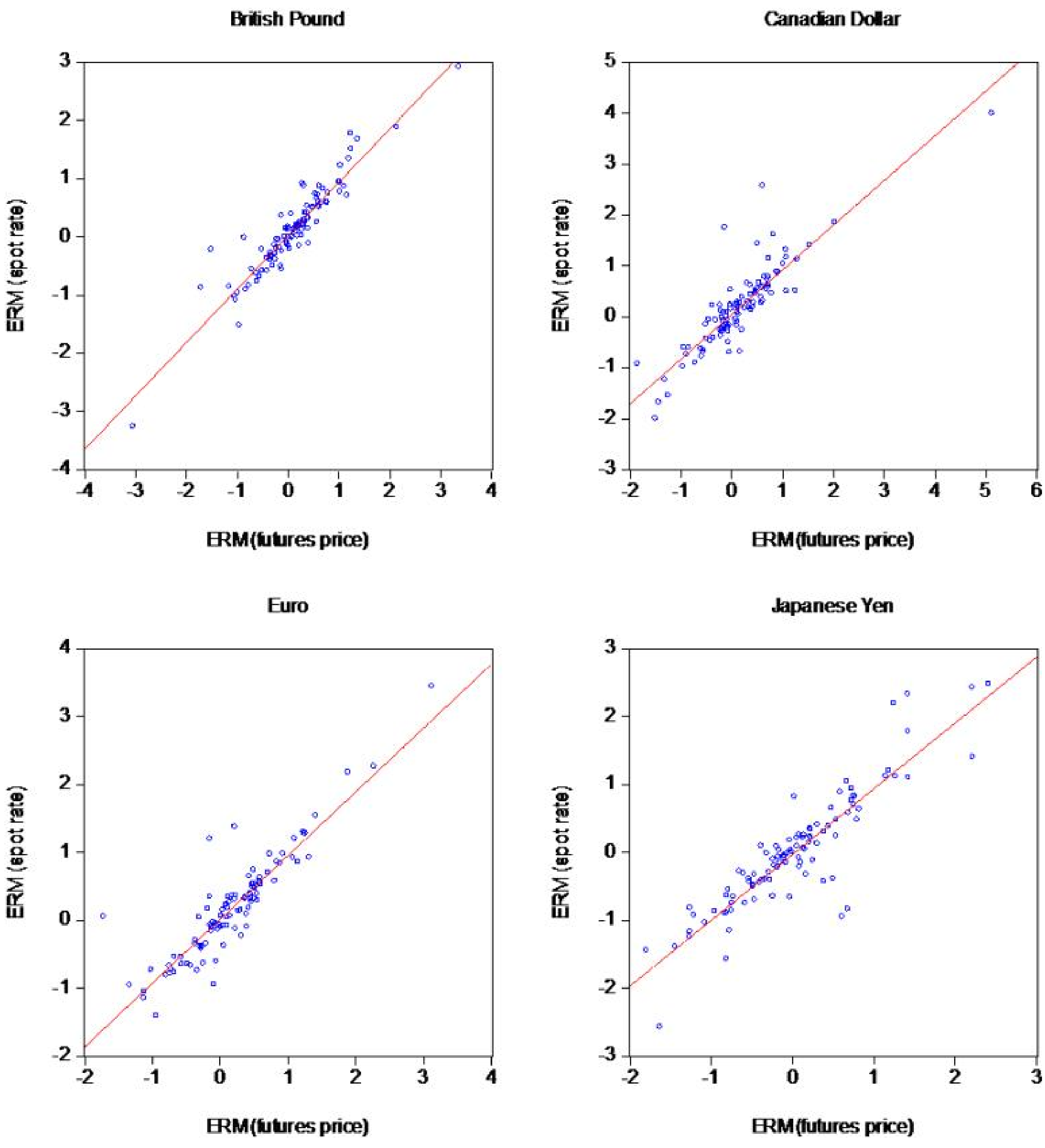
Sample: January 2003 - September 2014, 101 observations

Figure 7: Long-term rate surprises: 10-year spot rate vs. 10-year futures prices



Sample: January 2003 - September 2014, 101 observations

Figure 8: Exchange rate movements: spot rate vs. futures rate



Sample: January 2003 - September 2014, 101 observations

Table 1: The effect of conventional monetary policy (with 5-year expected inflation) on dollar

	α_0	α_1	α_2	R^2	No. obs.
British pound	0.091	-1.844^{**}	7.494^{***}	0.276	49
	(0.090)	(0.687)	(2.051)		
Canadian dollar	0.252^{*}	-0.871	7.029^{**}	0.159	49
	(0.140)	(0.784)	(3.471)		
Euro	0.121	-1.117	2.684^{*}	0.060	49
	(0.087)	(0.966)	(1.374)		
Japanese yen	0.057	-0.842	-4.303^{***}	0.158	49
	(0.103)	(0.697)	(1.235)		
Trade-weighted	0.164	-1.031	3.894^{**}	0.128	49
	(0.111)	(0.837)	(2.263)		

Sample: January 2003 - October 2008

Note: Newey-West standard errors in parentheses. *, **, *** denote significance at 10%, 5%, 1% levels, respectively. Both exchange rate changes and surprises are in percentages, so the slopes can be interpreted as effect of a 1 bp surprise of federal funds rate surprise or expected inflation surprise on the exchange rate in bps.

Table 2: The effect of conventional monetary policy (with 10-year expected inflation) on dollar

	α_0	α_1	α_2	R^2	No. obs.
British pound	0.079	-1.244^{*}	8.448^{***}	0.215	49
	(0.088)	(0.705)	(2.604)		
Canadian dollar	0.243^{*}	-0.344	8.682^{**}	0.147	49
	(0.128)	(0.636)	(3.398)		
Euro	0.117	-0.903	3.038	0.050	49
	(0.084)	(0.975)	(2.005)		
Japanese yen	0.059	-1.114^{*}	-6.416^{***}	0.196	49
	(0.099)	(0.574)	(1.804)		
Trade-weighted	0.158	-0.725	4.502^{*}	0.120	49
	(0.105)	(0.765)	(2.592)		

Sample: January 2003 - October 2008

Note: Newey-West standard errors in parentheses. *, **, *** denote significance at 10%, 5%, 1% levels, respectively. Both exchange rate changes and surprises are in percentages, so the slopes can be interpreted as effect of a 1 bp surprise of federal funds rate surprise or expected inflation surprise on the exchange rate in bps.

Table 3: The effect of unconventional monetary policy (with 5-year bond futures) on dollar

	β_0	β_1	R^2	No. obs.
British pound	0.131	−0.347	0.048	52
	(0.087)	(0.226)		
Canadian dollar	0.021	-0.630^{***}	0.206	52
	(0.100)	(0.144)		
Euro	0.148^{**}	-0.983^{***}	0.418	52
	(0.065)	(0.159)		
Japanese yen	-0.175^{**}	-1.417^{***}	0.675	52
	(0.068)	(0.164)		
Trade-weighted	0.053	-0.850^{***}	0.339	52
	(0.081)	(0.158)		

Sample: November 2008 - September 2014

Note: Newey-West standard errors in parentheses. *, **, *** denote significance at 10%, 5%, 1% levels, respectively. The slopes can be interpreted as effect of a 1 unit unconventional monetary policy surprise on the exchange rate in bps. Negative coefficients indicate dollar appreciation.

Table 4: The effect of unconventional monetary policy (with 10-year bond futures) on dollar

	β_0	β_1	R^2	No. obs.
British pound	0.146	-0.175^{*}	0.045	52
	(0.090)	(0.095)		
Canadian dollar	0.053	-0.267^{***}	0.136	52
	(0.098)	(0.078)		
Euro	0.193^{**}	-0.466^{***}	0.345	52
	(0.075)	(0.105)		
Japanese yen	−0.114	-0.715^{***}	0.631	52
	(0.073)	(0.095)		
Trade-weighted	0.093	-0.397^{***}	0.276	52
	(0.085)	(0.092)		

Sample: November 2008 - September 2014

Note: Newey-West standard errors in parentheses. *, **, *** denote significance at 10%, 5%, 1% levels, respectively. The slopes can be interpreted as effect of a 1 unit unconventional monetary policy surprise on the exchange rate in bps. Negative coefficients indicate dollar appreciation.

Table 5: Adjustment parameter γ_1 and γ_2 for unconventional monetary policy surprises

	γ_0	γ_1	γ_2	R^2	No. obs.
5-year	0.004	1.663^{***}	-0.551^{***}	0.120	101
	(0.032)	(0.323)	(0.079)		
10-year	0.044	1.964^{***}	-3.944	0.068	101
	(0.057)	(0.569)	(3.509)		

Sample: January 2003 - September 2014

Note: γ_1 and γ_2 can be interpreted as the effect of a 1 bp change in the federal funds rate surprise and the expected inflation surprise on the long-term rate surprise. Newey-West standard errors in parentheses. *, **, *** denote significance at 10%, 5%, 1% levels, respectively.

Table 6: Test for structural break in γ_2 at November 2008

H_0: No Structural Break	5-year	10-year
P-value	0.387	0.122

Sample: January 2003 - September 2014

Table 7: federal funds rate surprise channel: conventional vs. adjusted unconventional monetary policy (with 5-year expected inflation)

	Conventional	Adj. Unconventional	Ratio
British pound	-1.844^{**}	-0.577	0.313
Canadian dollar	-0.871	-1.048^{***}	1.203
Euro	-1.117	-1.636^{***}	1.464
Japanese yen	-0.842	-2.357^{***}	2.800
Trade-weighted	-1.031	-1.414^{***}	1.371

Note: Figures in the table can be interpreted as the effects of a 1 bp federal funds rate surprise on the exchange rate in bps. Negative coefficients indicate dollar appreciation. *, **, *** denote significance at 10%, 5%, 1% levels, respectively.

Table 8: federal funds rate surprise channel: conventional vs. adjusted unconventional monetary policy (with 10-year expected inflation)

	Conventional	Adj. Unconventional	Ratio
British pound	−1.244*	−0.343*	0.276
Canadian dollar	−0.344	−0.525***	1.528
Euro	−0.903	−0.916***	1.015
Japanese yen	−1.114*	−1.405***	1.262
Trade-weighted	−0.725	−0.779***	1.075

Note: Figures in the table can be interpreted as the effects of a 1 bp federal funds rate surprise on the exchange rate in bps. Negative coefficients indicate dollar appreciation. *, **, *** denote significance at 10%, 5%, 1% levels, respectively.

Table 9: Expected inflation surprise channel: conventional vs. adjusted unconventional monetary policy (with 5-year expected inflation)

	Conventional	Adj. Unconventional	Ratio
British pound	7.494***	0.191	0.026
Canadian dollar	7.029**	0.347***	0.049
Euro	2.684*	0.542***	0.202
Japanese yen	−4.303***	0.781***	−0.182
Trade-weighted	3.894**	0.469***	0.120

Note: Figures in the table can be interpreted as the effects of a 1 bp expected inflation surprise on the exchange rate in basis points. Negative coefficients indicate dollar appreciation. *, **, *** denote significance at 10%, 5%, 1% levels, respectively.

Table 10: Expected inflation surprise channel: conventional vs. adjusted unconventional monetary policy (with 10-year expected inflation)

	Conventional	Adj. Unconventional	Ratio
British pound	8.448***	0.689*	0.082
Canadian dollar	8.682**	1.054***	0.121
Euro	3.038	1.839***	0.605
Japanese yen	−6.416***	2.822***	−0.440
Trade-weighted	4.502*	1.565***	0.348

Note: Figures in the table can be interpreted as the effects of a 1 bp expected inflation surprise on the exchange rate in basis points. Negative coefficients indicate dollar appreciation. *, **, *** denote significance at 10%, 5%, 1% levels, respectively.

Table 11: Robustness checks of trade-weighted dollar value responses via federal funds rate surprise channel: conventional vs. adjusted unconventional monetary policy

	Conventional	Adj. Unconventional	Ratio
5-year			
Benchmark	-1.031	-1.414^{***}	1.371
Alternative $LongRate\_surp_t$	-1.031	-1.383^{***}	1.342
Alternative $ExchRate\_Mov_t$	-1.664	-1.448^{***}	0.870
Alternative $LongRate\_surp_t$ and $ExchRate\_Mov_t$	-1.664	-1.479^{***}	0.888
10-year			
Benchmark	-0.725	-0.779^{***}	1.075
Alternative $LongRate\_surp_t$	-0.725	-0.715^{**}	0.987
Alternative $ExchRate\_Mov_t$	-1.424	-0.840^{***}	0.590
Alternative $LongRate\_surp_t$ and $ExchRate\_Mov_t$	-1.424	-0.772^{***}	0.542

Note: Figures in the table can be interpreted as the effects of a 1 bp federal funds rate surprise on the exchange rate in basis points. Negative coefficients indicate dollar appreciation. *, **, *** denote significance at 10%, 5%, 1% levels, respectively.

Table 12: Robustness checks of trade-weighted dollar value responses via expected inflation surprise channel: conventional vs. adjusted unconventional monetary policy

	Conventional	Adj. Unconventional	Ratio
5-year			
Benchmark	3.894^{**}	0.469^{***}	0.120
Alternative $LongRate\_surp_t$	3.894^{**}	0.443^{***}	0.114
Alternative $ExchRate\_Mov_t$	3.270	0.480^{***}	0.147
Alternative $LongRate\_surp_t$ and $ExchRate\_Mov_t$	3.270	0.473^{***}	0.145
10-year			
Benchmark	4.502^{*}	1.565^{***}	0.348
Alternative $LongRate\_surp_t$	4.502^{*}	0.926^{**}	0.206
Alternative $ExchRate\_Mov_t$	4.134^{*}	1.687^{***}	0.408
Alternative $LongRate\_surp_t$ and $ExchRate\_Mov_t$	4.134^{*}	1.000^{***}	0.242

Note: Figures in the table can be interpreted as the effects of a 1 bp expected inflation surprise on the exchange rate in basis points. Negative coefficients indicate dollar appreciation. *, **, *** denote significance at 10%, 5%, 1% levels, respectively.