ARMG Publishing "Thinking ahead"

# Monetary Policy Surprises and the Responses of Asset Prices: An Event Study Analysis[1]

**Yucheng Jiang**

PhD, The People's Bank of China, Financial Research Institute, Beijing, China

**Gang Wang**

PhD, Merton M. Sealts, Jr. Visiting Assistant Professor, The College of Wooster, USA

## Abstract

The monetary policy shocks have been widely regarded to have effects on the financial markets. Before the 2008 financial crisis, the Federal Reserve adjusted the federal funds target rate to implement the monetary policy. This paper uses event studies to examine the relationship between the Federal Reserve's interest rate decisions and the asset prices. We find that treasury bills and exchange rates of the developed countries were significantly influenced by the FED's unexpected monetary policy shocks from the year of 1989 to 2008. However, in the same period, exchange rates of the emerging markets responded weakly to the policy surprises. We also have observed that international equity markets and commodity prices were not sensitive to the rate decisions of the Federal Reserve. In addition, Treasury bill yields responded significantly to the anticipated and unanticipated rate decisions in both pre and post FOMC meeting days. We also show that the FED's unexpected monetary policy had significant 5 day post announcement impacts on prices of almost all assets.

**Keywords:** monetary policy, financial markets, federal reserve, rational expectation.

**JEL Classification:** E44, E52, G14, G15.



## 1. Introduction

The interest rate decisions of central banks are very important events in financial markets. The movements of financial asset prices after monetary policy events especially interest the monetary policy makers, since financial markets are the reflections of real economies. Bernanke and Kuttner (2005) once point out that financial markets are the immediate and direct transmission channels that link the monetary policy and real economic activities. The monetary authority, like the central bank, decides monetary policy, directs the financial market through the implementation and expectation, and then influences the real economic activities, such as the output, the unemployment rate, and the price of goods and services. Since financial asset prices are the part of the price equilibrium through investments and financing behaviors, the study of asset price responses to the monetary policy is essential in understanding the transmission mechanism from central bank's monetary policy to the real economy. Furthermore, market participants in the private sector, such as traders and portfolio managers from financial institutions, focus on how asset prices could response before and after the announcements or the implementation of the monetary policy, in order to make better borrowing, lending and investment decisions.

Monetary policy has been demonstrated to have both direct and indirect impacts on almost all asset classes through the adjustment of short term nominal interest rates, given that nominal interest rates are key variables in asset pricing and portfolio choice. The implementation of monetary policies, such as trading on treasury and federal agency securities, have the direct influence on the asset prices' behavior. In the U.S., the trading is implemented by the Federal Reserve Bank of New York through primary dealers, and then followed by the change of interbank borrowing and lending and the fixed income arbitrage from the financial market participants. Previous researchers incorporate event studies to find that the monetary policy has indirect influence on asset prices though signaling the market that the central bank will implement the monetary

[1] We thank the State Administration of Foreign Exchange (SAFE) in China and the People's Bank of China give us useful comments. We thank the seminar participants from the John E. Walker Department of Economics, Clemson University and the Federal Reserve Bank of Atlanta. We thank to Professor Gerald Dwyer for his innovative ideas on gauging market expectation.

policy in future periods. In international finance framework, due to the arbitrage between two countries[2] freely traded floating exchange rate movements are partly driven by interest rate differentials. This theoretical relationship can be derived from the uncovered interest rate parity (UIP) hypothesis where it predicts that high interest currency should depreciate against the low interest rate currency, because profits should be arbitraged away to zero[3].

This paper quantifies the market expectation of the monetary policy. By modeling the price data of forward looking Federal Fund Futures rate (FFR) which is traded at the Chicago Mercantile Exchange (CME), this paper decomposes the Federal Reserve Bank's rate decision into the unexpected and expected components. Previous researchers have found that only the unexpected market news have impacts on asset prices. They give the reason that financial markets can assimilate financial information and learn to be at their "efficient" and "fair" value immediately, because a large number of market participants compete for the best prices[4]. This paper tries to estimate whether and how the Fed's interest rate decisions impact the U.S. asset prices such as treasury prices, U.S. equity prices, U.S. dollar exchange rates and so on. In addition, we also evaluate the spillover effects of changes in the federal funds target rate on international equity and commodity prices.

This paper is arranged by the following theme: Section I gives the introduction; Section II discusses the communication between the Federal Open Market Committee and market participants; Section III briefly investigates the previous related literatures; Section IV presents how we separate the monetary policy change into expected and unexpected parts, and introduces the regression model used in this paper; Section V summarizes the empirical data sets; Section VI discusses the results that how the asset prices respond to the monetary policy surprises on event days; Section VII models the effects in an 11 day event window and studies the responses on 11 event days, through which we can see the drift effects on asset prices of the change of monetary policy; Section VIII concludes.

## 2. Evolution of Central Bank Communication

Before February 1994, there was no public announcement from the Federal Open Market Committee (FOMC) regarding the Fed Fund Target Rate following a FOMC meeting. The financial market's behavior is based on the private sector's observation of the Open Market Operation[5] which is executed by the trading desk of the Federal Reserve Bank of New York. As the transparency increased, the unexpected part of the monetary policy change has been reduced to a lower level, which is consistent with one of the roles for the monetary policy: to sustain financial stability. The monetary authority reacted to outside economic random shocks, such as the spike and the drop of asset prices and financial crisis. Because the bubble and crisis are hard to predict, it is reasonable to expect that unexpected monetary policy will still reappear in the future, although the transparency between Fed and the public has been improved a lot by post-meeting announcements and the FOMC minutes. Our study is still meaningful in revealing the economic behavior based on market expectation and efficiency. Table 2 lists the historic rate decisions by the Federal Reserve from 1989 to 2008, which covers the period of monetary policy mystique (2/24/1989 to 9/4/1992), the period of Alan Greenspan lead policy reaction to the dot-com equity price bubble (11/16/1999 to 5/16/2000), and the period of the sub-prime mortgage crisis (9/18/2007 to 12/16/2008). Figure 1 presents the time series of the Fed Fund Target Rate and Figure 2 displays the historical rate decision. Figure 3 shows the sizes of the unexpected components of the policy changes, where we could observe that there were more unexpected rate decisions in the hidden period prior to 1994. We also could observe that there were less unexpected rate decisions but in greater sizes during the 2000 bubble and the 2007-08 financial crisis periods. The an-

[2] International fixed income arbitrage can be illustrated as a carry trade behavior. By borrowing money from low interest countries and lending them in high interest rate countries, the international investors gain from the interest rate differential and exchange rate appreciation. Usually, U.S. interbank market is an important place for financing and investing, because the U.S. dollar is the most popular currency asset in the money market. In addition, for the low interest rate in the U.S., the U.S. dollar is usually used to fund the investment to increase the leverage. Third, the carry trade between Japan and the U.S. is profitable in some period of time. Thus, the trading activity between the U.S. and Japan is very sensitive to the slight monetary policy between those two countries. For the carry trading, please read Burnside (2011), Daniel Hodrick and Lu(2014) and Jiang(2016).

[3] Regression work of UIP test and the theoretical argument, please read Chinn(2006) and Lothian and Wu(2011). UIP hypothesis is based on the non-arbitrage argument, which is consistent with the efficient market hypothesis and economics theory.

[4] The liquidity in the secondary markets are usually very good and efficient price discovery could be realized by trading activities.

[5] For more research about the transparency of monetary policy, please read: **G**oodfriend (1986), Yellen et al. (2012) and Wynne et al. (2013).

nouncements of the quantitative easing in the U.S. have been found to be significant in impacting domestic and international financial markets, the evidence of which is given by Joyce, Lasaosa, Stevens, Tong, et al. (2011); Glick and Leduc(2012); Wright(2012); Swanson and Williams(2014) and Fawley and Neely(2014).

## 3. Literature review

A large amount of papers examined the relationship between market nominal term structure of interest rates and monetary policy surprises. Since short term interest rates are considered to be the first transmission channel[6] of monetary policy, a lot of researchers studied the nominal interest rates' reaction to monetary policy expectation and implementation, spans from short term to long term, short horizon to long horizons. In addition, the story of Taylor rule tells us that the central bank mainly targeted short-term nominal interest rate in order to control the inflation rate and growth rate of an economy. However, the previous results are mixed. Dwyer and Hafer (1989) tested the unanticipated part of economic data releasing and its impact on nominal interest rate which are implied from mid-term and long term government bonds. They found that releasing of official government statistics has varied impacts on nominal bond interest rate over time by running rolling regression. Other people's findings are also fruitful. Cook and Hahn (1989) found that Fed fund target rate increases are positively related to the T-bill rate (55 bps) and 30 years bond yield (10 bps). Edelberg, Marshall, et al. (1996) found a large, highly significant response of bill rates to policy shocks, but only a small, marginal significant response of bond rates. Kuttner (2001) used the Fed fund futures to gauge the size of the monetary policy and separated it into the expected and unexpected part. He found that short term interest rate only responds to the unexpected change of fed fund rate, but not to the expected change of target rate. Furthermore, long term interest rate is less sensitive to the short term policy changes. By studying the money markets of Australia, New Zealand, Canada, and UK, Kearns, Manners, et al. (2005) found that an unanticipated tightening of 25 basis points policy rate in Australia is associated with exchange rate appreciation of 0.35 percent. Pagano, Lombardi, and Anzuini (2010) found that expansionary U.S. monetary policy shocks drove up the commodity price index and all of its index's components. Hypothetical unanticipated 100 basis points hike in the federal funds target rate is associated with roughly an 3 percent decrease in West Texas Intermediate oil prices, which was been figured out by Rosa (2013). Jansen and Zervou (2015) found that increases in one percentage point surprise of federal fund rate decreases the one day stock return by 1.33 percent during the period of 1989 to 2000, and by 7.47 percent during the period 2001 to 2007, so the effect is varied over different time periods. Bernanke and Kuttner (2005) found that a hypothetical unanticipated 25 basis points cut in the federal fund rates target is associated with about one percent increase in broad stock indexes. In addition, the unanticipated monetary policy actions on expected excess returns accounted for the largest part of the response of stock prices. Fawley and Neely (2014) investigated the related research in recent years and gave the summary to those empirical findings.

## 4. Measuring monetary policy and the empirical model

From the efficient market hypothesis (EMH) proposed by Malkiel and Fama (1970), asset prices only respond to the unanticipated part of the economic information, as the financial markets are forward looking and exhibit future equilibrium. Due to the fact that private entities are majority forces of financial markets, the group decisions of buying and selling assets in a centralized market can improve the market efficiency and help to discover fair values of the assets. Private sectors look at the positive and negative news of the economy and decide to buy or sell securities by their own judgment. Measuring the market expectation can be done by reading the news and comparing the pre and post event news, but quantifying the expectation is not an easy task, since most of the expectation is reflected from the market news. Kuttner (2001) pioneered a tool to quantify the size of the monetary policy shock by using the Federal Fund Rate Futures contract which is an interest rate derivatives traded in Chicago Board of Trade (CBOT). The settlement futures rate is traded by the average of that month's effective fed fund rate, plus a risk premium:

[6] Also the most important channel, Federal Reserve Bank of New York illustrated the monetary policy transmission process as the following steps: the Federal Reserve Bank trades the treasury and federal agent securities market by open market operations, in order to change and influence the fed fund rate in to the target level (policy rate). Fed fund rate is the overnight inter-bank lending rate from one financial institution to another similar financial institution, it's change and controlling by federal reserve can impact other short term interest rate and long term interest rate further. Market interest rate thereby can direct the trader's behavior by arbitrage on financial assets, such as stock market, exchange rate, corporate bonds and other assets, and the change of asset prices can therefore influence the consumer behaviors and real business practice.

$$FFR_{s,t}^{1} = E_t \frac{1}{m}\sum_{i=1}^{m} r_i + \rho_{s,t}^{1} \quad (1)$$

For the equation above, $FFR_{s,t}^{1}$ denotes the yield of the first federal fund futures contract[7] at day $t$ of month $s$, which is equal to the expected average federal fund rate, $r_i$ , from day 1 to day $m$ in that month. We assume that month $s$ has total $m$ days, and $\rho_{s,t}^{1}$ is the risk premium for the first futures contract. From the past observation of data sets, we can decompose the futures rate further by:

$$FFR_{s,t}^{1} = \frac{1}{m}\sum_{i=1}^{t} r_i + E_t \frac{1}{m}\sum_{i=t+1}^{m} r_i + \rho_{s,t}^{1} \quad (2)$$

Then, we have:

$$FFR_{s,t}^{1} = \frac{t}{m}\bar{r}_{i\le t} + \frac{m-t}{m} E_t \bar{r}_{i>t} + \rho_{s,t}^{1} \quad (3)$$

Where $\bar{r}_{i\le t}$ is the average effective fed fund rate before rate decision day $d$ and $E_t \bar{r}_{i>t}$ is the expected average fed fund rate after rate decision in month $s$. Kuttner (2001) thinks that the difference in fed future rate in the FOMC rate decision day correctly captures the market difference in expectation before and after the rate decision[8]. Then we could quantify the unexpected rate decision by the following formula:

$$FFR_{s,t}^{1} - FFR_{s,t-1}^{1} \approx \frac{m-t}{m}\Delta FFR_t^{unexpected} \quad (4)$$

Consequently, the unexpected part of the fed fund rate decision could be computed by:

$$\Delta FFR_t^{unexpected} = \frac{m}{m-t}(FFR_{s,t}^{1} - FFR_{s,t-1}^{1}) \quad (5)$$

One concerning about using the difference of the event day's closing price to measure the unexpected part of the rate decision is that other data releases and information shock could contaminate the event day's federal fund futures price behaviors. However, most of the data releases and fundamental changes have been reflected in the future monetary policy behavior. Over the very short horizons, monetary policy is the major driven force of the short-term interest rate, thus we do not need to worry about other informational shocks.

---

[7] FFR stands for Federal Fund Futures Rates, which is calculated by $FFR_{s,t}^{1} = 100 - Futures\_prices_{s,t}^{1}$ in this paper's data transformation processes. We have the data sets of the form like Futures Prices, which is quoted by the 100 - interest rate (%) in Chicago Board of Trade (CBOT).

[8] The quantitative measure of the change of the FFR in two different day is:

$$FFR_{s,t}^{1} - FFR_{s,t-1}^{1} = \frac{t}{m}\bar{r}_{i\le t} + \frac{m-t}{m}E_t\bar{r}_{i>t} + \rho_{s,t}^{1} - \frac{t-1}{m}\bar{r}_{i\le t-1} - \frac{m-(t-1)}{m}E_{t-1}\bar{r}_{i>t-1} - \rho_{s,t-1}^{1}$$

$$= \frac{t-1}{m}\bar{r}_{i\le t-1} + \frac{1}{m}r_{i=t-1} + \frac{m-t}{m}E_t\bar{r}_{i>t} + \rho_{s,t}^{1} - \frac{t-1}{m}\bar{r}_{i\le t-1} - \frac{m-t}{m}E_{t-1}\tilde{r}_{i>t} - \frac{1}{m}r_{i=t-1} - \rho_{s,t-1}^{1}$$

$$\approx \frac{m-t}{m}\Delta FFR_t^{unexpected}$$

Finally, we have the approximate difference in expectation on target federal fund rate: $\Delta FFR_t^{unexpected} = E_t\bar{r}_{i>t} - E_{t-1}\tilde{r}_{i>t}$.

Once we have computed the unexpected component of the rate decision, then we can compute the expected component of the rate decision by subtracting the unexpected component from the actual rate decision. The variables have the following relationships:

$$\Delta FFR_t^{expected} = \Delta FFR_t - \Delta FFR_t^{unexpected} \quad (6)$$

One day response is usually enough to detect the surprising effect, since the asset prices after event day could be easily contaminated by other information, but we will examine the effect in the last section by extending our regression framework into more event days[9] . In this paper, we add a GARCH(1,1) process to detect the relationship between monetary policy and asset prices response in event days. The estimation of the monetary policy on asset prices can be written as the following function:

$$R_t = \gamma_0 + \gamma_1 \Delta FFR_t^{expected} + \gamma_2 \Delta FFR_t^{unexpected} + \varepsilon_t \quad (7)$$

Besides, we assume different variance across time period that:

$$\varepsilon_t \mid \varepsilon_{t-1}, \varepsilon_{t-2}, \varepsilon_{t-3}, \ldots \sim N(0, u_t^2) \quad (8)$$

Where

$$u_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 u_{t-1}^2 \quad (9)$$

In the equation above, $R_t \approx \log(P_t) - \log(P_{t-1})$ denote the return of asset prices in the event date $t$ compares to the previous date $t-1$. $P_1$ is the asset prices at day $t$ and $P_{t-1}$ is the asset prices at day $t-1$, which is the closing price before interest rate decision date. $\gamma_0$, $\gamma_1$ and $\gamma_2$ denote the regression coefficients for equation (7), they are the reflection of the size of the monetary policy effect. We assume that the error term $\varepsilon_t$ is distributed normally, but we relax the assumption that it is independent and identically distributed (IID). Thus, in this paper, a GARCH(1,1) model, which is introduced by Bollerslev (1986), based on the pioneering work of Engle (1982) on ARCH, has been employed to estimate the process of variation in variances of the time series regression error term $\varepsilon_t$. The GARCH specification is illustrated by the equation (9), while $\beta_0$, $\beta_1$ and $\beta_2$ are the coefficients of maximum likelihood estimation (MLE) based on the GARCH(1,1) processes. $\varepsilon_{t-1}^2$ is the squared last period residual estimate, and $u_{t-1}^2$ is the variances of the error term. We study the event day's response of multiple asset prices to the unexpected and expected part of the monetary policy.

## 5. The datasets

The datasets in this paper are collected mainly through Bloomberg. We use the first month Fed Fund Futures to gauge the size of the monetary policy shock. The daily time series with closing settlement price spans from February 1989 to December 2008. Given the superiority of the futures market data on predicting policy behavior, we use the possible maximum length of the Fed Fund Futures data from the first listed futures contract in 1989 to the post-crisis unconventional monetary policy period futures data in 2008. For the asset price's response part, we incorporate different kinds of asset classes in our research, based on the theory of transmission channels' signaling effect. First, we study the response of the term structure of interest rate in U.S. The yield curve is constructed based on the implied nominal interest rate of 3, 6, and 12 months; 2, 5, 10 and the 30 years Treasury securities. The dependent variables are the differences in basis points in the study of Treasury securities. For currencies, we select the group 10 (G-10) exchange rates which are the popular currency pairs in trading volume: U.S. Dollar (USD), EURO (EUR), Pounds Sterling (GBP), Swiss Franc (CHF), Japanese Yen (JPY), Canadian Dollar (CAD), Australian Dollar (AUD), New Zealand Dollar (NZD), Swedish Krona (SEK), Norwegian Krone (NOK). In addition, 9 Emerging market currency pairs are

[9] In addition, direct observation of trading behaviors supports the argument that most of the unexpected announcement can drive the asset prices in that day, but it also disappears very fast.

added in the study: Brazilian Real (BRL), South African Rand (SAR), Polish Zloty (PLN), Romanian Leu (RON), Indian Rupee (INR), Czech Koruna (CZK), Chilean Peso (CLP), Hungarian Forint (HUF), and Mexican Peso (MXN). Equities Indexes are studied, both for developed and developing countries. We include S&P 500 index as the approximate response of U.S. equity market; Nikkei 225 for Japan; DAX for Germany or Euro Areas; FTSE 100 for United Kingdom; Hang Seng Index which is traded in Hong Kong for Chinese Companies; and IBOVESPA Index for Brazilian Listed Companies. Commodities Prices also have been added, they are Gold Spot Prices and the first contract of WTI Crude Oil Futures in Chicago Mercantile Exchange (CME). Table 1 summarizes the information of financial market data sets. Figure 1 plotted the historical level of the fed fund target rate. In recent years, the short term interest rate is not so volatile and it is neither not so serially correlated, but the Federal Reserve usually adjusts their bench market policy rate consecutively, followed by several times of rate hiking or rate cutting.

## 6. Effects of the Federal Reserve's interest rate decisions

The Federal Open Market Committee (FOMC) sets the federal funds target rate at a level that can improve the macroeconomic condition. After an interest decision announcement, the 3-month and 6-month Treasury rates will respond first, followed by the movements of the long-term Treasury rates[10]. In addition, foreign exchange rates, domestic and international stock market prices, and the commodities prices are other asset prices that the short term target rate can influence further.

### A. Effects on interest rates

The long-term interest rate is the future period short-term interest rate, and thus is partly determined by the short-term rate through the yield curve arbitrages. Figure 4 displays the time series of the short-term and the long-term interest rates in the US. From the graph, we can observe directly that the correlations among interest rates are very high. The closely related price pattern for treasury securities is consistent with the story that the Fed can impact the short-term interest rates and thereby change the long-term interest rates. Table 4, Panel A reports the results of the regression indicated by equation (7) and equation (9). We also observe that only the unexpected changes of the monetary policy influenced the treasury rates significantly. Although the 3-month and 6-month rates are sensitive to the expected part of the rate decision, the sizes of sensitivity are very small, which are only one fourth of the sizes of the coefficients from unexpected rate decision. Specifically, an unexpected 100 basis points (bps) cut of the federal funds target rate will lower the 3-month treasury rate by 44 bps, the 6-month by 37 bps, the 1-year by 33 bps, the 2 year by 31 bps, the 5 year by 23 bps, the 10 year by 9 bps and the 30 year by 2 bps. The impacts on yield curve favored the short-term interest rates more than the long-term ones. At the same time, the goodness of fit ( $R^2$ ) of the regressions decreased as the dependent variables changed from short-term to long-term interest rate changes. Volatility prediction is mixed, some variances are significantly related to the past variances, while some are significantly related to the past squared residuals. Our results on interest rate responses to the monetary policy surprises are consistent with the previous study done by Kuttner (2001), the sample length of which spans from 1989 to 2000[11].

Next, we conduct a new study by excluding the rate decision observations from the dot-com bubble (1999-2000) and sub-prime mortgage crisis period (2007-2008). The regression results are shown in Table 4, Panel B. In response to the persistent soaring of high tech company stock prices, the Fed[12] held four consecutive interest hikes from 5.25 percent to 6.5 percent, from December 16, 1999 to the May 16, 2000. From the September 18, 2007 to the December 16, 2008, the Fed cut the federal fund rate from 5.25 percent to 0-0.25 percent level. The purpose of the prompt rate cut is to support the falling housing prices, boost investments and consumption activities, provide liquidity to the market, and finally try to bail out the economy from the crisis. These periods are different from the normal policy time, since most of the decisions are temporal and

[10] Long term rates move after short term rates since a long term rate is a traded future short term rate.

[11] This part is similar to Kuttner (2001) and Bernanke and Kuttner (2005) in ideas and objective, but the data and the model is different. We have better data quality to test the hypothesis. We derived the futures contract's expectation formation process, as well as the modeling in volatility by GARCH(1,1), a non linear relationship is included. And the assumption of IID error term is also relaxed due to the time series data's property. This is paper is different from Jansen and Zervou (2015) in data sample selection, ideas and objectives.

[12] The Federal Reserve is chaired by Alan Greenspan during the dot-com bubble period, so as the related monetary policies.

emergent reactions to market volatility. After excluding the observations in Bubble and Crisis periods, however, the results are not much different from the results by using the full data sample.

We also estimate the shift of the Treasury yield curve during the interest rate decision events. Figure 5 displays a shift of the yield curve when the market encountered a monetary policy surprise during 2007-08 financial crisis periods. The Fed cut the target interest rate by 75 bps from 4.25 percent to 3.5 percent. However, the federal funds futures rate only implied a modest 9 bps decrease, which led to a 66 bps decrease of unexpected component. The results are consistent with previous findings in this paper(Table 4, Panel A, B) that the short term interest rates of the yield curve lowered more than the long term interest rates. We also observe that after an unexpected cut of federal funds target rate, the yield curve shifted downward and became steeper. The uncertainty of the future monetary policy can explain the more sensitivity of short-term rates than long-term rates to the Fed's interest rate decisions.

**B. Effects on foreign exchange rates**

In theory, an increase in the US interest rate will cause capital inflow to the US, induce investor to buy more dollars, and appreciate the US dollar against other currencies. In this part, we estimate the effects of the Fed's interest rate decisions on the exchange rates of foreign currencies in G-10 and emerging economies, and we treat US dollar as the basis currency. We run the regressions by replacing the dependent variables as the foreign exchange rate returns and report the results in Table 5. In general, an unexpected hike of the federal funds target rate appreciated US dollar against other currencies. In the case of using full data sample, an unexpected 100 bps increase in the federal funds target rate depreciated G-10 currencies enormously on the same day, except for Euro (EUR) and Great Britain Pound (GBP). Similarly, emerging currencies, especially Russian Rubble (RUB), South Africa Rand (ZAR) and Czech Republic Koruna (CZK) depreciated a lot on the same day of the event. When excluding the dot-com bubbles and financial crisis periods and rerun the regressions, we observe that although foreign currencies depreciated on the event day, the sizes of depreciation diminished. This difference tells use that foreign exchange rates were more sensitive to the US monetary policy shocks in the crisis periods than in the ordinary periods. In addition, the results are much different from the results of the treasury market, in which the responses of treasury rates to monetary policy shocks are indifferent whether crisis periods are excluded or not.

***C.* Effects on equity prices**

Although previous findings claim that monetary policy drives U.S. equities market, Bernanke and Kuttner (2005), Jansen and Zervou (2015), we find insignificant responses of equity prices in the US and international equity markets to the unexpected changes of the Fed's interest rate decisions. The results do not vary so much even when we exclude the bubble and crisis periods.

**D. Effects on commodities prices**

Although Bernanke (2013)[13] held a negative view of predicting gold prices, we find that the Fed's monetary policy shocks did have significant impacts on gold prices. From Table 7, an unexpected 100 bps increase in the federal funds target rate led to a 46 bps decline of the gold spot price return with full data sample and a 57 bps decline when bubble and crisis periods are excluded. As gold prices are considered as the indicator of future period inflation, our results further indicate that the Fed's interest rate shocks have influence on the expected inflation as well. We find the unexpected increase in the federal funds target rate boosted the oil futures price, however, the effects were not statistically significant.

## 7. Pre-meeting and post-meeting effects

In order to know financial markets' behaviors around the Fed's interest rate decisions, we then evaluate the responses of asset prices in an 11-day event window[14]. We regress the asset return on each day in the event window on expected and unexpected parts of the monetary policy change on the event day. The regression is expressed as:

$$R_{t+i} = \gamma_{0i} + \gamma_{1i}\Delta FFR_t^{expected} + \gamma_{2i}\Delta FFR_t^{unexpected} + \varepsilon_{t+i} \quad (10)$$

[13] For more details of Bernanke's speech, please click the link below: http://business.financialpost.com/news/economy/ben-bernanke-nobody-understands-gold-prices-including-me.

[14] A symmetric window with five pre-event days and five post-event days.

For the formula showed above, $i \in [-5,5]$ and $R_{t+i}$ denotes the asset returns on day $t + i$ in an event window. Through the empirical estimation on this regression function's coefficients, we can observe the movements of asset prices before and after an interest rate decision. Table 8, 9, and 10 show the effects of expected and unexpected monetary policy changes on prices of assets in different markets. From Table 8, we see that unexpected policy effects are larger in magnitude than expected policy effects in general. Although the asset returns of 1 day before and 1 day after the FOMC rate decision days are significantly impacted by the rate decision of the Fed, the coefficients are much smaller. The non-event day coefficients are only 1/3 or 1/4 of the size of the event days. When comparing the effects on Treasury rates of different maturities, we find that the monetary policy shocks have significant pre-meeting and post-meeting effects only on the short-term rates, but not on the long term rates. For instance, the 3-month and 6-month Treasury rates both increased by about 11 bps one day before the event day, the 1-year and 2-year Treasury rates only increased by about 8 bps, while the increases of longer term Treasury rates are tiny and insignificant. Figure 6 shows the coefficients of [-5, 5] event window estimation of the monetary policy's effect. We can conclude that only the unexpected monetary policy shock could impact the bond yield. In most of the cases, they have impacts on event day 0, but continue to event day +1 and +3.

From Table 9, we find serious post-announcement effects on exchange rates, but the effects diminished after the 4th and the 5th days. Post-announcement effects can be interpreted as the under reaction of markets, while the efficient markets hypothesis does not hold. For example, an unexpected 100 basis points cut of the Federal Funds rate target appreciated Swedish Krona vs U.S. dollars (SEK/USD) exchange rate by 0.61% on day 0 and 0.45% on day 1, while the exchange rate only depreciated by 0.34% on day 4 and 0.35% on day 5. For another example, after an unexpected increase of 100 bps of the Federal funds rate target, the Great Britain Pound (GBP) appreciated by 0.38% on day 0 and 0.50% on day 1. However, started from the day 2, the GBP depreciated and the depreciation were getting larger in the following days. Similar results can be seen from most of the exchange rates.

Different from the previous results, in Table 10, we do not find any evidence of significant one day effects of monetary policy shock on equity prices. However, it is obvious that the equities indices in other countries are negatively related to the unexpected interest rate hikes of the federal funds rate target. For instance, a 100 bps unexpected increase in the federal funds rate target decreased Hong Kong's Hang Seng Index by 2.84% on the 2nd event day, and then the index return continued to decline on the 3rd and the 5th days.

## Conclusions

This paper uses event studies in a macroeconomic framework to study the responses of a broad class of assets to monetary policy surprises in the US. The assets include U.S. government bonds and equities, U.S. dollar against the major G-10 and major emerging market currencies, international stock markets, and commodity prices. We use the Federal Fund Futures rate to gauge the market expectation of the interest rate decision of the FOMC and separate the market expectation on target rate decision into unexpected and expected components. By using GARCH(1,1) specification in a one day event horizon, we find that treasury bills and exchange rates of developed countries were significantly influenced by the unexpected component of the Fed's monetary policy from 1989 to 2008, while emerging market exchange rates responded weakly to the Fed's monetary policy surprises. In addition, we find that international equity and commodity markets were not sensitive to the Fed's monetary policy in an one day horizon. Given one day window case, the results are different when we extend the event window into 11 days (i.e., [-5, 5]). The unexpected component of the monetary policy impacted the financial markets in a long horizon, which is contrary to the efficient market hypothesis. Almost all of the financial assets in our study significantly responded to the monetary policy shock during five days after the meeting. However, the results are slightly different among bond yields, foreign exchange rates and international equities. When encountering an unexpected increase in federal funds rate, the Treasury bills had late responses but not midterm notes and long term bonds. In other words, they responded a little before the decision makings of the interest rate, which infers that the bond markets are more informative than other financial markets. The exchange rates had a mean reversion behavior on post-meeting days, which means after rate decision date, they usually recovered back in the next few days. Non-US equity markets were not affected by the Fed's monetary policy shock so much. However, a surprise in Fed's monetary policy had effects on the U.S. stock market for several days which could consecutively influence non-US stock markets, especially the emerging markets. Further studies could be conducted to show that how long the monetary policy influenced each asset price and how many days the effects were persisting.

## References


1. Bernanke, Ben (2013). Ben Bernanke: Nobody understands gold prices, including me. Financial Post.
2. Bernanke, Ben S., and Kenneth N. Kuttner (2005). What explains the stock market's reaction to federal reserve policy? *The Journal of Finance*, 60, 1221–1257.
3. Bollerslev, Tim (1986). Generalized autoregressive conditional heteroskedasticity, *Journal of Econometrics*, 31, 307–327.
4. Burnside, Craig (2011). Carry trades and risk. *Technical report*, National Bureau of Economic Research.
5. Chinn, Menzie D. (2006). The (partial) rehabilitation of interest rate parity in the floating rate era: Longer horizons, alternative expectations, and emerging markets. *Journal of International Money and Finance*, 25, 7–21.
6. Cook, Timothy, and Thomas Hahn (1989). The effect of changes in the federal funds rate target on market interest rates in the 1970s. *Journal of Monetary Economics*, 24, 331–351.
7. Daniel, Kent, Robert J. Hodrick, and Zhongjin Lu (2014). The carry trade: Risks and drawdowns. *Technical report*, National Bureau of Economic Research.
8. Dwyer Jr., Gerald P., and Rick W. Hafer (1989). Interest rates and economic announcements, Review. *Working papers 2005-064*, Federal Reserve Bank of St. Louis.
9. Edelberg, Wendy, David Marshall et al. (1996). Monetary policy shocks and long-term interest rates, *Economic Perspectives -Federal Reserve Bank of Chicago*, 20, 2–17.
10. Engle, Robert F. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of united kingdom inflation, *Econometrica: Journal of the Econometric Society*, 987–1007.
11. Fawley, Brett W., and Christopher J. Neely (2014). The evolution of federal reserve policy and the impact of monetary policy surprises on asset prices. Federal Reserve Bank of St. Louis, *Review 96*.
12. Glick, Reuven, and Sylvain Leduc (2012). Central bank announcements of asset purchases and the impact on global financial and commodity markets. *Journal of International Money and Finance*, 31, 2078–2101.
13. Goodfriend, Marvin (1986). Monetary mystique: Secrecy and central banking, *Journal of Monetary Economics*, 17, 63–92.
14. Jansen, Dennis W., and Anastasia S. Zervou (2015). The time varying effect of monetary policy surprise on stock returns: Bursting bubble beating forward guidance.
15. Jiang, Yucheng (2016). *Essays on Empirical Monetary and Financial Economics*.
16. Joyce, Michael, Ana Lasaosa, Ibrahim Stevens, Matthew Tong et al. (2011). The financial market impact of quantitative easing in the United Kingdom. *International Journal of Central Banking*, 7, 113–161.
17. Kearns, Jonathan, Phil Manners et al. (2005). The impact of monetary policy on the exchange rate: A study using intraday data. *Research Discussion Paper – RDP 2005-02*.
18. Kuttner, Kenneth N. (2001). Monetary policy surprises and interest rates: Evidence from the fed funds futures market. *Journal of Monetary Economics*, 47, 523–544.
19. Kuttner, Kenneth N., Patricia C. Mosser et al. (2002). The monetary transmission mechanism: some answers and further questions. *Federal Reserve Bank of New York. Economic Policy Review*, 8, 15–26.
20. Lothian, James R., and Liuren Wu (2011). Uncovered interest-rate parity over the past two centuries. *Journal of International Money and Finance*, 30, 448–473.
21. Malkiel, Burton G., and Eugene F. Fama (1970). Efficient capital markets: A review of theory and empirical work. *The Journal of Finance*, 25, 383–417.
22. Pagano, Patrizio, Marco Lombardi, and Alessio Anzuini (2010). The impact of monetary policy on commodity prices. *ECB working paper 1232*.
23. Rosa, Carlo (2013). The financial market effect of fomc minutes. *Economic Policy Review*, 19.
24. Swanson, Eric T., and John C. Williams (2014). Measuring the effect of the zero lower bound on medium-and longer-term interest rates. *The American Economic Review*, 104, 3154–3185.
25. Wright, Jonathan H. (2012). What does monetary policy do to long-term interest rates at the zero lower bound? *The Economic Journal*, 122, F447–F466.
26. Wynne, Mark A. et al. (2013). A short history of fomc communication. *Economic Letter*, 8.
27. Yellen, Janet L. et al. (2012). Revolution and evolution in central bank communications: a speech at the Hass School of Business. University of California, Berkeley, Berkeley, California, November 13, 2012, *Technical report*.

## Appendices

Table 1. Summary of data sets and key variables

This table reports the source of the data sets and the time span of the financial market data. They are daily frequency. Most the data sets are drawn from the Bloomberg Terminal. We use spot exchange rate, interest rate, commodities and equities index to identify the response of the financial markets, which are supposed to play the same role when other people use the futures contract of those financial assets. After Dec 2008, the Federal Reserve had kept the fed fund target rate into 0-0.25 percent level, and although the futures prices are available, there is no rate decision since 2015. While before 1989 Feb, the Futures contract of the fed fund rate has not been introduced, thus the data is not available for researchers.

| *Financial Market Variables* | *Source of Data* | *Sample Periods* | *Frequency* |
|---|---|---|---|
| Front Month Fed Fund Futures Contract #1 | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Front Month Fed Fund Futures Contract #2 | Quandl | Feb 1989-Dec 2008 | Daily |
| U.S. 3 Month Treasury Bill | Bloomberg | Feb 1989-Dec 2008 | Daily |
| U.S. 6 Month Treasury Bill | Bloomberg | Feb 1989-Dec 2008 | Daily |
| U.S. 12 Month Treasury Bill | Bloomberg | Feb 1989-Dec 2008 | Daily |
| U.S. 2 Year Treasury Notes | Bloomberg | Feb 1989-Dec 2008 | Daily |
| U.S. 5 Year Treasury Notes | Bloomberg | Feb 1989-Dec 2008 | Daily |
| U.S. 10 Year Treasury Notes | Bloomberg | Feb 1989-Dec 2008 | Daily |
| U.S. 30 Year Treasury Bonds | Bloomberg | Feb 1989-Dec 2008 | Daily |
| U.S. S&P 500 Index | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Japan, Nikkei 225 Index | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Hong Kong (PRC), Hang Seng Index | Bloomberg | Feb 1989-Dec 2008 | Daily |
| U.K., FTSE 100 Index | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Germany, DAX Index | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Gold Spot Prices, U.S. dollar denominated | Bloomberg | Feb 1989-Dec 2008 | Daily |
| CME, WTI Crude Oil Futures, Contract #1 | Bloomberg | Feb 1989-Dec 2008 | Daily |
| EURO, EUR Spot Exchange Rate | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Pounds Sterling, GBP Spot Exchange Rate | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Swiss Franc, CHF Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Japanese Yen, JPY Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Canadian Dollar, CAD Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Australian Dollar, AUD Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| New Zealand Dollar, NZD Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Sweden Krone, SEK Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Norwegian Krone, NOK Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Brazilian Real, BRL Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| South African Rand, ZAR Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Polish Zloty, PLN Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Romanian Leu, RON Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Indian Rupee, INR Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Czech Koruna, CZK Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Chilean Peso, CLP Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Hungarian Forint, HUF Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |
| Mexican Peso, MXN Spot | Bloomberg | Feb 1989-Dec 2008 | Daily |

ARMG Publishing "Thinking ahead"

## Table 2. Historic Rate Decision for U.S. Federal Reserve Board, Feb 1989 to Dec 2008

Table 2 lists the historic rate decision. The Mystique periods (orange colored) are the times before February 1994, the FOMC did not announce their rate decision, but implemented the monetary policy through Open Market Operation through the trading desk of the New York Fed. The Grey color area covers the period of bubble and financial crisis periods. The orange area covers the periods of no announcement monetary policy periods.

| Date | Changes | New level | | Time | Methods of announcement | Intermeeting? | Unexpected | Expected |
|---|---|---|---|---|---|---|---|---|
| 12/16/2008 | -1 | 0-0.25 | | 2:15 PM | Post-meeting press release | | -0.11 | -0.89 |
| 10/29/2008 | -0.5 | 1 | | 2:15 PM | Post-meeting press release | | -0.28 | -0.22 |
| 10/8/2008 | -0.5 | 1.5 | | 7:00 AM | Immediate release (press release) | | -0.14 | -0.36 |
| 4/30/2008 | -0.25 | 2 | | 2:15 PM | Post-meeting press release | | 0.3 | -0.55 |
| 3/18/2008 | -0.75 | 2.25 | | 2:15 PM | Post-meeting press release | | 0.16 | -0.91 |
| 1/30/2008 | -0.5 | 3 | | 2:00 PM | Intermeeting press release | Y | 0 | -0.5 |
| 1/22/2008 | -0.75 | 3.5 | | 2:00 PM | Post-meeting press release | | -0.67 | -0.08 |
| 12/11/2007 | -0.25 | 4.25 | | 2:00 PM | Intermeeting press release | Y | 0.01 | -0.26 |
| 10/31/2007 | -0.25 | 4.5 | | 2:15 PM | Post meeting press release | | 0 | -0.25 |
| 9/18/2007 | -0.5 | 4.75 | | 2:15 PM | Post meeting press release | | -0.14 | -0.36 |
| 6/29/2006 | 0.25 | 5.25 | | 2:15 PM | Post-meeting press release | | -0.08 | 0.33 |
| 5/10/2006 | 0.25 | 5 | | 2:00 PM | Discount rate change press release | Y | -0.01 | 0.26 |
| 3/28/2006 | 0.25 | 4.75 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 1/31/2006 | 0.25 | 4.5 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 12/13/2005 | 0.25 | 4.25 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 11/1/2005 | 0.25 | 4 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 9/20/2005 | 0.25 | 3.75 | | 2:15 PM | Post meeting press release | | 0.01 | 0.24 |
| 8/9/2005 | 0.25 | 3.5 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 6/30/2005 | 0.25 | 3.25 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 5/3/2005 | 0.25 | 3 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 3/22/2005 | 0.25 | 2.75 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 2/2/2005 | 0.25 | 2.5 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 12/14/2004 | 0.25 | 2.25 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 11/10/2004 | 0.25 | 2 | | 2:15 PM | Post meeting press release | | 0 | 0.25 |
| 9/21/2004 | 0.25 | 1.75 | | 2:15 PM | Post meeting press release | | 0.02 | 0.23 |
| 8/10/2004 | 0.25 | 1.5 | | 2:15 PM | Post meeting press release | | 0.02 | 0.23 |
| 6/30/2004 | 0.25 | 1.25 | | 2:15 PM | Post meeting press release | | 0.15 | 0.1 |
| 6/25/2003 | -0.25 | 1 | | 2:15 PM | Post meeting press release | | 0 | -0.25 |
| 11/6/2002 | -0.5 | 1.25 | | 2:15 PM | Post meeting press release | | -0.19 | -0.31 |
| 12/11/2001 | -0.25 | 1.75 | | 2:15 PM | Post meeting press release | | 0 | -0.25 |
| 11/6/2001 | -0.5 | 2 | | 2:20 PM | Post meeting press release | | -0.1 | -0.4 |
| 10/2/2001 | -0.5 | 2.5 | | 2:15 PM | Post meeting press release | | -0.07 | -0.43 |
| 9/17/2001 | -0.5 | 3 | | 8:20 AM | Intermeeting press release | Y | -0.3 | -0.2 |
| 8/21/2001 | -0.25 | 3.5 | | 2:15 PM | Post meeting press release | | 0.01 | -0.26 |
| 6/27/2001 | -0.25 | 3.75 | | 2:12 PM | Post meeting press release | | 0.04 | -0.29 |
| 5/15/2001 | -0.5 | 4 | | 2:15 PM | Post meeting press release | | -0.07 | -0.43 |
| 4/18/2001 | -0.5 | 4.5 | | 10:54 AM | Intermeeting press release | Y | -0.39 | -0.11 |
| 3/20/2001 | -0.5 | 5 | | 2:15 PM | Post meeting press release | | 0.05 | -0.55 |
| 1/31/2001 | -0.5 | 5.5 | | 2:15 PM | Post meeting press release | | 0 | -0.5 |
| 1/3/2001 | -0.5 | 6 | | 1:13 PM | Intermeeting press release | Y | -0.01 | -0.49 |
| 5/16/2000 | 0.5 | 6.5 | | 2:15 PM | Post meeting press release | | 0.05 | 0.45 |
| 3/21/2000 | 0.25 | 6 | | 2:15 PM | Post meeting press release | | -0.03 | 0.28 |
| 2/2/2000 | 0.25 | 5.75 | | 2:15 PM | Post meeting press release | | -0.05 | 0.3 |
| 11/16/1999 | 0.25 | 5.5 | | 2:15 PM | Post meeting press release | | 0.08 | 0.17 |
| 8/24/1999 | 0.25 | 5.25 | | 2:15 PM | Post meeting press release | | 0.02 | 0.23 |
| 6/30/1999 | 0.25 | 5 | | 2:15 PM | Post meeting press release | | -0.3 | 0.55 |
| 11/17/1998 | -0.25 | 4.75 | | 2:15 PM | Post meeting press release | | -0.05 | -0.2 |

Table 2 (cont.). Historic Rate Decision for U.S. Federal Reserve Board, Feb. 1989 to Dec. 2008

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10/15/1998 | -0.25 | 5 | | 3:15 PM | Intermeeting press release | Y | 0.04 | -0.29 |
| 9/29/1998 | -0.25 | 5.25 | | 2:15 PM | Post meeting press release | | 0 | -0.25 |
| 3/25/1997 | 0.25 | 5.5 | | 2:15 PM | Post meeting press release | | 0.04 | 0.21 |
| 1/31/1996 | -0.25 | 5.25 | | 2:15 PM | Post meeting press release | | -0.16 | -0.1 |
| 12/19/1995 | -0.25 | 5.5 | | 2:15 PM | Post meeting press release | | -0.1 | -0.15 |
| 7/6/1995 | -0.25 | 5.75 | | 2:15 PM | Post meeting press release | | -0.01 | -0.24 |
| 2/1/1995 | 0.5 | 6 | | 2:15 PM | Post meeting press release | | 0.05 | 0.45 |
| 11/15/1994 | 0.75 | 5.5 | | 2:20 PM | Post meeting press release | | 0 | 0.75 |
| 8/16/1994 | 0.5 | 4.75 | | 1:18 PM | Post meeting press release | | 0 | 0.5 |
| 5/17/1994 | 0.5 | 4.25 | | 2:26 PM | Post meeting press release | | 0.13 | 0.37 |
| 4/18/1994 | 0.25 | 3.75 | | 10:06 AM | Post meeting press release | | 0.09 | 0.16 |
| 3/22/1994 | 0.25 | 3.5 | | 2:20 PM | Post meeting press release | | -0.03 | 0.28 |
| 2/4/1994 | 0.25 | 3.25 | | 11:05 PM | Post meeting press release | | 0.11 | 0.14 |
| 9/4/1992 | -0.25 | 3 | | 11:30 AM | Open market operation | Y | -0.21 | -0.04 |
| 7/2/1992 | -0.5 | 3.25 | | 9:15 AM | Discount rate change press release | Y | -0.35 | -0.15 |
| 4/9/1992 | -0.25 | 3.75 | | 11:30 AM | Open market operation | Y | -0.23 | -0.02 |
| 12/20/1991 | -0.5 | 4 | | 8:30 AM | Discount rate change press release | Y | -0.26 | -0.24 |
| 12/6/1991 | -0.25 | 4.5 | | 11:30 AM | Open market operation | Y | -0.08 | -0.17 |
| 11/6/1991 | -0.25 | 4.75 | | 8:45 AM | Discount rate change press release | Y | -0.12 | -0.13 |
| 10/31/1991 | -0.25 | 5 | | | | | -0.62 | 0.37 |
| 9/13/1991 | -0.25 | 5.25 | | 9:10 AM | Discount rate change press release | Y | -0.05 | -0.2 |
| 8/6/1991 | -0.25 | 5.5 | | 11:30 AM | Open market operation | Y | -0.14 | -0.11 |
| 4/30/1991 | -0.25 | 5.75 | | 9:30 AM | Discount rate change press release | Y | -0.3 | 0.05 |
| 3/8/1991 | -0.25 | 6 | | 11:30 AM | Open market operation | Y | -0.16 | -0.1 |
| 2/1/1991 | -0.5 | 6.25 | | 9:15 AM | Discount rate change press release | Y | -0.53 | 0.03 |
| 1/9/1991 | -0.25 | 6.75 | | | | | -0.12 | -0.13 |
| 12/18/1990 | -0.25 | 7 | | 3:30 PM | Discount rate change press release | Y | 0.02 | -0.27 |
| 12/7/1990 | -0.25 | 7.25 | | 11:30 AM | Open market operation | Y | -0.26 | 0.01 |
| 11/13/1990 | -0.25 | 7.5 | | | | | -0.03 | -0.22 |
| 10/29/1990 | -0.25 | 7.75 | | 11:30 AM | Open market operation | Y | -0.21 | -0.04 |
| 7/13/1990 | -0.25 | 8 | | 11:30 AM | Open market operation | Y | -0.13 | -0.12 |
| 2/24/1989 | 0.25 | 9.75 | | | | | 0.04 | 0.21 |
| Total observation: 79 | | | | | | | | |

Source: Federal Reserve Bank of Kansas and New York City.

Table 3. Unusual periods for monetary policy in United States, 1989 to 2008

We intend to omit the data point/observations during the financial crisis periods, for robustness checks. In the table below, we only list the crisis events that have been covered by the time from 1989 to 2008 which is the time length of our data sample.

| Years | Financial Crisis Event and the Federal Reserve's Reaction on Monetary Policy |
|---|---|
| 2007 to 2008 | Subprime Mortgage Crisis. The crash of the U.S. housing market triggered the crisis, followed by the bankruptcy of large financial institutions and stock market turmoil. Fed's reaction on policy: Interest Rate Cut from 5.25% to 0-0.25% level, from the 18th Sept, 2007 to the 16th Dec, 2008's zero lower bound. The chairman was Ben S. Bernanke. |
| 1999 to 2000 | Dot-com Bubble. Internet related stock prices raised to a level that is apparently higher than their fundamental values. Fed's reaction on policy: Four consecutive Interest Rate hikes from 5.25% to 6.5%, from the 16th December, 1999 to the 16th May, 2010. The chairman was Alan Greenspan. |
| Prior to September 1994 | No announcements after the FOMC meeting, but Open Market Operation on Fed Fund Rate. It is called the mystique period of monetary policy. |

This figure shows the historic level of the fed fund target rate. We can see that the interest rate lowers as the time approaches the recent periods. After the subprime mortgage financial crisis, Federal Reserve has kept the target Fed Fund Rate at 0.00-0.25% level until December 2015.

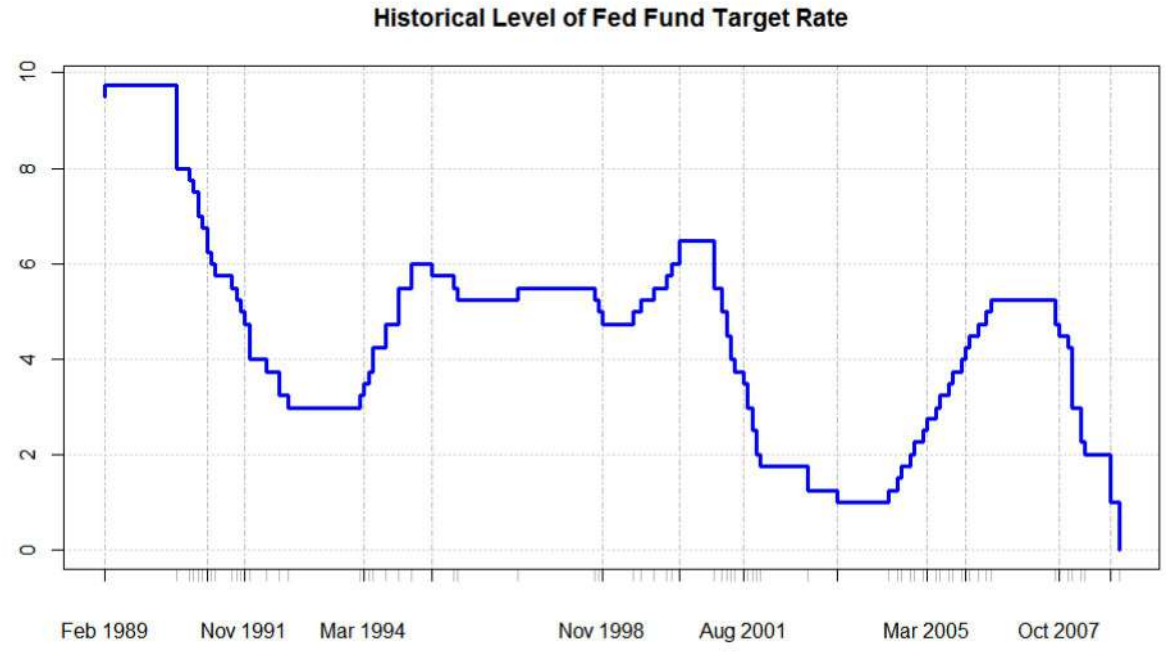


**Figure 1. The evolution of the Fed Fund target rate**

Figure 2 displays the changes of rate decision from February 1989 to December 2008.

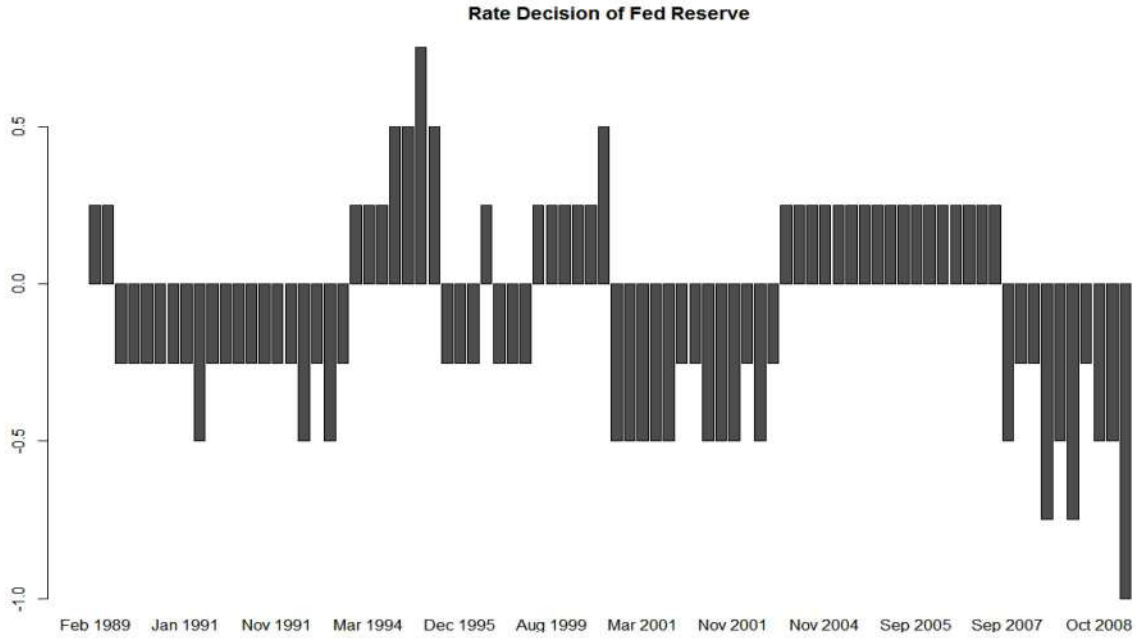


**Figure 2. The distribution of rate decision across different time period**

The figure below shows the unexpected component of the monetary policy which is implied from the Fed Fund Futures, we use the equation:

$$\Delta FFR_t^{unexpected} = \frac{m}{m-t}(FFR_{s,t}^1 - FFR_{s,t-1}^1)$$

In order to compute the unexpected interest rate changes: $\Delta FFR_t^{unexpected}$. Where $m$ is the number of days in month $s$, $t$ represents the event day. Below is the figure that listed the $\Delta FFR_t^{unexpected}$ over time. We can directly observe that before 1994, there are much more unexpected rate decisions, the sizes are big enough to drive the market prices. During the financial crisis period from 2007 to 2008, the market (fed fund fu-

tures) also had wrong predictions of the actual rate decision behaviors and the monetary policy shock still existed in that period, although the Federal Reserve started to increase the transparency between monetary authority and market participants.

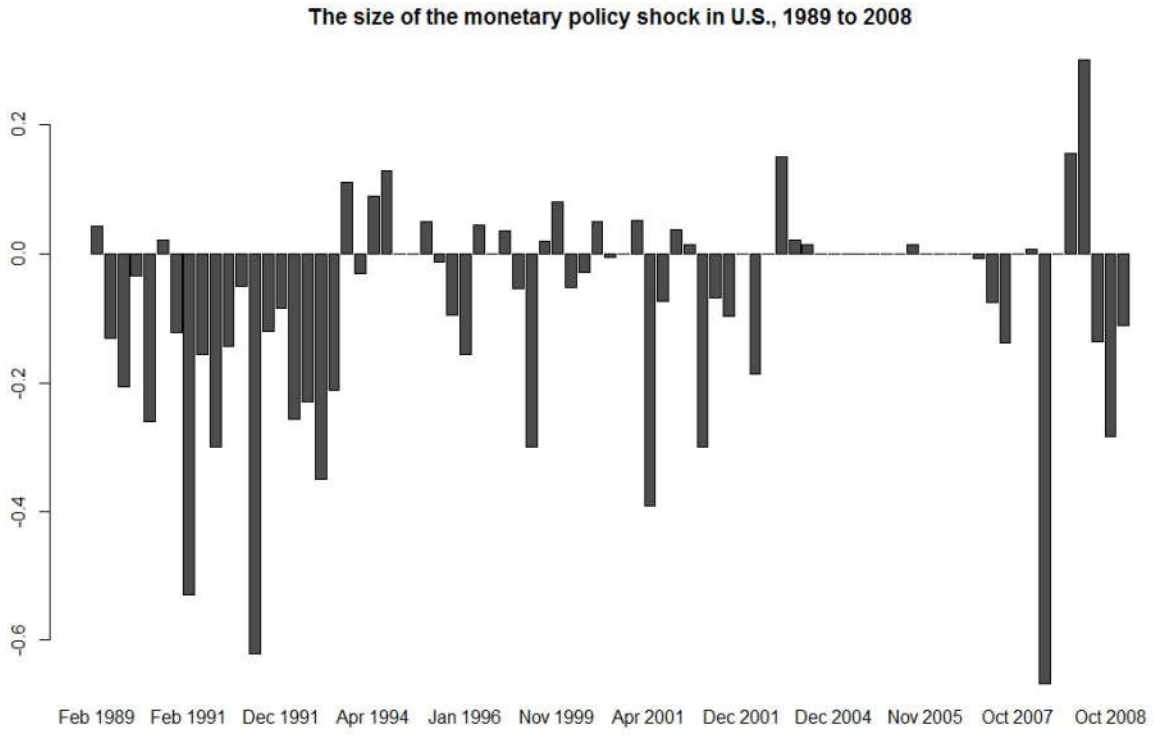


**Figure 3. The size of the unexpected monetary policy which is measured by Fed Fund Futures**

This figure displays the time series of short-term and long-term interest rates in the US. We can observe that the short-term and long-term interest rates followed the same trends at most of the time. FF1 stands for the federal funds futures rate, 3m indicates the 3-month treasury rate, and 30y stands for the 30-year treasury rate.

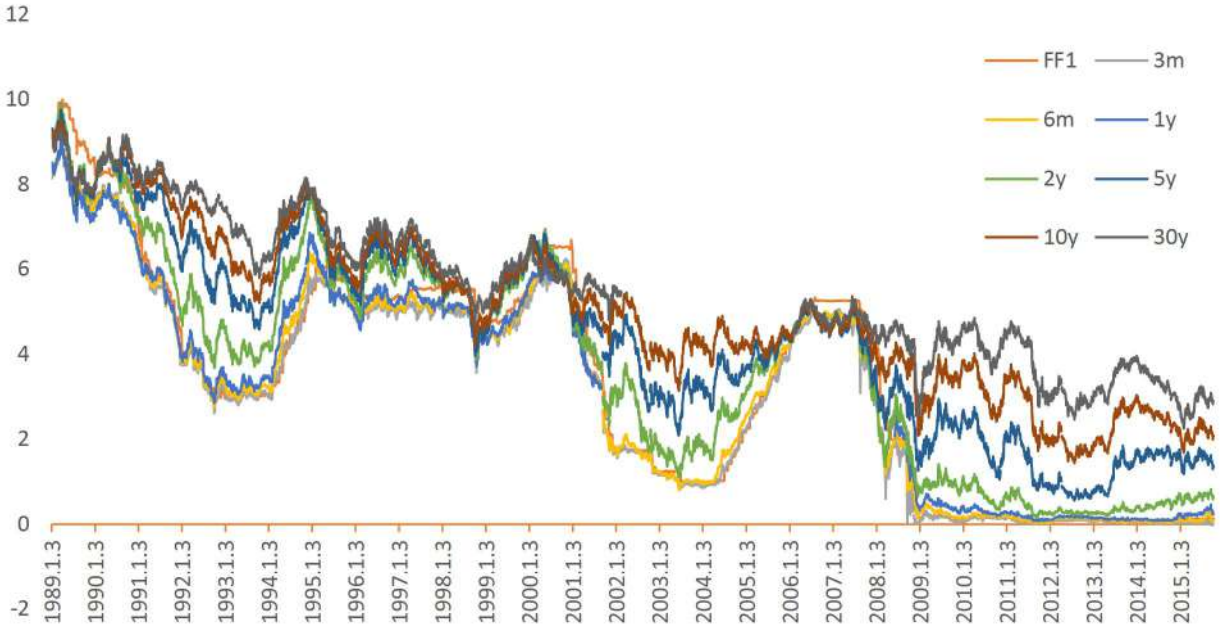


**Figure 4. Historical interest rate in the U.S.**

Table 4. Responses of treasury rates to the Fed's monetary policy change

The results of this table are based on the GARCH (1,1) process regression:

$$R_t = \gamma_0 + \gamma_1 \Delta FFR_t^{expected} + \gamma_2 \Delta FFR_t^{unexpected} + \varepsilon_t$$

$$\varepsilon_t | \varepsilon_{t-1}, \varepsilon_{t-2}, \varepsilon_{t-3}, \ldots \sim N(0, u_t^2)$$

$$u_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 u_{t-1}^2$$

$R_t$ denotes the asset returns on the event day $t$. $\gamma_0, \gamma_1$ and $\gamma_2$ are the linear regression coefficients. $\beta_0, \beta_1$ and $\beta_2$ are the coefficients of the GARCH(1,1) process. $\varepsilon_t$ is the residual of the mean equation, while $u_t$ is the variances of $\varepsilon_t$. The values in parentheses denote the robust standard errors.

| Panel A (Full sample) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameters | 3 month | 6 month | 12 month | 2 year | 5 year | 10 year | 30 year |
| $\gamma_0$ | -0.013 | -0.021** | -0.009 | 0.001 | -0.005 | 0.002 | -0.029** |
| | (0.013) | (0.009) | (0.012) | (0.010) | (0.011) | (0.010) | (0.011) |
| $\gamma_1$ | 0.167*** | 0.104*** | 0.005 | 0.041 | -0.009 | -0.041* | -0.067* |
| | (0.032) | (0.025) | (0.040) | (0.032) | (0.030) | (0.025) | (0.038) |
| $\gamma_2$ | 0.442*** | 0.371*** | 0.335*** | 0.314*** | 0.229*** | 0.092** | 0.016 |
| | (0.046) | (0.033) | (0.080) | (0.057) | (0.063) | (0.042) | (0.059) |
| $\beta_0$ | 0.004 | 0.005** | 0.001* | 0.001 | 0.002 | 0.002** | 0.002 |
| | (0.007) | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) | (0.005) |
| $\beta_1$ | -0.042 | 0.448** | 0.539** | 0.173 | 0.120 | 0.647* | 0.071 |
| | (0.067) | (0.164) | (0.24) | (0.120) | (0.141) | (0.343) | (0.200) |
| $\beta_2$ | 0.570 | -0.070 | 0.405* | 0.641*** | 0.678** | 0.182 | 0.587 |
| | (0.821) | (0.289) | (0.233) | (0.174) | (0.229) | (0.179) | (0.972) |
| $R^2$ | 0.51 | 0.48 | 0.39 | 0.27 | 0.14 | 0.04 | 0.06 |
| Durbin- Watson | 1.83 | 2.22 | 2.00 | 2.30 | 2.17 | 2.14 | 2.14 |
| Obs. | 79 | 79 | 46 | 79 | 79 | 79 | 63 |
| Panel B (Subsample) | | | | | | | |
| Parameters | 3 month | 6 month | 12 month | 2 year | 5 year | 10 year | 30 year |
| $\gamma_0$ | -0.011 | -0.019** | -0.004 | -0.002 | -0.007 | -0.001 | -0.001*** |
| | (0.015) | (0.008) | (0.016) | (0.001) | (0.013) | (0.000) | (0.000) |
| $\gamma_1$ | 0.166*** | 0.096*** | 0.104 | 0.061 | 0.019 | -0.018 | -0.067*** |
| | (0.027) | (0.025) | (0.058) | (0.041) | (0.042) | (0.092) | (0.000) |
| $\gamma_2$ | 0.418*** | 0.316*** | 0.380*** | 0.309*** | 0.282*** | 0.161** | 0.008*** |
| | (0.064) | (0.036) | (0.106) | (0.065) | (0.070) | (0.042) | (0.000) |
| $\beta_0$ | 0.004 | 0.003*** | 0.001 | 0.002 | 0.000 | 0.000 | 0.000 |
| | (0.007) | (0.001) | (0.001) | (0.001) | (0.000) | (0.001) | (0.000) |
| $\beta_1$ | -0.045 | 0.769*** | 0.465 | 0.172 | -0.154 | -0.132 | 6.336*** |
| | (0.071) | (0.164) | (0.296) | (0.154) | (0.103) | (0.092) | (0.634) |
| $\beta_2$ | 0.574 | -0.033 | 0.437 | 0.618* | 1.15*** | 1.161*** | 0.000 |
| | (0.733) | (0.041) | (0.310) | (0.286) | (0.146) | (0.130) | (0.143) |
| $R^2$ | 0.46 | 0.43 | 0.42 | 0.29 | 0.14 | 0.05 | -0.12 |
| Durbin- Watson | 1.95 | 1.96 | 2.01 | 2.15 | 2.13 | 2.19 | 1.74 |
| Obs. | 65 | 65 | 42 | 65 | 65 | 65 | 65 |

Notes: the code***denote the significance level of $\alpha<0.01$;**$\alpha<0.05$;*$\alpha<0.10$.

This figure shows the shift of the Treasury yield curve after one of the rate decision events during the 2008 financial crisis period. The Federal Reserve Board cut the target interest rate from 4.25% to 3.5%, which are 75 basis points. However, the federal fund futures rate only implied a modest 0 to 25 basis points cut, which led to an unexpected decrease of 66 basis points. The dashed line is the yield curve on January 18, 2008, which is the prior trading day before FOMC rate decision. The solid line is the yield curve on January 22, 2008, which is the event day. We can see that after the unexpected cutting of federal funds target rate, the yield curve shifted downward and became steeper.

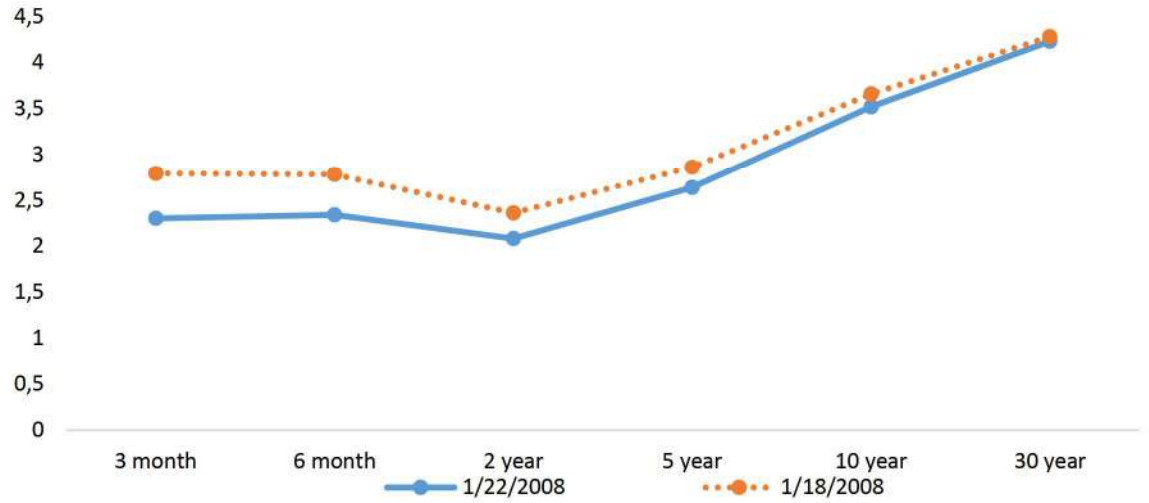


**Figure 5. The unexpected interest rate cut and the movement of the yield curve**

Table 5. Responses of foreign exchange rates to the Fed's monetary policy change

This table reports the results of G-10 and Emerging Market exchange rates. All the exchange rates are denoted as $\frac{Foreign\ Currency}{US\ dollar}$. The estimation is based on GARCH(1,1) process regression, which is express as equation (8) and (9). The robust standard errors are reported in the parentheses.

| *Panel A: G-10* exchange rates (full sample) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameters | *EUR* | *GBP* | *JPY* | *CAD* | *CHF* | *NOK* | *SEK* | *AUD* | *NZD* |
| $\gamma_0$ | 0.049 | -0.003 | 0.015 | -0.016*** | -0.027 | -0.004 | 0.004 | 0.092** | 0.034 |
| | (0.024) | (0.032) | (0.030) | (0.000) | (0.041) | (0.012) | (0.030) | (0.034) | (0.057) |
| $\gamma_1$ | 0.017 | -0.184** | 0.014 | 0.051 | 0.189 | 0.104*** | 0.294*** | 0.007 | -0.054 |
| | (0.070) | (0.094) | (0.096) | (0.083) | (0.132) | (0.000) | (0.087) | (0.160) | (0.158) |
| $\gamma_2$ | -0.211* | -0.376** | 0.654*** | 0.063 | 0.528** | 0.608*** | 0.630*** | 0.135 | 0.050 |
| | (0.126) | (0.175) | (0.169) | (0.068) | (0.241) | (0.197) | (0.236) | (0.282) | (0.361) |
| $\beta_0$ | 0.032* | 0.016* | 0.016 | 0.001*** | 0.027** | 0.005 | 0.021* | 0.012*** | 0.021** |
| | (0.016) | (0.011) | (0.011) | (0.000) | (0.016) | (0.005) | (0.012) | (0.002) | (0.006) |
| $\beta_1$ | 0.565* | 0.083 | 0.516* | -0.188*** | -0.025 | -0.191*** | -0.090** | -0.163*** | -0.035 |
| | (0.274) | (0.119) | (0.323) | (0.037) | (0.056) | (0.054) | (0.034) | (0.023) | (0.032) |
| $\beta_2$ | 0.041 | 0.609** | 0.423* | 1.063*** | 0.728*** | 1.113*** | 0.807*** | 1.030*** | 0.83*** |
| | (0.282) | (0.234) | (0.214) | (0.053) | (0.241) | (0.06) | (0.139) | (0.040) | (0.052) |
| $R^2$ | 0.01 | 0.13 | 0.07 | -0.03 | 0.13 | 0.09 | 0.123 | -0.004 | 0.003 |
| Durbin-Watson | 1.41 | 2.00 | 2.30 | 1.66 | 1.84 | 1.88 | 1.98 | 2.12 | 1.83 |
| Obs | 79 | 79 | 79 | 79 | 79 | 79 | 79 | 79 | 79 |
| Panel B: G-10 exchange rates (subsample) | | | | | | | | | |
| Parameters | *EUR* | *GBP* | *JPY* | *CAD* | *CHF* | *NOK* | *SEK* | *AUD* | *NZD* |
| $\gamma_0$ | 0.062** | 0.012 | 0.004 | -0.026 | -0.072*** | -0.027 | -0.049** | 0.037 | 0.012 |
| | (0.025) | (0.037) | (0.028) | (0.025) | (0.002) | (0.039) | (0.020) | (0.056) | (0.068) |
| $\gamma_1$ | 0.018 | -0.134*** | 0.066* | 0.012 | 0.146 | -0.006 | 0.115 | 0.051 | -0.023 |
| | (0.076) | (0.004) | (0.095) | (0.066) | (0.168) | (0.180) | (0.141) | (0.201) | (0.179) |
| $\gamma_2$ | -0.053 | -0.280 | 0.656*** | 0.067 | 0.333 | 0.387*** | 0.379 | 0.051 | 0.153 |
| | (0.137) | (0.235) | (0.173) | (0.150) | (0.315) | (0.007) | (0.259) | (0.376) | (0.432) |
| $\beta_0$ | 0.038* | 0.000 | 0.032* | 0.009 | 0.002 | 0.002 | 0.001 | 0.005 | 0.046 |
| | (0.019) | (0.005) | (0.021) | (0.011) | (0.007) | (0.005) | (0.005) | (0.006) | (0.298) |
| $\beta_1$ | 0.531* | -0.133 | 0.801* | 0.069 | -0.125 | -0.144** | -0.126** | -0.177** | -0.015 |
| | (0.243) | (0.128) | (0.426) | (0.131) | (0.071) | (0.053) | (0.051) | (0.087) | (0.146) |
| $\beta_2$ | -0.066 | 1.140*** | 0.013 | 0.527 | 1.118*** | 1.124*** | 1.113*** | 1.000*** | 0.56 |
| | (0.270) | (0.204) | (0.205) | (0.532) | (0.157) | (0.096) | (0.113) | (0.082) | (2.917) |
| $R^2$ | -0.01 | 0.07 | 0.08 | -0.01 | 0.05 | 0.04 | 0.06 | 0.006 | 0.004 |
| Durbin-Watson | 2.08 | 2.06 | 2.10 | 1.74 | 2.41 | 2.14 | 2.27 | 2.00 | 2.08 |
| Obs | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 |

Table 5 (cont.). Responses of foreign exchange rates to the Fed's monetary policy change

| Panel C: G-10 exchange rates (full sample) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameters | *EUR* | *GBP* | *JPY* | *CAD* | *CHF* | *NOK* | *SEK* | *AUD* | *NZD* |
| $\gamma_0$ | -0.037 | 0.020 | -0.066 | -0.027*** | -0.033 | -0.05** | -0.028 | 0.003 | -0.018*** |
| | (0.026) | (0.027) | (0.047) | (0.006) | (0.047) | (0.018) | (0.063) | (0.010) | (0.000) |
| $\gamma_1$ | 0.244*** | 0.008 | 0.099 | -0.054 | 0.234 | 0.329*** | 0.105 | -0.012 | 0.006*** |
| | (0.002) | (0.095) | (0.134) | (0.086) | (0.145) | (0.036) | (0.167) | (0.032) | (0.002) |
| $\gamma_2$ | 0.561** | 0.450*** | 0.334 | 0.042 | -0.031 | 0.840*** | -0.430* | -0.088** | 0.005* |
| | (0.186) | (0.108) | (0.250) | (0.217) | (0.380) | (0.133) | (0.240) | (0.044) | (0.003) |
| $\beta_0$ | -0.003** | 0.001 | 0.023*** | 0.002** | 0.009 | 0.009*** | 0.012** | 0.001*** | 0.000 |
| | (0.001) | (0.001) | (0.001) | (0.000) | (0.007) | (0.002) | (0.004) | (0.000) | (0.000) |
| $\beta_1$ | -0.060*** | 0.138** | -0.112*** | -0.231*** | 0.071 | -0.160*** | 0.067 | -0.075*** | -0.049** |
| | (0.007) | (0.065) | (0.016) | (0.057) | (0.082) | (0.043) | (0.068) | (0.015) | (0.022) |
| Panel C: G-10 exchange rates (full sample) | | | | | | | | | |
| Parameters | *EUR* | *GBP* | *JPY* | *CAD* | *CHF* | *NOK* | *SEK* | *AUD* | *NZD* |
| $\beta_2$ | 1.157*** | 0.781*** | 0.826*** | 1.115*** | 0.766*** | 0.982*** | 0.723*** | 0.912*** | 1.178*** |
| | (0.037) | (0.044) | (0.043) | (0.100) | (0.128) | (0.091) | (0.100) | (0.032) | (0.038) |
| $R^2$ | -0.003 | 0.04 | 0.08 | -0.10 | 0.07 | 0.24 | -0.04 | -0.01 | -0.18 |
| Durbin-Watson | 2.08 | 2.47 | 2.33 | 0.81 | 1.75 | 1.62 | 1.89 | 1.85 | 1.34 |
| Obs | 79 | 79 | 79 | 49 | 79 | 79 | 79 | 79 | 79 |
| Panel D: G-10 exchange rates (subsample) | | | | | | | | | |
| Parameters | *EUR* | *GBP* | *JPY* | *CAD* | *CHF* | *NOK* | *SEK* | *AUD* | *NZD* |
| $\gamma_0$ | 0.048 | 0.024 | -0.059* | -0.016 | -0.053 | -0.067 | -0.040 | -0.006 | -0.014*** |
| | (0.094) | (0.031) | (0.026) | (0.030) | (0.049) | (0.045) | (0.063) | (0.021) | (0.000) |
| $\gamma_1$ | -0.304 | 0.006 | 0.174* | -0.084 | 0.129 | 0.238** | 0.132 | -0.051 | -0.009*** |
| | (0.190) | (0.104) | (0.086) | (0.085) | (0.174) | (0.103) | (0.180) | (0.074) | (0.001) |
| $\gamma_2$ | 0.746 | 0.460*** | -0.072 | 0.094 | -0.575 | 0.326* | -0.654** | -0.169 | 0.003 |
| | (1.627) | (0.114) | (0.204) | (0.101) | (0.506) | (0.208) | (0.278) | (0.128) | (0.451) |
| $\beta_0$ | 0.003 | 0.001 | 0.032* | 0.001 | 0.008 | 0.002 | 0.010 | 0.005 | 0.000 |
| | (0.002) | (0.001) | (0.018) | (0.002) | (0.010) | (0.003) | (0.035) | (0.006) | (0.000) |
| $\beta_1$ | -0.040*** | 0.199* | -0.538* | 0.817 | 0.092 | -0.119*** | 0.111 | -0.071** | 0.303 |
| | (0.004) | (0.096) | (0.336) | (0.572) | (0.124) | (0.039) | (0.218) | (0.026) | (0.251) |
| $\beta_2$ | 1.138*** | 0.765*** | -0.116 | 0.427 | 0.768*** | 1.056*** | 0.741 | 0.565 | 1.131*** |
| | (0.030) | (0.068) | (0.418) | (0.261) | (0.250) | (0.038) | (0.786) | (0.604) | (0.042) |
| $R^2$ | -0.09 | 0.04 | 0.05 | 0.01 | 0.10 | 0.16 | 0.11 | 0.07 | -0.12 |
| Durbin-Watson | 1.99 | 2.09 | 2.76 | 1.95 | 1.22 | 1.83 | 1.74 | 1.99 | 1.50 |
| Obs | 65 | 65 | 65 | 35 | 65 | 65 | 65 | 65 | 65 |

Note: the code***denote the significance level of $\alpha<0.01$;**$\alpha<0.05$;*$\alpha<0.10$.

Table 6. Responses of equity prices to the Fed's monetary policy change

| Panel A (full sample) | | | | | | |
|---|---|---|---|---|---|---|
| Parameters | S&P 500 (U.S.) | FTSE 100 (U.K.) | DAX (Germany) | Hang Seng (Hong Kong, PRC) | Nikkei 225 (Japan) | Ibovespa (Brazil) |
| $\gamma_0$ | 0.099 | 0.042 | 0.148 | 0.093 | 0.011* | 0.496* |
| | (0.098) | (0.075) | (0.076) | (0.165) | (0.069) | (0.320) |
| $\gamma_1$ | -0.0262 | -0.107 | -0.061 | 0.154 | 0.211 | -0.568 |
| | (0.0262) | (0.197) | (0.185) | (0.880) | (0.213) | (0.610) |
| $\gamma_2$ | 0.282 | -0.238 | -0.094 | 0.769 | 0.624* | -1.421 |
| | (0.457) | (0.396) | (0.423) | (0.974) | (0.355) | (3.294) |
| $\beta_0$ | 0.067 | 0.056** | 0.044** | -0.081 | 0.098 | 1.557 |
| | (0.065) | (0.027) | (0.021) | (0.071) | (0.063) | (7.570) |
| $\beta_1$ | 0.110 | 0.035 | 0.032 | -0.038*** | 1.154** | -0.035 |
| | (0.128) | (0.073) | (0.074) | (0.007) | (0.441) | (0.180) |

Table 6 (cont.). Responses of equity prices to the Fed's monetary policy change

| Panel A (full sample) | | | | | | |
|---|---|---|---|---|---|---|
| Parameters | S&P 500 (U.S.) | FTSE 100 (U.K.) | DAX (Germany) | Hang Seng (Hong Kong, PRC) | Nikkei 225 (Japan) | Ibovespa (Brazil) |
| $\beta_2$ | 0.717*** | 0.692*** | 0.765*** | 1.056*** | 0.210** | 0.560 |
| | (0.244) | (0.147) | (0.087) | (0.026) | 0.083 | (2.168) |
| $R^2$ | 0.02 | 0.02 | 0.00 | -0.02 | 0.00 | 0.04 |
| Durbin-Watson | 1.99 | 2.36 | 1.90 | 2.07 | 2.17 | 2.22 |
| Obs | 79 | 79 | 79 | 79 | 79 | 60 |
| Panel B (subsample) | | | | | | |
| Parameters | S&P 500 (U.S.) | FTSE 100 (U.K.) | DAX (Germany) | Hang Seng (Hong Kong, PRC) | Nikkei 225 (Japan) | Ibovespa (Brazil) |
| $\gamma_0$ | -0.011 | 0.053 | 0.134* | 0.041 | 0.080 | 0.393 |
| | (0.075) | (0.077) | (0.084) | (0.061) | (0.081) | (0.523) |
| $\gamma_1$ | 0.091 | -0.066 | -0.024 | 0.314*** | 0.184 | -0.298 |
| | (0.267) | (0.202) | (0.267) | (0.014) | (0.228) | (1.341) |
| $\gamma_2$ | -0.065 | -0.030 | -0.130 | 0.467** | 0.172 | -2.76 |
| | (0.563) | (0.534) | (0.467) | (0.156) | (0.359) | (6.190) |
| $\beta_0$ | 0.031 | 0.330* | 0.019 | -0.002 | 0.245** | 1.856 |
| | (0.037) | (0.189) | (0.021) | (0.007) | (0.010) | (6.428) |
| $\beta_1$ | 0.311 | 0.180 | 0.138 | -0.040*** | 0.636** | -0.044 |
| | (0.234) | (0.289) | (0.147) | (0.004) | (0.283) | (0.149) |
| $\beta_2$ | 0.671*** | -0.520 | 0.784*** | 1.142*** | -0.038 | 0.567 |
| | (0.197) | (0.684) | (0.157) | (0.043) | (0.038) | (1.567) |
| $R^2$ | -0.02 | 0.00 | 0.01 | -0.04 | -0.06 | 0.03 |
| *Durbin-Watson* | 2.10 | 1.60 | 1.86 | 2.06 | 1.68 | 2.18 |
| *Obs* | 65 | 65 | 65 | 65 | 65 | 46 |

Note: the code***denote the significance level of $\alpha<0.01$;**$\alpha<0.05$;*$\alpha<0.10$.

Table 7. Reponses of commodity prices to the Fed's monetary policy change

| Panel A (full sample) | | |
|---|---|---|
| Parameters | Gold Spot | WTI Oil Futures |
| $\gamma_0$ | 0.015 | 0.045 |
| | (0.046) | (0.121) |
| $\gamma_1$ | -0.142 | -0.020 |
| | (0.136) | (0.365) |
| $\gamma_2$ | -0.467* | 0.266 |
| | (0.053) | (0.907) |
| $\beta_0$ | 0.005** | 0.319 |
| | (0.002) | (0.256) |
| $\beta_1$ | -0.112*** | -0.109 |
| | (0.036) | (0.076) |
| $\beta_2$ | 1.077*** | 0.788*** |
| | (0.053) | (0.221) |
| $R^2$ | 0.08 | -0.00 |
| Durbin-Watson | 2.00 | 1.88 |
| Observations | 79 | 79 |

Table 7. Reponses of commodity prices to the Fed's monetary policy change

| Panel B (subsample) | | |
|---|---|---|
| Parameters | Gold Spot | WTI Oil Futures |
| $\gamma_0$ | -0.049 | 0.004 |
| | (0.056) | (0.091) |
| $\gamma_1$ | -0.212 | 0.422 |
| | (0.175) | (0.334) |
| $\gamma_2$ | -0.570* | 0.118 |
| | (0.278) | (0.818) |
| $\beta_0$ | 0.043 | 0.060 |
| | (0.032) | (0.062) |
| $\beta_1$ | -0.058 | -0.157* |
| | (0.061) | (0.087) |
| $\beta_2$ | 0.90** | 1.092*** |
| | (0.265) | (0.059) |
| $R^2$ | 0.04 | 0.02 |
| Durbin-Watson | 1.82 | 1.84 |
| Observations | 65 | 65 |

Note: the code***denote the significance level of $\alpha<0.01$;**$\alpha<0.05$;*$\alpha<0.10$.

Table 8. Responses of treasury rates to the Fed's monetary policy change in an 11-day event window

| Treasuries | Expected policy effect | | | | | | | | | | | Unexpected policy effect | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Event days | | | | | | | | | | | Event days | | | | | | | | | | |
| | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |
| 3 months | -0.02 (0.03) | 0.02 (1.09) | 0.03 (0.02) | 0.04* (0.02) | 0.04** (0.02) | **0.18*** (0.03)** | 0.08*** (0.03) | 0.03 (0.03) | -0.11*** (0.03) | -0.02 (0.02) | 0.01 (0.02) | 0 (0.05) | 0.01 (0.04) | 0.06* (0.03) | 0.10* (0.05) | 0.11*** (0.04) | **0.44*** (0.05)** | 0.10* (0.06) | 0.06 (0.05) | 0.10*** (0.05) | 0.01 (0.03) | -0.01 (0.03) |
| 6 months | 0 (0.02) | 0.04 (0.02) | 0.02 (0.02) | 0.05* (0.02) | 0.03** (0.02) | **0.10*** (0.03)** | 0.05** (0.02) | 0.03 (0.02) | -0.08*** (0.02) | -0.00 (0.02) | 0.00 (0.02) | 0.04 (0.03) | 0.03 (0.04) | 0.04 (0.03) | 0.08* (0.04) | 0.11*** (0.03) | **0.37*** (0.03)** | 0.09** (0.05) | 0.01 (0.04) | 0.06 (0.04) | 0.08*** (0.03) | -0.03 (0.03) |
| 12 months | 0.01 (0.02) | 0.04 (0.03) | 0.01 (0.02) | 0.02 (0.02) | 0.06*** (0.02) | **0.01 (0.04)** | 0.04 (0.03) | 0.02 (0.03) | -0.01 (0.02) | -0.00 (0.02) | -0.04** (0.02) | 0.01 (0.05) | 0 (0.05) | 0.05 (0.03) | 0.05 (0.04) | 0.08** (0.04) | **0.34*** (0.08)** | 0.04 (0.06) | 0.06 (0.05) | 0.02 (0.03) | 0.03 (0.03) | 0.01 (0.03) |
| 2 year | 0 (0.02) | 0.01 (0.03) | -0.02 (0.02) | 0.04 (0.03) | 0.05 (0.02) | **0.04 (0.03)** | 0.03 (0.02) | -0.00 (0.02) | -0.02 (0.02) | 0.02 (0.02) | -0.02 (0.02) | 0.04 (0.04) | 0.08 (0.05) | 0.03 (0.04) | 0.09 (0.06) | 0.07** (0.04) | **0.31*** (0.06)** | 0.03 (0.04) | -0.00 (0.05) | 0.04 (0.04) | 0.03 (0.04) | -0.04 (0.04) |
| 5 year | -0.01 (0.02) | 0 (0.03) | -0.03 (0.02) | 0.02 (0.03) | 0.05*** (0.02) | **-0.01 (0.03)** | 0.04 (0.02) | 0.00 (0.03) | -0.04* (0.02) | 0.00 (0.02) | -0.04** (0.02) | 0.04 (0.04) | 0.05 (0.05) | 0.03 (0.04) | 0.07 (0.06) | 0.04 (0.03) | **0.23*** (0.06)** | 0.02 (0.04) | -0.04 (0.05) | 0.00 (0.04) | 0.03 (0.03) | -0.03 (0.04) |
| 10 year | -0.01 (0.02) | 0 (0.02) | -0.04* (0.02) | 0 (0.03) | 0.03** (0.02) | **-0.04* (0.02)** | 0.06*** (0.02) | 0.01 (0.02) | -0.03 (0.02) | -0.00 (0.02) | -0.03 (0.02) | 0.02 (0.04) | 0.05 (0.04) | 0.01 (0.04) | 0.06 (0.05) | 0.02 (0.03) | **0.09* (0.04)** | 0.02 (0.06) | -0.03 (0.04) | 0.02 (0.04) | 0.02 (0.03) | -0.01 (0.04) |
| 30 year | 0 (0.02) | 0.01 (0.03) | -0.04* (0.02) | -0.01 (0.02) | 0.03* (0.02) | **-0.07* (0.04)** | 0.07*** (0.02) | 0.02 (0.02) | -0.01 (0.02) | -0.01 (0.02) | -0.02 (0.02) | 0.03 (0.04) | 0.07 (0.05) | 0.01 (0.03) | 0.03 (0.04) | 0.01 (0.03) | **0.02 (0.06)** | -0.01 (0.04) | -0.03 (0.04) | 0.02 (0.04) | 0.02 (0.03) | 0.03 (0.03) |

Note: the code***denote the significance level of $\alpha<0.01$;**$\alpha<0.05$;*$\alpha<0.10$.

Table 8 reports the results of extended horizon regression: $R_{t+i} = \gamma_{0i} + \gamma_{1i}\Delta FFR_t^{expected} + \gamma_{2i}\Delta FFR_t^{unexpected} + \varepsilon_{t+i}, i \in [-5, 5]$ which are event days in the regression. The bracket reports the robust standard error. We estimate the coefficients of effects from expected and unexpected components of the monetary policy shock by using OLS.

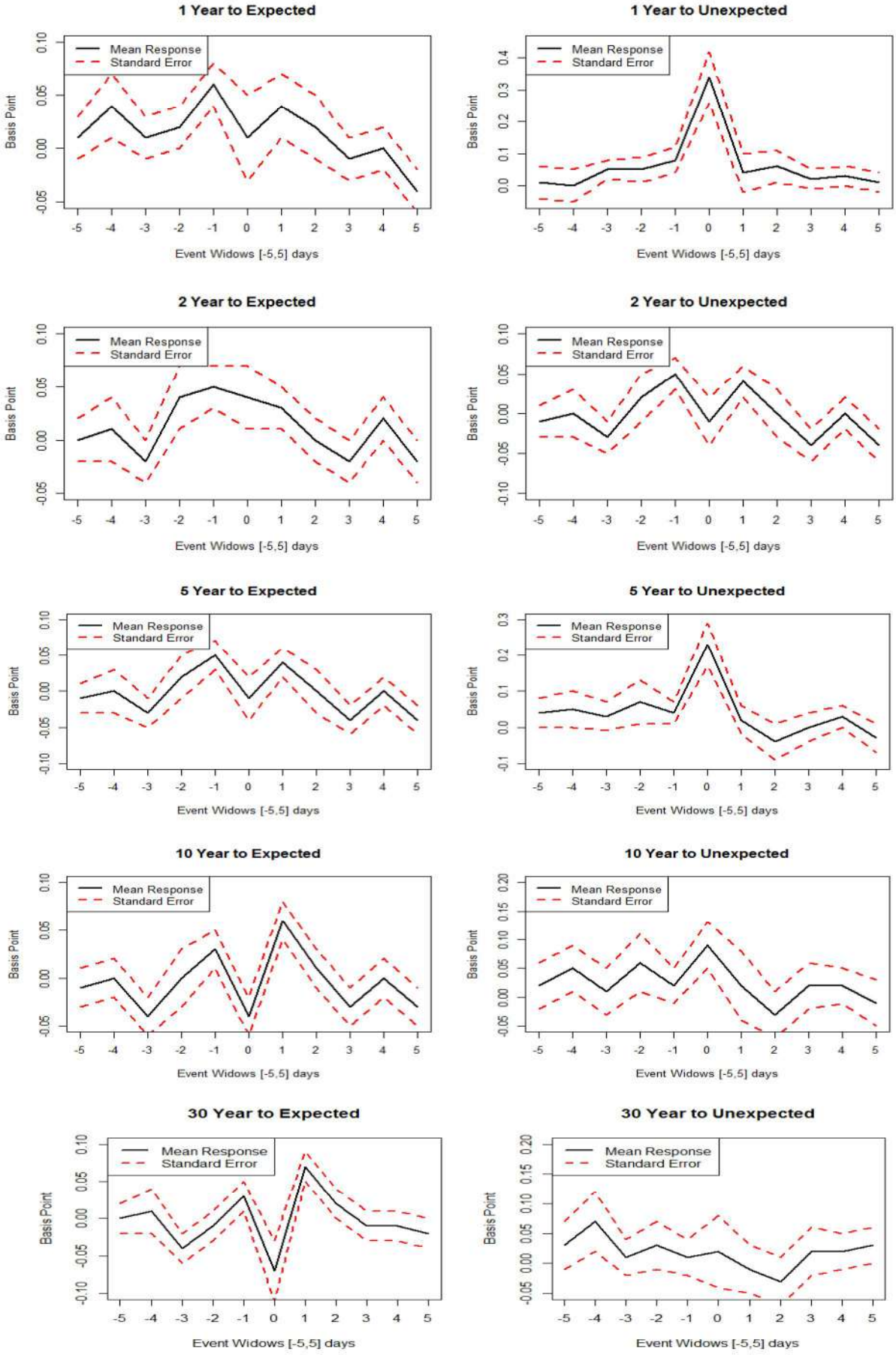


**Figure 6. Responses of treasury rates to the fed's monetary policy change in an 11-day event window**

Table 9. Responses of exchange rates to the Fed's monetary policy change in an 11-day event window

| Currencies | Expected policy effect | | | | | | | | | | | Unexpected policy effect | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Event days | | | | | | | | | | | Event days | | | | | | | | | | |
| | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |
| EUR | 0.24*** (0.08) | -0.09 (0.11) | -0.07 (0.11) | -0.03 (0.09) | -0.03 (0.09) | **0.02 (0.07)** | -0.13 (0.12) | 0.08 (0.11) | 0.04 (0.10) | 0.06 (0.10) | 0.07 (0.10) | -0.01 (0.15) | 0.08 (0.19) | 0.07 (0.19) | 0.12 (0.17) | 0.12 (0.17) | **-2.11* (0.13)** | -0.35* (0.22) | 0.10 (0.21) | 0.28* (0.19) | -0.24 (0.18) | 0.37* (0.18) |
| GBP | 0.10 (0.09) | -0.20** (0.08) | -0.12 (0.09) | 0.11 (0.09) | -0.05 (0.13) | **-0.18** (0.09)** | 0.05 (0.09) | 0.27** (0.10) | -0.10 (0.09) | 0.09 (0.08) | 0.06 (0.09) | 0.03 (0.17) | 0.17 (0.16) | 0.09 (0.17) | -0.08 (0.16) | -0.29 (0.23) | **-0.38** (0.18)** | -0.50*** (0.16) | 0.08 (0.19) | 0.24 (0.17) | 0.05 (0.12) | 0.41** (0.17) |
| JPY | -0.02 (0.11) | 0.02 (0.10) | 0.05 (0.11) | 0.01 (0.09) | 0.01 (0.09) | **0.01 (0.10)** | -0.12 (0.11) | -0.21 (0.10) | 0.07 (0.09) | -0.13 (0.08) | -0.07 (0.12) | 0.27 (0.21) | -0.19 (0.19) | 0.07 (0.20) | 0.09 (0.17) | 0.09 (0.17) | **0.65*** (0.17)** | -0.22 (0.21) | 0.14 (0.18) | -0.03 (0.17) | 0.00 (0.14) | -0.19 (0.21) |
| CAD | -0.11 (0.09) | 0.18*** (0.06) | 0.02 (0.07) | -0.02 (0.05) | -0.02 (0.05) | **0.05 (0.08)** | -0.06 (0.08) | 0.06 (0.08) | 0.03 (0.08) | -0.05 (0.08) | -0.00 (0.06) | -0.48*** (0.16) | -0.03 (0.12) | 0.02 (0.13) | -0.10 (0.09) | -0.10 (0.09) | **0.06 (0.07)** | 0.37** (0.15) | -0.18 (0.15) | 0.12 (0.14) | 0.23* (0.14) | -0.02 (0.12) |
| CHF | -0.15 (0.10) | 0.16 (0.12) | -0.03 (0.10) | 0.09 (0.11) | 0.09 (0.11) | **0.19 (0.13)** | 0.18 (0.14) | -0.23** (0.11) | -0.03 (0.11) | -0.02 (0.07) | -0.08 (0.11) | 0.24 (0.18) | -0.13 (0.21) | 0.04 (0.19) | -0.02 (0.19) | -0.02 (0.19) | **0.53*** (0.24)** | 0.11 (0.26) | 0.10 (0.20) | -0.23 (0.21) | 0.11 (0.14) | -0.42** (0.20) |
| NOK | -0.21 (0.12) | 0.20 (0.13) | -0.01 (0.11) | -0.03 (0.10) | 0.17 (0.10) | **0.10*** (0.00)** | 0.21* (0.14) | -0.36** (0.13) | -0.01 (0.11) | -0.10 (0.08) | -0.04 (0.10) | -0.03 (0.22) | 0.12 (0.24) | 0.14 (0.21) | 0.01 (0.18) | 0.65*** (0.19) | **0.61*** (0.20)** | 0.45* (0.25) | 0.06 (0.23) | -0.27 (0.21) | 0.01 (0.15) | -0.44** (0.19) |
| SEK | -0.25 (0.11) | 0.24** (0.11) | 0.07 (0.13) | -0.08 (0.10) | -0.08 (0.10) | **0.29*** (0.09)** | 0.18 (0.14) | -0.25** (0.10) | -0.03 (0.10) | -0.13 (0.11) | -0.02 (0.11) | 0.15 (0.20) | -0.11 (0.20) | 0.05 (0.24) | -0.13 (0.18) | -0.13 (0.18) | **0.63*** (0.24)** | 0.41* (0.26) | 0.01 (0.19) | -0.34 (0.19) | -0.06 (0.20) | -0.35* (0.20) |
| AUD | 0.19* (0.10) | -0.10 (0.10) | -0.14 (0.17) | -0.08 (0.11) | -0.08 (0.11) | **0.01 (0.16)** | -0.13 (0.14) | 0.02 (0.11) | -0.07 (0.10) | -0.08 (0.11) | 0.19* (0.11) | 0.04 (0.19) | -0.05 (0.19) | 0.34 (0.31) | 0.18 (0.20) | 0.18 (0.20) | **0.14 (0.28)** | -0.34 (0.26) | 0.15 (0.20) | 0.38** (0.18) | -0.06 (0.20) | 0.01 (0.20) |
| NZD | 0.15 (0.12) | -0.11 (0.10) | -0.14 (0.17) | -0.08 (0.11) | -0.08 (0.11) | **-0.05 (0.16)** | -0.21 (0.13) | -0.07 (0.12) | 0.03 (0.10) | -0.02 (0.11) | 0.08 (0.08) | 0.14 (0.21) | -0.12 (0.19) | 0.46 (0.31) | 0.13 (0.20) | 0.13 (0.20) | **0.05 (0.36)** | -0.64** (0.24) | 0.22 (0.21) | 0.14 (0.18) | 0.20 (0.21) | 0.31** (0.15) |
| RUB | -0.25 (0.25) | 0.13* (0.08) | -0.06 (0.18) | 0.06 (0.12) | -0.02 (0.14) | **-0.30 (0.19)** | 0.02 (0.10) | -0.21 (0.29) | -0.17 (0.22) | 0.01 (0.08) | 0.05 (0.05) | 0.00 (0.63) | -0.30 (0.21) | -0.24 (0.47) | -0.12 (0.30) | 0.00 (0.35) | **0.56** (0.19)** | 0.14 (0.26) | 0.12 (0.72) | 0.01 (0.55) | -0.00 (0.20) | -0.09 (0.14) |
| ZAR | -0.04 (0.19) | 0.07 (0.16) | -0.04 (0.12) | -0.09 (0.10) | -0.10 (0.16) | **0.01 (0.10)** | -0.07 (0.14) | 0.21 (0.16) | -0.22 (0.15) | -0.08 (0.15) | -0.14 (0.11) | -0.84** (0.35) | 0.30 (0.30) | 0.20 (0.21) | 0.23 (0.19) | 0.53* (0.29) | **0.45*** (0.11)** | 0.19 (0.25) | 0.31 (0.30) | -0.38 (0.28) | 0.08 (0.27) | -0.24 (0.20) |
| PLN | -0.24 (0.14) | 0.12 (0.11) | 0.21* (0.11) | -0.11 (0.10) | 0.04 (0.18) | **0.17* (0.09)** | 0.02 (0.13) | 0.05 (0.14) | 0.01 (0.12) | 0.03 (0.14) | -0.01 (0.11) | -0.45 (0.35) | -0.55 (0.28) | 0.19 (0.28) | -0.35 (0.25) | 0.81 (0.46) | **0.33 (0.25)** | 0.23 (0.34) | 0.04 (0.34) | -0.60** (0.30) | 0.15 (0.35) | -0.12 (0.27) |
| RON | -0.06 (1.08) | -1.71 (2.40) | 0.02 (0.14) | -0.29 (0.70) | -0.01 (0.14) | **-0.08 (0.08)** | 0.08 (0.12) | 0.04 (0.17) | 0.02 (0.32) | 0.04 (0.20) | -0.04 (0.11) | -2.87 (1.84) | -6.03 (4.07) | 0.25 (0.23) | -2.60** (1.19) | 0.30 (0.24) | **0.04 (0.22)** | 0.30 (0.22) | -0.41 (0.32) | -0.45 (0.55) | 0.25 (0.34) | -0.18 (0.18) |
| HUF | -0.18 (0.12) | 0.17 (0.11) | 0.08 (0.12) | -0.07 (0.10) | 0.22 (0.15) | **0.13 (0.17)** | 0.10 (0.13) | -0.00 (0.13) | -0.12 (0.11) | -0.08 (0.13) | -0.17* (0.10) | -0.44 (0.31) | -0.40 (0.28) | -0.03 (0.31) | 0.05 (0.25) | 0.70* (0.39) | **-0.03 (0.38)** | 0.66** (0.33) | 0.13 (0.32) | -1.03** (0.27) | -0.00 (0.34) | -0.14 (0.24) |
| CZK | -0.12 (0.12) | 0.14 (0.15) | 0.17 (0.12) | -0.07 (0.10) | 0.07 (0.13) | **0.24** (0.10)** | -0.07 (0.14) | -0.04 (0.10) | -0.06 (0.10) | -0.01 (0.14) | -0.11 (0.11) | -0.60** (0.31) | 0.29 (0.39) | 0.12 (0.30) | -0.18 (0.26) | 0.62* (0.33) | **0.84*** (0.13)** | -0.06 (0.34) | 0.04 (0.26) | -0.94*** (0.26) | 0.14 (0.35) | -0.29 (0.30) |
| CLP | 0.08 (0.11) | 0.14 (0.15) | 0.07 (0.13) | 0.08 (0.10) | -0.01 (0.10) | **0.13 (0.18)** | -0.07 (0.08) | -0.13 (0.11) | -0.09* (0.05) | -0.02 (0.09) | 0.09 (0.08) | -0.50** (0.21) | 0.29 (0.39) | 0.16 (0.25) | -0.18 (0.18) | -0.01 (0.17) | **-0.43* (0.24)** | 0.50*** (0.15) | -0.02 (0.20) | 0.09 (0.10) | 0.19 (0.16) | 0.04 (0.15) |
| INR | -0.04 (0.04) | 0.08** (0.04) | 0.09 (0.04) | -0.03 (0.04) | -0.02 (0.04) | **-0.05 (0.07)** | 0.03 (0.03) | 0.06* (0.04) | -0.03 (0.07) | -0.07 (0.06) | -0.06 (0.05) | -0.11* (0.07) | -0.13 (0.07) | -0.03 (0.07) | -0.10 (0.07) | 0.03 (0.08) | **-0.09** (0.04)** | 0.06 (0.06) | 0.00 (0.07) | 0.03 (0.13) | 0.04 (0.11) | -0.14 (0.10) |

Table 9 (cont.). Responses of exchange rates to the Fed's monetary policy change in an 11-day event window

| Currencies | Expected policy effect | | | | | | | | | | | Unexpected policy effect | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Event days | | | | | | | | | | | Event days | | | | | | | | | | |
| | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |
| MXN | 0.00 (0.01) | 0.14 (0.15) | -3.83 (13.10) | 0.01 (0.00) | 0.01 (0.00) | **-0.01*** (0.00)** | 0.00 (0.01) | 0.01 (0.00) | 0.01 (0.01) | 0.01 (0.01) | 0.01 (0.00) | 0.00 (0.02) | 0.29 (0.39) | -18.98 (24.02) | 0.02*** (0.01) | 0.01 (0.01) | **0.01* (0.00)** | -0.00 (0.02) | 0.02** (0.01) | 0.02 (0.02) | -0.01 (0.02) | 0.02** (0.01) |
| BRL | 0.02 (0.18) | 0.14 (0.15) | 0.39** (0.15) | -0.17 (0.21) | 0.03 (0.16) | **-0.23 (0.17)** | -0.05 (0.16) | -0.01 (0.20) | 0.16 (0.13) | -0.14 (0.17) | 0.20 (0.18) | -0.76* (0.43) | 0.29 (0.39) | 0.36 (0.36) | -0.20 (0.50) | 0.55 (0.37) | **-0.27 (0.75)** | 0.17 (0.37) | -0.73 (0.46) | -0.47 (0.29) | -0.22 (0.40) | 0.22 (0.41) |

Note: the code***denote significance level of $\alpha<0.01$;**$\alpha<0.05$;*$\alpha<0.10$.

Table 10. Responses of equity and commodity prices to the Fed's monetary policy change in an 11-day event window

| Treasuries | Expected policy effect | | | | | | | | | | | Unexpected policy effect | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Event days | | | | | | | | | | | Event days | | | | | | | | | | |
| | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 | -5 | -4 | -3 | -2 | -1 | **0** | 1 | 2 | 3 | 4 | 5 |
| S&P 500 | -0.23 | -0.17 | 0.11 | 0.26* | 0.33 | **-0.03** | 0.33 | 0.17 | -0.38 | 0.10 | 0.11 | 0.62* | 0.13 | 0.27 | -0.05 | -0.72 | **0.28** | -0.72 | -0.65* | -0.01 | -0.43 | -0.19 |
| FTSE 100 | -0.23 (0.17) | -0.25 (0.19) | -0.02 (0.18) | 0.50 (0.38) | 0.43** (0.20) | **-0.11 (0.20)** | 0.43** (0.20) | 0.02 (0.19) | -0.16 (0.23) | 0.19 (0.23) | 0.08 (0.23) | 0.66** (0.31) | 0.67* (0.34) | 0.15 (0.35) | 0.40 (0.67) | 0.56 (0.38) | **-0.24 (0.40)** | 0.55* (0.38) | -0.36 (0.34) | 0.01 (0.40) | -0.66 (0.40) | -0.15 (0.39) |
| DAX | 0.09 (0.23) | -0.43 (0.27) | -0.14 (0.20) | 0.21 (0.25) | 0.34 (0.33) | **-0.06 (0.19)** | 0.34 (0.33) | 0.13 (0.25) | -0.07 (0.32) | 0.01 (0.24) | 0.12 (0.25) | 0.43 (0.41) | 0.64 (0.49) | 0.31 (0.38) | -0.32 (0.46) | 0.43 (0.61) | **-0.09 (0.42)** | 0.43 (0.61) | 0.38 (0.46) | 0.25 (0.56) | -0.67 (0.42) | -0.46 (0.44) |
| Hang Seng | -0.32 (0.29) | -0.65** (0.29) | 0.10 (0.36) | 0.50 (0.38) | -0.00 (0.36) | **0.15 (0.88)** | -0.00 (0.36) | -0.54 (0.42) | 0.21 (0.33) | 0.18 (0.25) | 0.04 (0.29) | 0.26 (0.51) | 0.73 (0.52) | 0.59 (0.66) | 0.40 (0.67) | -0.47 (0.66) | **0.77 (0.97)** | -0.47 (0.66) | -2.84*** (0.75) | -1.04 (0.57) | 0.67 (0.43) | -0.66 (0.48) |
| Nikkei 225 | -0.03 (0.28) | -0.21 (0.24) | -0.06 (0.32) | 0.90*** (0.26) | -0.14 (0.32) | **0.21 (0.21)** | -0.14 (0.32) | -0.34 (0.31) | 0.15 (0.26) | -0.45 (0.35) | -0.34 (0.29) | -0.27 (0.55) | 0.43 (0.43) | 1.42** (0.57) | 0.21 (0.46) | -0.08 (0.57) | **0.62* (0.36)** | -0.08 (0.57) | -1.54** (0.56) | -0.52 (0.49) | -0.25 (0.64) | -0.23 (0.51) |
| Ibovespa | 0.60 (0.86) | -0.38 (0.49) | -0.19 (0.57) | 0.15 (0.58) | 0.55 (0.43) | **-0.57 (0.61)** | 0.55 (0.43) | 0.67 (0.52) | -0.87 (0.92) | -0.69 (0.55) | -0.26 (0.91) | 1.35 (1.56) | 1.52* (0.86) | 1.61 (1.01) | -2.91** (1.04) | 0.10 (0.78) | **-1.42 (3.29)** | 0.10 (0.76) | 0.42 (1.01) | -2.65 (1.71) | -1.69 (1.04) | 1.77 (1.66) |
| Gold Price | 0.15 (0.15) | -0.14 (0.18) | -0.23* (0.12) | -0.19 (0.14) | -0.09 (0.16) | **-0.14 (0.14)** | -0.09 (0.16) | 0.23 (0.16) | -0.06 (0.12) | -0.09 (0.15) | -0.04 (0.15) | 0.40 (0.27) | -0.15 (0.33) | 0.30 (0.22) | 0.12 (0.26) | -0.01 (0.29) | **-0.47* (0.05)** | -0.01 (0.29) | -0.64** (0.29) | 0.44** (0.22) | -0.48* (0.27) | 0.30 (0.28) |
| WTI Crude | 0.89* (0.46) | -0.59* (0.34) | -0.49 (0.38) | 0.33 (0.49) | 0.87** (0.36) | **-0.02 (0.37)** | 0.87** (0.36) | 1.09*** (0.36) | 0.01 (0.47) | -1.50*** (0.50) | 0.26 (0.47) | 1.92** (0.85) | 0.15 (0.62) | -0.34 (0.72) | 1.00 (0.92) | -0.20 (0.74) | **0.27 (0.91)** | -0.20 (0.74) | 0.74 (0.69) | -0.08 (0.82) | -0.03 (0.86) | 1.03 (0.86) |

Notice: the code***denote significance level of $\alpha<0.01$; **$\alpha<0.05$; * $\alpha<0.10$.