FOMC Minutes: As a Source of Central Bank Communication Surprise

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Abstract

This paper examines whether and to what extent publications of the Federal Open Market Committee (FOMC) minutes contain significant information for the expectation of future monetary policy in the US. We construct measure of new surprise series with intradaily data for the Fed futures contracts and the responses of stock markets, fixed income markets and exchange rates to these surprises during 2004–2017. We find that the release of FOMC minutes affects the market volatility and financial asset prices respond significantly to FOMC minutes announcements. Finally, volatility and the volume of reactions increase during the zero lower bound. Specifically, this research finds that the release of FOMC minutes induces *"higher than normal"* volatility and shows that financial markets respond quickly and significantly to the release of FOMC minutes.

Keywords: Central Bank Communication, FOMC Minutes, Monetary Policy Shocks
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1 Introduction

On May 18, 2016, the Fed released the minutes of the Federal Open Markets Committee (FOMC), which makes interest rate decisions,that was held on April 27, 2016. This release led to a massive reaction in the financial markets. U.S. Stocks fell, Treasury yields rose and the US Dollar soared (i.e. a nine-week high against the Swiss Franc and a three-week high against the Yen). Financial agents attributed this outsize response to the release of FOMC minutes. The financial world had interpreted this release as suggesting that the Fed would raise interest rate sooner than previously expected. For example;

> **The New York Times**: *The Federal Reserve sent a sharp, simple message to financial markets on Wednesday: Pay attention. The Fed is thinking seriously about raising its benchmark interest rate at its next meeting, in June...*
>
> **The Guardian:** *US Fed says June hike possible...*
>
> **CNBC:** *Fed likely to hike in June if data improve...*
>
> **Reuters:** *Fed signals interest rate hike firmly on the table for June...*

Although market participants were already aware of the key decision of April 18, 2016 FOMC meeting, the reaction to the release of minutes for this meeting was striking, particularly considering that all discussions were made three weeks prior and no policy change was affected on that day. However, contrary to expectations, the Fed decided *not* to raise interest rates on June 17, 2016 and reaffirmed the current target rate. With the statement and minutes of this June 17, 2016 meeting, the market changed the expectation and positions based on the low probability of any action on interest rates for until December 2016 meeting. What is understood from these announcements and markets' reactions is that FOMC minutes may contain *new* information albeit lagged, on the future expectation of monetary policy and this *information* has the ability to change market reactions. Therefore, this research evaluates whether this reaction of asset markets on May 18, 2016 to the minutes of April 27, 2016 was a typical response to Federal Reserve policy, in other words, whether FOMC minutes matter for the market or not.

Before the 1990s, most central banks were shrouded in mystery. In recent years central banks have become increasingly concerned about communicating the likely path of future monetary policy effectively to markets, particularly the Fed have expanded their emphasis on communication as a

tool of monetary policy since that effective monetary policy communication can shape the public's expectations, reduce uncertainty, and provide accountability for politically independent central banks. On this regard, the Fed provides investors and public with a large number of communications and guides which contain information and signals on the future monetary policy stance such as FOMC meeting statements, minutes of meetings, governor and other Fed officials' speeches, press conferences, and transcripts[1].

In the United States, the FOMC has been releasing the minutes of rate-setting meetings for many years, but up to 2004 minutes were only released after the subsequent meeting. Since 2004, the minutes have been released in the third week after the meeting to which they refer, and weeks before the next scheduled meeting, so they potentially have informational content about future monetary policy decisions. Moreover, as time has passed the minutes have gradually given a more detailed flavour of the discussion at the meeting. The pattern is for the FOMC to meet eight times a year, and to release a statement immediately after the meeting that explains the decision, but with no indication of voting patterns or how much disagreement there was. The minutes are published three weeks later, and give information about minority views within the committee, how much disagreement was expressed, etc.

The minutes summarise the views expressed by members, which may include some further elaboration of the reasons for the interest rate decision and details of any minority views, but their more important function is to convey information about the likely future path of interest rates and/or quantitative easing. To the extent that publication of the minutes helps the markets to anticipate the likely course of monetary policy, one would expect that, the greater the information provided by the minutes, the greater would be the effect on the financial markets of the publication of the minutes of the meeting relative to the effect of the publication of the statement accompanying the next interest rate decision, since more information about the likely decision has been previously released in the minutes. This is particularly likely to be true during the long period of unchanged interest rates after the financial crisis, when the main policy decisions concerned the path of quantitative easing.

There has been some empirical research on the effect of the publication of the FOMC minutes on financial markets. Rosa (2013) has examined the volatility of stock markets, three-year and ten-year Treasury bond yields and some bilateral US dollar exchange rates at five-minute intervals after the publication of a set of minutes or a statement. He finds that these prices are significantly more volatile immediately after the publication of a set of minutes than at the same time of day

[1]For more information about the central bank communication and their importance see; Blinder et al. (2008), Rosa (2016), Hansen et al. (2017), and Hansen and McMahon (2016)

on the same day of the week when there are no monetary policy announcements. Jubinski and Tomljanovich (2013) have looked at the intra-daily returns on a large number of US stocks, and they find that individual equity prices tend to be significantly less volatile in the half-hour before the release of the minutes, and significantly more volatile than in other periods in the fifteen minutes after the release. What has not so far been done is to apply to minutes the methods used by Gürkaynak et al. (2005) and Hausman and Wongswan (2011) in order to judge whether policy statements immediately after meetings have helped to change markets' expectation of the future as reflected in current and future federal funds interest rates. The idea behind these papers is that the shift in federal funds rates in the short interval after the release of the statement is a measure of the unanticipated content of the statement.

In this paper we use the same methods to estimate the amount of information conveyed in the minutes, and how it relates to the information conveyed by the statement accompanying the next meeting, and also to estimate the effects on a wider range of asset prices.

The remainder of this paper proceeds as follows. Section-2 begins by introducing the Fed communications and FOMC minutes. Thereafter, Section-4 and -3 describe future contracts as a expectation tool and methodology, respectively. Then, Section-5 constructs monetary policy surprise index and Section-6 gives data information and Section-8 offers discussions of the empirical results and compares these with the previous chapter and finally, conclusions are drawn.

2 The Fed Communication and FOMC Minutes

With the recent financial crisis, in many advanced countries, short-term interest rates reached the zero-lower bound (ZLB) and the communication about the future policy has become an essential part of central banking. The ZLB is generally considered an important limitation on the ability of central banks to conduct conventional monetary policy. However, Swanson and Williams (2014) claimed that changing the current level (ZLB) of the policy rate is not the only way of making effective monetary policy. They reported that during the ZLB period unconventional monetary policies and communication methods such as forward guidance shaped the market's expectation about future interest rate policy and mitigated the limitations imposed by the ZLB. In fact, Woodford (2005) emphasised the importance of management of expectations in order to increase the effectiveness of the policy. In parallel with this, Bernanke (2004) underlined that transparency in central bank communication enhances the effectiveness of monetary policy. In the case of the U.S, over the last decade, central bank communication has gained the essential position in Fed monetary policy.

According to Woodford (2005) the Fed's communication strategy has evolved substantially over time. Over the recent decades, the Fed has undertaken sustained efforts to enhance the financial participants' understanding of its monetary policy. Further, the Fed has successfully transformed itself from a secretive to a highly transparent authority, with the intention of creating more effective monetary policy. According to Blinder et al. (2008) and Hansen et al. (2017), for instance, the Fed is a highly predictable central bank and is presumed to be the top-ranked among the most transparent central banks in the world. A recent strand of literature has analysed the asset price response to the release of FOMC statements. Some important studies include Kuttner (2001) for Treasury rates, Bernanke and Kuttner (2005) for stock exchanges, and Glick and Leduc (2015) for exchange rates. Gürkaynak et al. (2005) and Hausman and Wongswan (2011) documented that post-meeting statements have statistically significant and economically relevant effects on U.S. asset prices.

January 2002 saw the Fed amend its disclosure policy and clarify that FOMC would issue a statement immediately after each regular meeting. Until January 2002, no real-time policy decisions were revealed by the Fed after each meeting, rather only after the upcoming meeting. Markets were left guessing what the intended federal funds rate was after the first meeting. Therefore, it can be said that this is a lagged-learning procedure. As regards FOMC minutes, which have been published since 1936, the publication lag thereof was approximately 6-8 weeks after the corresponding meeting. Hence, simply it can be said that until January 2002, the statement did not announce any policy decision immediately after the meeting but was published without voting records. Minutes have the voting records and discussions but this information set could only be obtained 6-8 weeks after the current meeting (see Panel 1 in Figure -1).

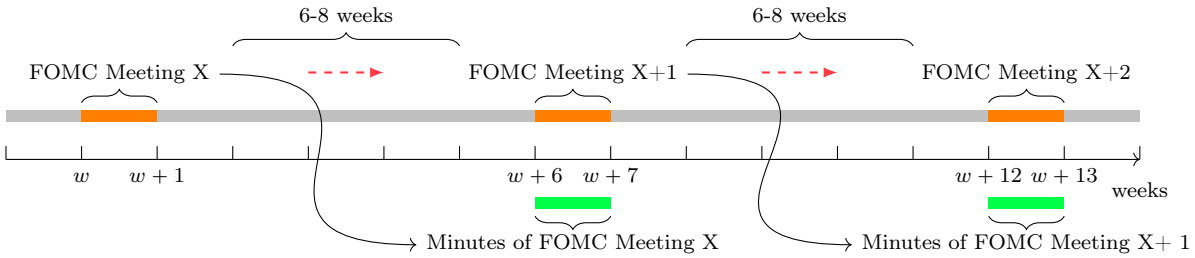
After 2002, the FOMC amended its disclosure policy and set out to make the outcomes of its meeting known via a post-meeting statement including a short rationale for the policy action immediately after each regularly scheduled FOMC meeting, irrespective of any changes to monetary policy. Thus, from 2002 the minutes and votes of individual FOMC members have been included in the next FOMC meeting statement. However, the minutes of meetings were still published 6-8 week later. Once again, market agents could only incorporate information from such minutes for previous meeting but not for the forthcoming meeting. For example, the market could learn how FOMC members interpret the recent economic and financial data such as the unemployment report and compare with their interpretation only at that time but they cannot assess what members think currently and what are the possible actions for the next meeting (see the panel 1 in Figure -1).

In December 2004, the FOMC decided to publish the minutes of each meeting earlier, to be precise, both three weeks after the meeting as well as three weeks prior to the following meeting.

Further, after this date, FOMC minutes were more a reflection of the views of both voting and non-voting members, where previously only voting members' views were reflected in the minutes. This is now standard procedure with Fed monetary policy (see Panel 2 in Figure -1). According to Fawley et al. (2013) these steps have enhanced the market´s understanding of the fed funds rate setting and have substantially decreased market uncertainty. Hence, this appears to have helped markets to predict future monetary policy actions and to have increased monetary policy effectiveness (Swanson, 2006). For example, Jung (2016) showed that these changes allowed market participants to more precisely formulate expectations as to what the FOMC's next policy decision might be.

In summary, figure-1 shows the recent timeline of Fed communication changes. The first panel illustrates that until December 2004, no policy decision was recorded after the meeting, and statements were published after the subsequent meeting without any voting records. Minutes contained voting records, but these minutes were published up to 6-8 weeks later. Furthermore, the voting record (only for voting members) was announced together with the statement on the day of FOMC meeting, however, FOMC minutes were published after the subsequent meeting. The last panel (panel-2) shows the current federal fund communication strategy. Minutes are now published exactly 3 weeks after the meeting and 3 weeks before the next meeting at 14:00 ET. Thus, time and date of the release of FOMC minutes are now foreknown. This dataset covers the period from December 2004 till November 2017, which reflects the recent and updated Fed strategy of communications.

Figure 1. Evolution of FOMC Announcements

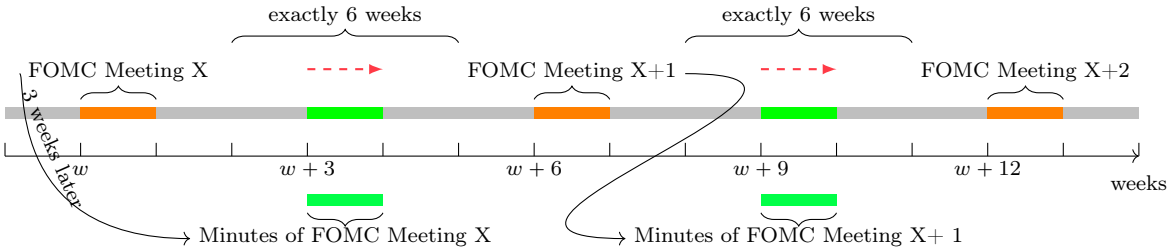


Until January 2002

- Statement without policy decision announcement and no voting records.
- Minutes of the previous meeting after 6-8 weeks with the voting record.

January 2002-December 2004

- Statement with policy decision announcement with the voting record.
- Minutes of the previous meeting after 6-8 weeks.



Since December 2004

- Statement with policy decision announcement with voting record + press conference since 2011.
- Minutes of the previous meeting is announced exactly 3 weeks later with the views of both voting and non-voting committee members.

3 Event Study Methodology

Economists have always been interested in the effects of a specific economic or non-economic event on asset prices (MacKinlay, 1997). A technique which is called *the event study method* can easily construct a measurement by using financial market data. Given rationality in the market place or under the efficient market condition, the usefulness and effectiveness of such a method come from the fact that the impact of a related event will be conveyed shortly in financial asset returns. Therefore, a measure of the event's financial effect can be constructed using these asset returns observed over a relatively short time period which is called "the event window". Through this research, the event study method has been applied to see the immediate impacts of Fed monetary policy announcements

on the financial asset prices.

Even though the event study method has a long history which goes back to 1930s, for example Dolley (1933) investigated the effects of stock splits on the nominal price changes at the time of the split. By improving this method Fama et al. (1969) introduced the event study technique which is almost the same as in use today. Amongst other Roley (1982), Fleming and Remolona (1999), Rudebusch (1998), and Ellingsen and Soderstrom (2001) are the seminal papers of the event study (MacKinlay, 1997). The method has fast become a key instrument in measuring the effects of monetary policy announcements on asset prices and economic fundamentals recently. Simply, the event study method offers a solution on measurement the effect of an event of interest over a pre-defined period. For instance, if one is looking at the effects of a recent unemployment report on stock prices with daily data, the event is here the release of unemployment report and the event window is a one-day period. Therefore, the main task of conducting an event study is first to determine the event of interest and define the period of interest. For instance, in the unemployment report case, the stock index might obtain information about the reports before the actual release and it can be examined this possibility by investigating pre-event returns. In our case, this research looks at the asset prices just before the Fed monetary policy announcement and after the announcement then investigates whether these differences are abnormal or not.

The event study method on the monetary policy analysis was popularised by Kuttner (2001). In addition to Kuttner (2001), Bernanke and Kuttner (2005) also investigated the effects of the US monetary policy news on financial asset by using the same method with daily data. Furthermore, Ehrmann and Fratzscher (2003) have applied the same method for the European Central Bank (ECB) to the European financial markets and have found that ECB communication has considerable effects on European financial asset prices. In a similar vein, Andersson (2010) analysed the responses of exchange rates to economic news and proved that there is an important relationship between the two.

Apart from central bank announcements or news, the event study method has also been used in a variety of different case. Boyd et al. (2005), for example, examined unemployment rate announcements and their effects on the equity prices in the US. It was found that if the unemployment rate was unexpectedly high, this announcement led stock prices to increase during expansion times, though, not during recession times. Rigobon and Sack (2005) showed that a rise in the probability of the war against Afghanistan in 2003 caused stock prices to decrease and increases oil futures quotes. Similarly, by using an event study Snowberg et al. (2013) further demonstrated the relationship between stock market prices and changes in perception of which candidate will win on

election day.

The efficient markets hypothesis assumes that market prices adjust quickly to any new information and prices should also reflect all information available. For example, in the minutes before the information or news related to asset prices is released, its content is unknown to financial market agents. After the news release, with efficient markets, the content of the news is quickly adjusted and conveyed by financial asset prices. In this regard French and Roll (1986) and Neely (2015) showed that asset prices react relatively rapidly to news. Thus, changes in price reflects markets' reactions to the new information received before or after any changes in financial market. This identification method is known as the event study technique and is used in this research.

According to recent finance literature, the event study is an appropriate method for determining the immediate effects of any surprise information on the market(Neely, 2015). The rationale for this method is that forward-looking financial markets should quickly incorporate all new information from a public announcement immediately after the announcement is made. Intuitively, financial participants would not be predicted to forgo large, risk-less, profitable trading opportunities for more than a couple of days or even hours, and thus the impact would be reflected in prices within a short period following monetary policy announcements that include new information (surprises) for financial markets. In this study, the event study technique measures the effects of monetary policy surprises by looking at the reaction of prices around a pre-defined window of the policy action. This is a simple yet powerful measurement of the changes. Event studies are supported by two main assumptions. First, event studies only measure price changes that occur within the pre-defined window and, secondly, they assume that price changes convey market responses to information regarding monetary policy obtained before or after the window.

4 Market Expectation Tool: Basic Concepts of Futures Contracts

There are many different financial market instruments to anticipate the future of monetary policy such as Treasury bills, fed funds futures, Euro-dollar futures, Euro-dollar deposits and federal funds loans, all of which differ in their liquidity and risk characteristics and thus, their ability to capture monetary policy shocks. For example, Kuttner (2001) uses the current month federal contracts, Gürkaynak et al. (2005) and Hausman and Wongswan (2011) the current month fed fund futures and Euro-dollar futures contracts, Rigobon and Sack (2003) the three-month Euro-dollar futures rate, and Ellingsen and Söderström (2004) the three-month Treasury bill rate. In this respect, Gürkaynak et al. (2007) investigated different financial market tools for forecasting monetary policy at various

horizons. It was found that the best measure of surprise for the immediate policy setting is fed funds futures rates which were used by Kuttner (2001), while for a more long-term perspective, which is the expected near-term policy path rather than the immediate policy setting, it was concluded that Euro-dollar future contracts seem a better tool. Therefore, in this research, owing to their forecasting ability, the fed fund futures contracts are used to proxy the target surprise as in Kuttner (2001) while 1-Year Euro-dollar futures are used for the path surprise, similar to Gürkaynak et al. (2005), Hausman and Wongswan (2011), and Glick and Leduc (2015).

Futures contracts are cash settled based upon the average daily effective target rate, as published by the New York Fed, during the course of the delivery month. These futures contracts provide an efficacious means of hedging and gaining exposure to interest rate risks. In simple terms, the fed funds futures are contracts with pay-outs at maturity, relied on the average effective federal funds rate during the expiration month. Futures contracts are a valuable market predictive tool since they reflect the common marketplace insight regarding the future stance of Fed policy. According to the CME, fed fund futures have a number of key benefits. They provide a gauge of market expectations about the Fed's action at future FOMC meetings. In addition, they offer trading in transparent markets with low transaction costs, daily market-to-market and the virtual elimination of counter-party credit risk. Furthermore, futures contracts offer liquid tools to manage risk or hedge against changes in Fed monetary policy. Fed fund futures and Eurodollar futures have the same structure. In this research, one-month current contract Fed fund futures and one-year ahead Eurodollar futures contracts have been used. These contracts were introduced in the literature of monetary policy announcements by Kuttner (2001) and extended by Gürkaynak et al. (2005).

Technically, the fed funds futures contract is quoted per the "IMM Index" or the price of fed futures contracts is 100 minus the expected Fed funds effective rate. Every contract represents the average overnight federal funds rate for the contract month. The value of the contract (ff) at expiration is $100 - r$, where r is the average effective federal funds rate over the expiry month. If the particular contract for instance, March 11, 2003 is priced 98.77, then it is understood that the market predicts the implied average fed funds effective rate for March 11, 2003 as 1.23% (100-98.77). Thus, it can be formulated:

$$\mathbb{E}[r] = 100 - ff \tag{1}$$

where $\mathbb{E}[r]$ is the expected interest rate and ff is the futures contract price.

Therefore, the market anticipation of the interest rate from the fed fund futures contracts' price

can be determined at any time. For example, if the current Fed funds target rate is 1% which means that $r = 1$ and the futures contract rate is $ff = 98.770$, then the expected interest rate is;

$$\mathbb{E}[r] = 1.23\% = 100 - ff = 100 - 98.770 \tag{2}$$

$$\mathbb{E}[\Delta(r)] = \mathbb{E}[r] - r \tag{3}$$

where $\mathbb{E}[\Delta(r)]$ is the expected *change* in interest rate and r is the current interest rate.

Equation 3 implies that the market is expecting that the FOMC will increase the rate of 25 basis points ($\mathbb{E}[\Delta(r)] = 1.23\% - 1 \approx 0.25\%$). This is due to the assumption that market participants have already priced their expectation prior to the announcements. However, if the contract price is 98.95, this suggests that the expected federal funds rates is 1.05% (100-98.95), therefore 0.05 (1.05%–1%) basis points indicates that markets do not expect any shift in rates with the upcoming FOMC meeting at that time. Moreover, the monetary policy surprise based on futures contract price is;

$$Surprise = \mathbb{E}[\Delta(r)] - \Delta(r) \tag{4}$$

where $\Delta(r)$ is the actual interest rate change and the surprise is the difference between expected change and actual change in the interest rate.

5 Measurement of Monetary Policy Surprises

Two proxies have been used for U.S. monetary policy surprises as opposed to the single proxy used in Kuttner (2001). Gürkaynak et al. (2005) provided evidence that monetary policy surprises contain more than just a surprise in the announced target rate. Further, the study showed that two factors are needed to capture the full extent of monetary policy surprises, one for the current target rate (target surprise) or the short-term surprise and the second for the expected path of future monetary policy for the future monetary policy surprise. The target surprise is the degree to which market participants have been able to anticipate the actual monetary policy decisions. The path surprise instead measures to what extent market participants have revised the future expected monetary policy path following the actual decision and/or monetary policy statements.

5.1 The Target Surprise

The target surprise can be defined as the difference between the announced target fed funds rate and anticipations derived from the futures contracts. The target surprise is computed from the change in the current-month fed funds futures contract rate in a precise time window around FOMC announcement. These futures enable market agents to place a bet in the month t on the average effective Fed target rate during the current or future month, represented as r_{t+m}, and $m \geqslant 0$. For example, a market participant on day d in month t can get at a fixed rate at the end of the month $t+m$ thus it can be symbolised by $ff_{d,t}^{(m)}$. For instance, if $m = 0$ then the contract is for the current month t, if $m = 1$ then it is for the next month, symbolised as $t + 1$, and so forth. Thus, $ff_{d,t}^{m}$ contract rate represents the market expectation of the average effective federal fund rate, r_{t+m}:

$$ff_{d,t}^{m} = \mathbb{E}_{d,t}[r_{t+m}] + \eta_{d,t}^{m} \tag{5}$$

where $\eta_{d,t}^{m}$ is a risk premium and $\mathbb{E}_{d,t}[r_{t+m}]$ is the market expectation of the target rate on the day d in month $t + m$.

Therefore, if an FOMC meeting is scheduled to take place on day d_0 of a month $t + 0$ with total D days, the rate of fed funds futures contract $ff_{d-1,t}$ which is the one day before $(d-1)$ the announcement in the current month $(m = 0)$ would be:

$$ff_{d_0-1,t} = \frac{d_0}{D_0} r_0 + \frac{D_0 - d_0}{D_0} \mathbb{E}_{d_0-1,t}(r_1) + \eta_{d_0-1,t} \tag{6}$$

where $ff_{d_0-1,t}$ is the closing-contract price on one-day before $(d_0 - 1)$ FOMC announcement day (d_0) in month t.

Equation-6 simply shows that $ff_{d-1,t}$ is a weighted average of the fed funds rate (r_0) that has prevailed so far (d days) in the month t and the rate (r_1) is that which is expected to prevail for the remainder $(D - d$ days) of the month plus a risk premium, $\eta_{d_0-1,t}$. By evaluating the equations-6 one-day ahead which is at the end of day d_0, we can reach:

$$ff_{d_0,t} = \frac{d_0}{D_0} r_0 + \frac{D_0 - d_0}{D_0} (r_1) + \eta_{d_0,t} \tag{7}$$

where $ff_{d_0,t}$ is the contract price at the end of FOMC announcement day in month t. Note that in both equations-6 and 7, m is zero and so $ff_{d_0,t}$ equals $ff_{d_0,t}^{0}$ but for simplicity, this is not denoted.

Equation-6 shows the rate of the contract just one day before FOMC meeting and the second equation-7 shows the new contract rate after FOMC meeting. These equations can be used to iden-

tify monetary policy shocks. As the futures contract rate will incorporate all information available to the markets, thus, any change in the futures rate over a small time window around FOMC statements will reflect changes in market predictions. Therefore, to see FOMC meeting surprise which is the unanticipated component of the monetary policy action is given by differencing the equation-6 from 7, known as the *Target Surprise*(TS) is: :

$$TS_{d_0,t} \equiv \mathbb{E}_{d_0-1,t}[r_1] - [r_1] \tag{8}$$

$$TS_{d_0,t} = [(\Delta ff_{d_0,t}) - (\Delta \eta_{d_0,t})]\frac{D_0}{D_0 - d_0} \tag{9}$$

where $\Delta ff_{d_0,t} \equiv ff_{d_0,t} - ff_{d_0-1,t}$ and $\Delta \eta_{d_0,t} \equiv \eta_{d_0,t} - \eta_{d_0-1,t}$. Similar to Gürkaynak (2005), it is assumed that the risk-premium[2] is constant thus, $\Delta \eta_{d_0,t} = 0$ in such a short time window where 20 minutes in our case. Hence, a policy surprise after FOMC announcement can be computed in the future contract rate at the end of FOMC meeting day from the one day before. It can be seen that the target surprise, $\mathbb{E}_{d_0-1,t}[r_1] - [r_1]$, is:

$$TS_{d_0,t} = \frac{D_0}{D_0 - d_0}(\Delta ff_{d_0,t}) \tag{10}$$

In a simple terms, the target surprise daily is defined as $TS_d = \frac{D}{D-d}(ff_d - ff_{d-1})$ where d is the announcement day and $d-1$ is the one day before the announcement, ff is the 30-days Fed fund futures. Similarly, target surprise intra-daily is defined as $TS_d = \frac{D}{D-d}(ff_{\tau+10} - ff_{\tau-10})$ where τ is the time of the announcement in day d. Hence $\tau + 10$ means 10 minutes after the announcement and $\tau - 10$ is 10 minutes before the announcement.

5.2 The Path Surprise

Although the target surprise (TS) may provide the best measure of unanticipated shifts to the immediate policy setting, this research is interested in expectation changes about the future policy at the next FOMC meeting. For instance, financial agents might shortly expect a potential federal funds rate cut, however, they cannot be sure whether this will occur with the next meeting or the meeting thereafter. To analyse shocks related to the current and future rate policy, the market expectation of average rates within specific intervals should be gauged: between the current and the next FOMC meeting, between the next meeting and the meeting thereafter, and so on so forth.

[2]More detailed discussions on risk-premium see Piazzesi and Swanson (2008)

These are only expectations, thus the surprises cannot be measured with the 1-month fed fund futures and so TS, in this regard, as in Hausman and Wongswan (2011) used a second surprise component, which is the path surprise, to capture the full extent of monetary policy.

Essentially, the target surprise is aimed at gauging the effects of current policy decision while the path surprise is intended to reflect news about any revision in monetary policy in the future. For this reason, in order to capture the long-time surprise, the path surprise is also used as a second surprise component. The similar method of target surprise is followed to gauge changes in expectations about r_2, the federal fund target rate that will prevail after the second FOMC meeting from now. If ff denotes the futures contract rate for the month containing the second FOMC announcement, then

$$ff_{d_0-1,t} = \frac{d_1}{D_1}\,\mathbb{E}_{d_0-1,t}[r_1] + \frac{D_1 - d_1}{D_1}\,\mathbb{E}_{d_0-1,t}[r_2] + \eta_{d_0-1,t} \tag{11}$$

where d_1 and D_1 are the day of that the second FOMC announcement and the number of days in the month containing this second FOMC meeting. Similarly, $\eta_{d_0-1,t}$ reflects the risk premium at the same as before. r_1 the interest rate after the first FOMC meeting and r_2 is the interest rate after the second FOMC meeting. Therefore, the first part of the equation-11 is the expectation of the interest rate for the first FOMC ($\mathbb{E}_{d_0-1,t}[r_1]$) on day $d_0 - 1$ and the second part of the equation-11 is the expectation of the interest rate for the second FOMC ($\mathbb{E}_{d_0-1,t}[r_2]$) again on day $d_0 - 1$. By evaluating the above equations ahead one day:

$$ff_{d_0,t} = \frac{d_1}{D_1}[r_1] + \frac{D_1 - d_1}{D_1}\,\mathbb{E}_{d_0,t}[r_2] + \eta_{d_0,t} \tag{12}$$

Thus, equation-12 indicates that r_2 needs to be predicted again with the new information available after the first FOMC meeting. $\mathbb{E}_{d_0,t}[r_2]$ denotes the expectation of r_2 on day d_0 where r_1 is already known after the first FOMC meeting. Differencing the equation-11 from the 12 then the path surprise is:

$$PS_{d_0,t} \equiv \mathbb{E}_{d_0,t}[r_2] - \mathbb{E}_{d_0-1,t}[r_2] \tag{13}$$

in detailed form:

$$PS_{d_0,t} = [(\Delta ff_{d_0,t}) - \frac{d_1}{D_1} TS_{d_0,t}]\frac{D_1}{D_1 - d_1} \tag{14}$$

where $\Delta ff_{d_0,t} \equiv ff_{d_0,t} - ff_{d_0-1,t}$ and again the risk-premium ($\Delta\eta_{d_0,t} = 0$) is constant. For the

intradaily path surprise:

$$PS_{d_0,t} = [(\Delta ff_{d_0,\tau,t}) - \frac{d_1}{D_1} TS_{d_0,\tau,t}] \frac{D_1}{D_1 - d_1} \tag{15}$$

where $\Delta ff_{d_0,\tau,t} \equiv ff_{d_0,\tau+10,t} - ff_{d_0,\tau-10,t}$

6 Data Information for FOMC Minutes

High-frequency US asset prices data was used which consists of quotes measured at ten-minute intervals of on-the-run CME futures contract for the shock series, S&P 500 for the stock market, EURO/USD for the exchange rate, and three-month and ten-year Treasury yields for the interest rates. The dataset covers all announcement and non-announcement days for the period December 2004 to November 2017. The exchange rate, EUR/USD rate, is defined as the Euro price of one U.S. Dollar such that a positive (negative) change implies an appreciation(depreciation) of the U.S. dollar.

As aforementioned, after the decision on December 2004, the Fed started to publish FOMC minutes on exact date and time of the meeting. However, previously FOMC minutes were released only after the next meeting finished and it takes generally 6-8 weeks (see upper section of the Figure-1). Hence, after December 2004 minutes have been published 3 weeks after and 3 weeks before the statement, exactly. This facilities with certainty the systemic measurement of market reaction. Thus, the full sample herein comprises a total of 103 FOMC minutes announcements and 103 FOMC statement announcements which means that we have a chance to compare every statement announcement to its minutes. Also, we divide our data set into two parts to investigate the zero lower boun period and we have 57 FOMC minutes announcements for the ZLB period. Prices at the end of each ten-minute interval are used to construct the series of ten-minute continuously financial asset price returns.

Table-1 presents the summary statistics for variables used in this research from December 2004 to November 2017 for different sub-samples. *Policy Change* was not added, since there is no policy change coming with FOMC minutes announcements. According to Table-1 the sample period of the whole dataset (Panel A) is December 2004–November 2017 and covers all ten-minute intervals in a day. To gauge the importance of FOMC minutes release, a comparison was made of the increase in the variance of other U.S. asset prices attributed to FOMC minutes with the response caused by the release of FOMC statement and non-announcement days. Panel B, C, and D show the summary statistics of non-announcement days, FOMC minutes announcement days, and FOMC

statement announcement days, respectively. Panel B, C, and D cover only the ten-minute interval during the period 13:00 - 16:00 to compare announcement effects. This period covers both FOMC announcements since minutes are released at 14:00 and statements are released at 14:15 and allow for comparison of volatility change one hour before and two hours after the announcements. The asset price return is the ten-minute percentage change for the Euro–U.S. dollar exchange rate and S&P500 index. Similarly, the ten-minute change in Treasury yields is measured in basis point change.

For the target and path surprises, only one observation for each day was used. For that reason, the number of observations for these surprise components is less than other observations. It can be seen, for example, in Panel C that the number of path surprise observations is 103 which means that there are 103 FOMC minutes announcement days.

Comparing the summary statistics of FOMC minutes (Panel C) to the summary statistics of FOMC statement (Panel D) and summary statistics of non-announcement days (Panel B), Table-1 indicates that the standard deviations of almost all variables of FOMC minutes are greater than the non-announcement days and smaller than FOMC statements. This is in parallel with our expectation given that FOMC statement is known as *the king* of all Fed announcements by financial market agents. Therefore, it can be said that this low volatility compare to FOMC statement announcement days and no policy changes with FOMC minutes are the main reasons for ruling out FOMC minutes as an important event for the financial markets. What is emphasised and investigated in this research is, in contrast, the effects of surprises coming from FOMC minutes on the financial markets by comparing non-announcement days. Therefore, these differences in between FOMC minutes announcement and non-announcement days may give an insight into level of volatility on the days of FOMC minutes announcements and why it should be considered.

Table 1. Summary Statistics

(A)	Whole Dataset & All Intervals for all days during 2004-2017						
	Obs	Mean	Std Dev.	Min	Max	Skewness	Kurtosis
EUR/USD (%)	511,934	0	0.05	-1.4	1.5	0.05	0.05
S&P 500 (%)	213,888	0	0.17	-4.53	3.72	0.17	0.17
10-Year (bps)	559,738	0	0.04	-14.1	22	0.04	0.04
3-Month (bps)	136,106	0	0.83	-75	34	0.83	0.83
Target Surprise (bps)	3,227	-0.03	2.45	-52.00	24.50	-3.39	110.86
Path Surprise (bps)	3,227	-0.03	5.48	-42.51	51.88	0.78	15.25
(B)	Non-Announcement Days & for 13:00-16:00 Period						
	Obs	Mean	Std Dev.	Min	Max	Skewness	Kurtosis
EUR/USD (%)	63,708	0	0.04	-0.79	0.58	0.04	0.04
S&P 500 (%)	98,371	0	0.14	-2.42	3.66	0.14	0.14
10-Year (bps)	89,019	0	0.04	-5.6	5.5	0.04	0.04
3-Month (bps)	41,974	0	0.71	-35	30	0.71	0.71
Target Surprise (bps)	3,013	-0.02	2.13	-35.00	24.50	-1.02	76.03
Path Surprise (bps)	3,013	0.04	5.41	-42.51	51.88	0.99	15.05
(C)	Minutes-Announcement Days & for 13:00-16:00 Period						
	Obs	Mean	Std Dev.	Min	Max	Skewness	Kurtosis
EUR/USD (%)	1,919	0	0.06	-0.56	0.4	0.06	0.06
S&P 500 (%)	1,938	0	0.15	-1.29	1.22	0.13	0.13
10-Year (bps)	1,930	0	0.05	-3.9	3.8	0.05	0.05
3-Month (bps)	1,917	0.01	0.48	-3	6	0.48	0.48
Target Surprise (bps)	103	0.06	3.12	-22.73	5.00	-6.64	59.78
Path Surprise (bps)	103	-0.55	6.28	-22.96	33.79	2.38	19.70
(D)	Statement-Announcement Days & for 13:00-16:00 Period						
	Obs	Mean	Std Dev.	Min	Max	Skewness	Kurtosis
EUR/USD (%)	2,256	0	0.11	-1.08	0.76	0.11	0.11
S&P 500 (%)	3,529	0	0.23	-3.76	2.75	0.23	0.23
10-Year (bps)	3,278	0	0.1	-9.8	22.0	0.1	0.1
3-Month (bps)	1,613	0.06	1.44	-10	27	1.44	1.44
Target Surprise (bps)	103	-0.33	6.56	-52.00	21.00	-3.94	33.50
Path Surprise (bps)	103	-1.24	8.52	-40.01	41.02	-0.26	12.00

Notes: Table reports the descriptive statistics for the variables used in the econometric analysis. The sample period of the whole dataset (Panel A) is December 2004–November 2017 and covers all ten-minute intervals in a day. Panel B, C, and D show the summary statistics of non-announcement days, FOMC minutes announcement days, and FOMC statement announcement days, respectively. Panel B, C, and D cover only the ten-minute interval during the period 13:00 - 16:00 to compare announcement effects. This period covers both FOMC announcements since minutes are released at 14:00 and statements are released at 14:15 and allow for comparison of volatility change one hour before and two hours after the announcements.

7 Econometric Model

Conducting an event study research on the effects of monetary policy requires the fulfilment of at least two main tasks; measuring, firstly, the surprise(s), and secondly, the effects of these surprises on asset prices, respectively. These tasks can be best performed with high-frequency data since it is a requirement to have a small-enough window around the news, and further that nothing other than the news should be affecting asset prices. If the window is longer, other surprise information will matter too, though, we argue that the daily window is too long to validate this assumption. For example, as MB-FK-AM (2019) showed that FOMC announcement dates frequently coincide with other relevant macroeconomic announcements such as *Unemployment Reports*. In this case, other news will affect the asset prices and so the volume and direction of surprises. Therefore, we suggest that using the intradaily data as an alternative, particularly for the analysis of the recession period since in recession or crises times the number of other important events, which are the potentially influential to the surprise components are more frequent then normal times and also markets become more sensitive to news during these times. Hence, this study argues that only high-frequency data can achieve this identification problem since in a small enough window around the news announcement, nothing other than the announcement should affect asset prices. Otherwise, for example, with a longer window, other shocks will matter and further, will contaminate the measurement.

Following Rigobon and Sack (2003), Rigobon and Sack (2004), and Gürkaynak and Wright (2013) the econometric modelling set-up is a system of two simultaneous structural equations that depend on a financial asset price. For example, stock price and a macro variable or monetary policy announcement on each other:

$$\Delta i_t = \beta \Delta r_t + \gamma z_t + \epsilon_t \tag{16}$$

$$\Delta r_t = \alpha(\Delta i_t - E\Delta i_t) + \delta z_t + \eta_t \tag{17}$$

in which Δi_t is the actual interest rate change which is zero on FOMC minutes announcement days and $E\Delta i_t$ is the any expected change coming with announcement. Δr_t is the changes in financial asset prices. z_t is a vector of other variables that might have effects, both on the announcements (i_t) itself and the financial asset price (r_t). Lastly, ϵ_t and η_t are uncorrelated error terms.

Equation 16 denotes a monetary policy response function that covers the anticipated response of

a policy to a set of other variables z_t and to the financial asset price r_t. Equation 17 is the financial asset price equation, that illustrates the asset price to be influenced by the FOMC announcements, i_t and also by the other variables, z_t.

Different from Rigobon and Sack (2003), the parameter of interest of this research is the α rather than β . The parameter of β is measuring the reaction of the monetary policy to the financial asset price changes, while this study is interested in the parameter α that measures the effects of the unanticipated FOMC announcements, $\Delta i_t - E\Delta i_t$ on the financial asset prices Δr_t.

However, it is a well-known fact that Equation 16 and 17 cannot be estimated consistently by using the ordinary least squares (OLS) due to the presence of simultaneous equations and omitted variables. Hence, the OLS estimation of the pass-through, α is biased since both variables, Δi_t and Δr_t , are simultaneously determined in the system.

To understand the difficulty of the econometric estimation, let us consider the system of Equation 16 and Equation 17 in matrix form :

$$\begin{pmatrix} 1 & -\beta \\ -\alpha & 1 \end{pmatrix} \begin{pmatrix} \Delta i_t \\ \Delta r_t \end{pmatrix} = \begin{pmatrix} \gamma \\ \delta \end{pmatrix} z_t + \begin{pmatrix} \epsilon_t \\ \eta_t \end{pmatrix} z_t \tag{18}$$

having solved, one can obtain the reduced-form solution of the system:

$$\begin{pmatrix} \Delta i_t \\ \Delta r_t \end{pmatrix} = \frac{1}{1-\alpha\beta} \left\{ \begin{pmatrix} \beta\delta + \gamma \\ \alpha\gamma + \delta \end{pmatrix} z_t + \begin{pmatrix} 1 \\ \alpha \end{pmatrix} \epsilon_t + \begin{pmatrix} \beta \\ 1 \end{pmatrix} \eta_t \right\} \tag{19}$$

Let denote σ_ϵ^2 is for the variance of monetary policy shock, σ_η^2 and σ_z^2 are for the variance of asset price shocks and other shocks, respectively. The OLS estimate:

$$\hat{\alpha}_{OLS} = \frac{Cov(\Delta i_t, \Delta r_t)}{Var(\Delta i_t)} \tag{20}$$

$$= \frac{(\beta\delta + \gamma)(\alpha\gamma + \delta)\sigma_z^2 + \alpha\sigma_\epsilon^2 + \beta\sigma_\eta^2}{\beta\delta + \gamma)^2\sigma_z^2 + \sigma_\epsilon^2 + \beta^2\sigma_\eta^2} \tag{21}$$

hence, the bias of the OLS estimate could be

$$\hat{\alpha}_{OLS} - \alpha = (1 - \alpha\beta)\frac{\beta\sigma_\eta^2 + \delta(\beta\delta + \gamma)\sigma_z^2}{\sigma_\epsilon^2 + \beta^2\sigma_\eta^2 + (\beta\delta + \gamma)^2\sigma_z^2} \tag{22}$$

According to the Equation 22 the OLS estimate is biased due to both

- simultaneity bias - if $\beta \neq 0$ and $\sigma_\eta^2 > 0$
- omitted variables bias - if $\gamma \neq 0$ and $\sigma_z^2 > 0$

To deal with this problem many studies focus on the narrow windows immediately surrounding the FOMC announcement using what has been known as event study methods that are largely used in literature such as Cook and Hahn (1989); Thorbecke (1997); Kuttner (2001); Bernanke and Kuttner (2005); Gürkaynak et al. (2005), and Hausman and Wongswan (2011).

The main logic $\beta \neq$ behind the event study method is that the bias in the OLS estimate will be limited if the following conditions hold to minimise the bias of the estimator.

$$\sigma_\epsilon^2 \gg \sigma_\eta^2 \tag{23}$$

$$\sigma_\epsilon^2 \gg \sigma_z^2 \tag{24}$$

in which case $\hat{\alpha}_{OLS} \cong \alpha$. In the limit, if σ_ϵ^2, the variance of the monetary policy shock becomes infinitely large relative to the variances of the other shocks, σ_η^2 and σ_z^2 or mathematically $\sigma_\epsilon^2/\sigma_\eta^2 \implies \infty$ and $\sigma_\epsilon^2/\sigma_z^2 \implies \infty$ therefore, the biases go to zero, and the OLS estimate now becomes consistent.

Nevertheless, the window lengths are generally of one or two-day length which is insufficient to remove this bias. Within a one-day period, for instance, there might be many other shocks such as unemployment report or growth rate announcements might appear and these might affect financial asset prices; thus, the affected asset prices alone will no longer be able to correctly convey the effect of the monetary policy announcement. Therefore, as shown in MB-FK-AM (2019), these conditions 23 and 24 may not hold, and the size of the bias could remain in those OLS estimates.

Under these circumstances, an event study with high-frequency data may offer a solution. For example, if a short enough window is considered, not even a day but minutes around an announcement, then it is reasonable to claim that the variance of shocks σ_η^2 and σ_z^2 are small, relative to

the variance of the shock to the news,σ_ϵ^2. Then, Equation 17, can be simply estimated by an OLS regression of Δr_t on Δi_t. The equation is estimated over windows that include only one announcement.

7.1 Measurement of Reactions

Hence, the empirical methodology to measure the responses of the asset prices to FOMC minutes follows that used by Gürkaynak et al. (2005) and Hausman and Wongswan (2011) for FOMC statements. Again, asset price returns over a 20-minute window around FOMC minutes announcement in which 10 minutes before and 10 minutes after the release of FOMC minutes are examined. Specifically, for each asset class on the days in which FOMC minutes take place, regression is run:

$$\Delta r_{x,d,\tau} = \alpha + \beta_1 TS_{d,\tau} + \beta_2 PS_{d,\tau} + \varepsilon_{x,d,\tau} \tag{25}$$

where $\Delta r_{x,d,\tau}$ is the return of each (x) asset class in the 20-minute window on the announcement day d at the announcement release time τ (14:00). $TS_{d,\tau}$ is the target surprise, $PS_{d,\tau}$ is the path surprise and $\varepsilon_{x,d,\tau}$ is the residual term. Therefore, as the intra-daily window is sufficiently narrow in time around the new information or surprise, it can be assumed that FOMC minutes are in no way affected by asset price movements or other macroeconomics news over that interval. For that reason, it is much less likely any other important news occurred within this narrow window that may have affected asset prices, hence increasing the precision power of equation-27 estimates.

7.2 Measurement of Volatility

To gauge each asset's volatility, the methodology of Kohn et al. (2003) and Rosa (2013) is followed and looks at whether, and to what extent, the volatility of asset prices is higher on FOMC minute release days compared with non-announcement days. More specifically, for both FOMC minute announcement and non-announcement days the standard deviation is defined as:

$$SD = \sqrt{\Sigma_{t=1}^{T}(r_t - \bar{r})^2/(T-1)} \tag{26}$$

where r_t is the ten-minute return, T is the number of observations in each sample, and $\bar{r}$ is the sample mean. Hence the *normal* is the volatility that would be expected to prevail on control or

non-announcement days. The main hypothesis is that as long as the information set of FOMC minutes is not always completely predicted, and this must be reflected in *higher* volatility of asset prices compared with a period free of such events which is non-event days or to the *normal* ones.

8 Results and Discussions

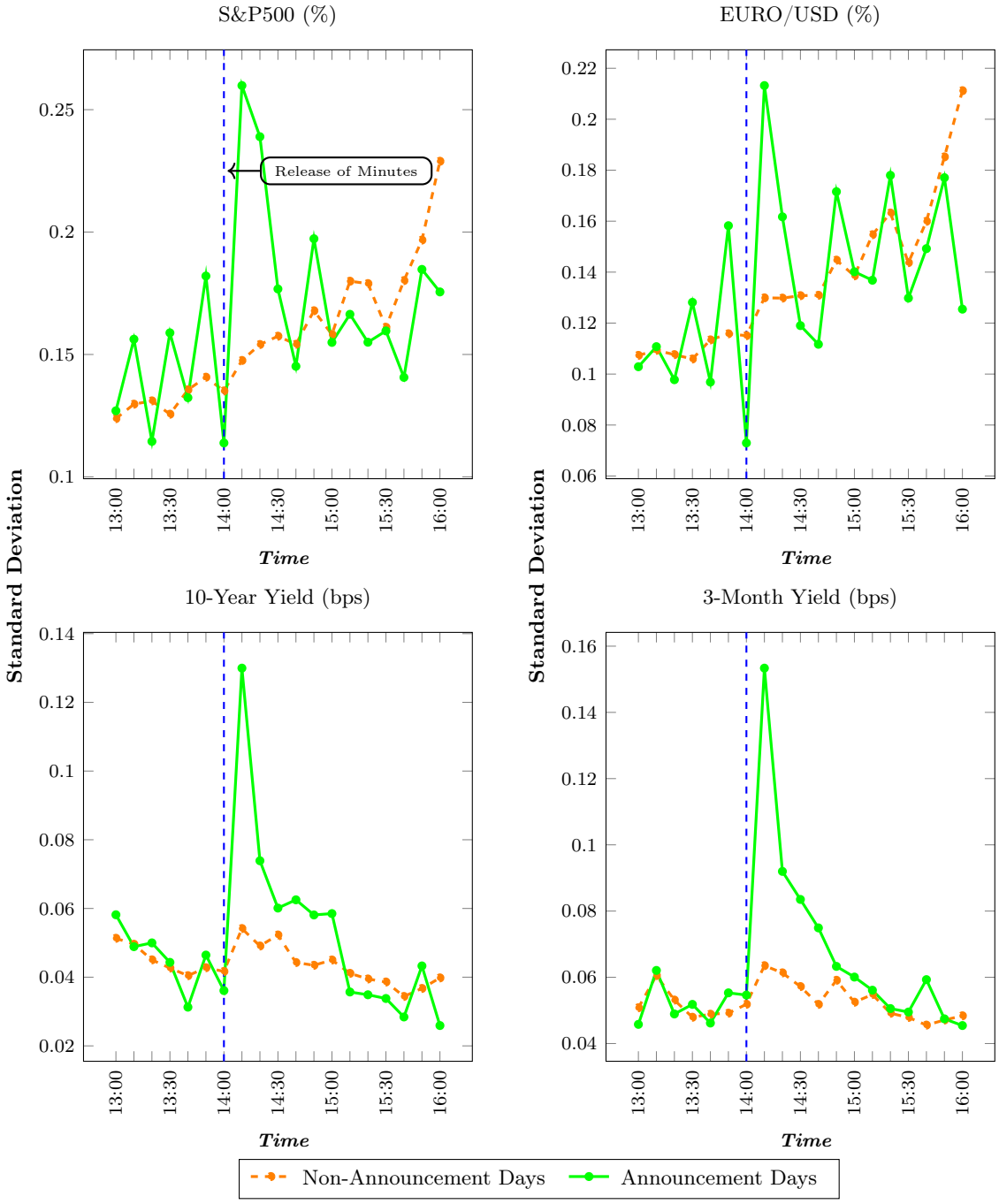
8.1 Asset Prices Volatility

At first, asset price volatility is considered in a short window bracketing FOMC minutes announcement compared to non-announcement days. The fundamental idea is that as long as some part of FOMC minute announcement contain an unpredicted factor, financial agents reconsider to some extent their anticipations, and asset prices will be more volatile on FOMC minutes announcements days than it would be otherwise. Figure-2 presents the volatility of asset prices on FOMC minutes announcement dates and times. As explained above in the data section, returns are ten-minute percentage changes for the S&P 500 and exchange rates and ten-minute basis points yield changes for Treasury rates. The interval spans from one hour before (from at 13:00) to two hours after (to at 16:00) the event time (at 14:00). The vertical dashed-line is placed at the announcement time of FOMC minutes, which is at exactly 14:00. All four graphs plot (i) the standard deviation of ten-minute asset price returns around FOMC minutes announcements with a solid [green] line, and (ii) the standard deviation of ten-minute asset price returns on non-announcement days (control days) and hours with a dashed [orange] line.

Graphs in Figure-2 document that the release of FOMC minutes increases the volatility of each asset price. Volatility summits at the time of announcement, and stays higher than normal for approximately a 20-minute after the announcement then the impacts short-lived the volatility returns to the normal level. Another interesting result is that the volatility of all asset prices decreased, for instance the S&P 500 and 10-Year Treasury yield reaches the lowest point, in the period 13:50-14:00 period in all of the ten-minute periods leading up to FOMC minutes release. One potential interpretation of this is that market participants take a *wait-and-see* approach and avoid any transactions just before FOMC minute release. This is consistent with the idea that the financial markets tend to be relatively quiet on days or minutes preceding important news or a regularly scheduled announcement.

More specifically, the volatility of the 10-Year Treasury yields at 14:00, which is the time of the release, suddenly jumps from 4 bps to around 16 bps, which is roughly three times greater than on FOMC minutes announcement days compared with a period free of such an announcement, and stays

Figure 2. The Volatility of Asset Prices around FOMC Minutes Releases



Notes: This figure plots (i) the standard deviation of ten-minute asset price returns around FOMC minutes release on FOMC announcement days with with a solid [green] line, and (ii) the standard deviation of ten-minute asset price returns on control days (non-announcement days) with a dashed [orange] line. Returns are ten-minute percentage changes for exchange rates and stock index while Treasury yields are based on basis point change. The sample period is December 2004–November 2017. The interval spans from one hour before (13:00) and two hours after (16:00) the event time (FOMC minutes are announced at 14:00 ET.). The vertical [blue] dashed line is placed at the release time of FOMC minutes which is 14:00 ET. The volatility of NASDAQ-100, DJIA, GBP/USD, and JPY/USD can be seen in Figure-**??** in Appendix.

significantly higher up to around 60-minutes after the release. Similarly, the volatility of the S&P 500 and EUR/USD exchange rate returns are approximately two and three times greater, respectively, on FOMC minutes announcement days compared to non-announcement days. In contrast, the volatility of the three-months interest rate is insignificant and there is no considerable difference between announcement and non-announcement days as regards volatility of three-month Treasury yields. Overall the Euro–U.S. dollar exchange rate is the most affected financial asset class, closely followed by 10-Year Treasury yields and the S&P 500 stock prices, whereas 3-Month Treasury yield in announcement days acts similar to non-announcement days. In sum, Figure-2 proves that FOMC minutes release substantially increases the volatility of US asset prices and provides *new* information for the markets and this information is incorporated into asset prices in minutes.

This study also investigates whether the volatility of asset prices, attributed to the minutes FOMC, has altered over time by dividing the sample into two sub-groups. The question that this part simply asks is whether or not, with the zero lower bound policy the volatility of market at the time of releasing of FOMC minutes has changed. The first sub-group is taken from the before the ZLB period which is from December 2004 to December 2008. On December 16, 2008, the FOMC decreased its key federal fund target rate by 75 basis point from 100 to 25 basis point. Thereafter, the interest rate corridor became *0 - 0.25* percent and this is known as *zero lower bound* (ZLB). This ZLB period took until December 2015. During this time the Fed did not change its key interest rate. In addition, there were almost no target policy surprises for the market participants during this seven-year period. As Swanson and Williams (2014) suggested that changing the current level of the policy rate is not the only option to make effective monetary policy. As one of important central bank communication tools, it is argued that the release of FOMC minutes could cause market volatility or at least might have a different volatility pattern before this period.

8.2 Reactions to FOMC Minutes

The literature mostly concentrate on the financial market's responses only to FOMC statements. However, surprises which comes from FOMC minutes have similar features to FOMC statements. Therefore, these surprises might have some meaningful impact on asset prices. In this research, I seek to answer the question: if FOMC minutes have meaningful impact on the volatility of financial markets, how do these volatilities affect the financial markets? To show this, equation-25 is regressed for all asset classes on FOMC minutes instead of FOMC statements in daily and intradaily data.

Specifically, for each asset class on the days in which FOMC minutes (and FOMC statement) take place, regression is run:

$$\Delta r_{x,d,\tau} = \alpha + \beta_1 TS_{d,\tau} + \beta_2 PS_{d,\tau} + \varepsilon_{x,d,\tau} \tag{27}$$

where $\Delta r_{x,d,\tau}$ is the return of each (x) asset class in the 20-minute window on the announcement day d at the announcement release time τ. $TS_{d,\tau}$ is the target surprise, $PS_{d,\tau}$ is the path surprise and $\varepsilon_{x,d,\tau}$ is the residual term.

This regression is run for both minutes and statement announcement days during 2004-2017 between at 14:00-14:20. Panel A for minutes Panel B for statement days. I have also tested the difference between coefficients and again the differences are statistically different from each other for statement and minutes in panel A and panel B.

Panel A in Table-2 shows the financial market responses to the monetary policy surprises coming from FOMC minutes rather than FOMC statements. According to Table-2, when considering the whole period (Panel A), except 3-Month interest rates, all assets react significantly to FOMC minutes. On average, a hypothetical 100-basis point surprise upward revisions in the future path of monetary policy is associated with a 17 basis point surprise rise in 10-Year Treasury rate, 1.18% appreciation of the US Dollar against the Euro, and almost 1% decrease in the S&P500 stock index. These findings are consistent with the expectation that if FOMC minutes contain some new information, this is mostly related to the long-term monetary policy actions, given that FOMC minutes are published three weeks after FOMC statement announcement and all information contained in FOMC minutes comes from previous actions. Consequently, financial participants would revise their future expectation rather than the next FOMC interest rate change. Therefore, the results are in parallel with the expectation that FOMC minutes have an impact on financial markets through long-term monetary policy surprises, which is the path surprise in our case. Similarly, a hypothetical 100-basis point surprise cut in the fed funds target rate is associated with a 1.77% decrease in the S&P500 stock index, 1.22% US dollar appreciation against the Euro, 16 and 9 basis point increase in the 10-Year and 3-Month Treasury yields. However, only the S&P500 stock index responds significantly to the target surprise.

Table 2. The Responses of the Financial Markets to FOMC Minutes

(Minutes)	Reactions to Minutes Surprise (2004-2017)							
	Target	SE	Path	SE	Cons	SE	Obs	R-Sq
S&P500 (%)	-1.77**	(0.81)	-0.94***	(0.22)	-0.01	(0.03)	103	0.16
EUR (%)	1.22	(0.88)	1.18***	(0.36)	-0.04**	(0.02)	103	0.13
10-Year (bps)	16.55	(20.74)	17.79***	(4.23)	0.84	(0.54)	103	0.16
3-Month (bps)	9.81	(8.39)	5.62	(3.26)	0.29	(0.27)	103	0.06
(Statement)	Reactions to Statement Surprise (2004-2017)							
	Target	SE	Path	SE	Cons	SE	Obs	R-Sq
S&P500 (%)	-3.18***	(0.66)	-2.82***	(0.71)	0.05	(0.04)	103	0.28
EUR (%)	0.24	(0.77)	3.63***	(0.58)	-0.00	(0.02)	103	0.35
10-Year (bps)	18.77	(31.30)	59.81***	(18.51)	0.10	(0.79)	103	0.15
3-Month (bps)	18.83***	(4.78)	3.18	(3.72)	-0.05	(0.37)	103	0.14

Notes: Table shows responses of asset prices to the surprise of FOMC minutes and statements. The sample period includes all FOMC statements minutes from December 2004 to November 2017 which is total 103 FOMC statements and 103 minutes announcements. Interest rates are in the bps unit, and S&P 500 and exchange rates are in percentage change. Robust standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

In addition Rosa (2013), our findings indicate that the release of FOMC minutes not only causes the volatility in financial markets but also financial market participants respond significantly to FOMC minutes release. This result also contrasts the claims of Jubinski and Tomljanovich (2013) that individual firms' equity returns are essentially unaffected by FOMC minutes releases. The differences between our and Jubinski and Tomljanovich (2013)'s finding might come from the sample size and type. Jubinski and Tomljanovich (2013) analysed only individual firms' reactions for a two year period, however, our data is more comprehensive and investigates three (stock market, exchange rate, and fixed income market) different main markets' reaction rather than individual firms over an almost 13 years perspective.

We have also tested the hypothesis 1) the coefficients of statement and minutes are different from non-announcement days and 2)coefficient of statement is different from the coefficients of minutes for both target and path surprise during the 2004-2017.

$$absTS = \alpha + \beta StatementDummy + \gamma MinutesDummy \tag{28}$$

$$absPS = \alpha + \beta StatementDummy + \gamma MinutesDummy \tag{29}$$

where StatementDummy is 1 if it is a statement announcement day otherwise 0 (no-announcement or minutes announcement day) and total 103 observation out of 3227 observation during 2004-2017. MinutesDummy is 1 if it is a minutes announcement day otherwise 0 (no-announcement or statement announcement day)and total 103 observation out of 3227 observation during 2004-2017. absTS is the absolute value of target surprise and absPS is the absolute value of path surprise. β are 1.52 and 1.87 for target and path surprise while γ are 0.11 and 0.94, respectively.

Table 3. Coefficients of Dummy Variables

	2004-2017	
	abs_TS	abs_PS
	(1)	(2)
Statement Announcement	1.527***	1.875***
	(6.76)	(4.49)
Minutes Announcement	0.109	0.947*
	(0.46)	(2.17)
Constant	0.557***	3.391***
	(13.02)	(42.88)
Observations	103	103

t statistics in parentheses

* (p<0.05), ** (p<0.01), *** (p<0.001)

The coefficient on the dummy variable Statement Announcement represents the difference between statement announcement and no announcement time, and the coefficient on the dummy variable of minutes announcement represents the difference between minutes announcement time and no announcement days. The t-ratio on statement of 6.76, and its P-value of 0.000, indicate that the means of no announcement times and statement announcement times are statistically significantly different at the 1% level. The P-value on minutes dummy is 0.64, indicating that the difference between the means of no announcement days and minutes announcement days is not statistically significant even at the 10% level for target surprise which is expected that we claim

that minutes has mostly have a long term impact rather than short term where target surprise is represented the short term surprise. Similarly for the path surprise both dummy variable are statistically significant from non-announcement times.

In addition, we have tested whether the difference between coefficients is significant or not.

$$\beta\ [Statement] - \gamma\ [Minutes] = 0, \qquad \text{for Target Surprises} \tag{30a}$$

$$\beta\ [Statement] - \gamma\ [Minutes] = 0, \qquad \text{for Path Surprises} \tag{30b}$$

Having tested individually for both target and path surprise the coefficients of dummy variables of statement and minutes, we reached that the differences are statistically significant for the target surprise but not for the path surprise (0.11 P value) since both have a similar coefficient. Here is the detailed results table:

Table 4. Test the Equality of Regression Coefficients

	Coef.	Std. Err.	t	P > t	[95% Conf.	Interval]
abs_TS						
(1) $\beta - \gamma = 0$	1.418	0.321	4.41	0.00	0.787	2.048
abs_PS						
(2) $\beta - \gamma = 0$	0.928	0.594	1.56	0.118	-0.236	2.093

In addition, we run regression on values of target surprise and path surprise on statement announcement and minutes announcement days seperately for again target surprise and path surprise to see the relationship between FOMC statement and its minutes announcement. For example

$$PS_{minutes} = \alpha + \beta PS_{statement} \tag{31}$$

$$TS_{minutes} = \alpha + \beta TS_{statement} \tag{32}$$

where $PS_{statement}$ is the path surprise surprise from statement announcement days whereas $PS_{minutes}$ is the path surprise from the minutes announcement days.

Table-5 shows the regression results for Equation-36 and 32. Also these regressions are run

Table 5. Relationship Between FOMC Statement vs FOMC Minutes

	Whole Period		ZLB Period		Non-ZLB Period	
VARIABLES	PS Minutes	TS Minutes	PS Minutes	TS Minutes	PS Minutes	TS Minutes
PS Statement	0.095		0.190**		-0.025	
	(0.077)		(0.075)		(0.141)	
TS Statement		-0.012		0.116***		-0.036
		(0.073)		(0.025)		(0.118)
Constant	-0.223	0.06	-0.760	-0.011	0.592	0.200
	(0.575)	(0.316)	(0.545)	(0.058)	(1.077)	(0.709)
Observations	103	103	57	57	46	46
R-squared	0.015	0.000	0.105	0.287	0.001	0.002

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

for the different period and second column show the ZLB period and third column show the non ZLB period. Second column in Table-5 indicates that the importance of minutes in terms of its relationship with the FOMC statement increased and became significant during the ZLB period.

8.3 Effects of Zero Lower Bound

In the wake of the recent financial crisis, the Fed has relied on unconventional policy tools such as large-scale asset purchases and took an unexpected decision to decrease short-term interest rates to the zero lower bound. Previous efforts (Neely (2015), Bauer and Neely (2014), Wright (2012), Swanson and Williams (2014), Krishnamurthy and Vissing-Jorgensen (2011), Gagnon et al. (2011), and d'Amico et al. (2012)) investigated the effects of these unconventional monetary policies. However, these papers mainly focused either solely on FOMC statement or quantitative easing announcements based on FOMC statement. In contrast, the goal of this section is to assess the effects of the release of FOMC minutes on financial market by comparing the zero lower bound period (2008-2015) with the conventional period (2004-2008).

In doing so, the equation-25 is regressed on two different periods which are before the ZLB period (2004-2008) and during the ZLB period (2008-2015). These results are presented in Panel A and B in Table-6. According to Panel B which is for the ZLB period, the responses of the stock market, exchange rate and ten-year yield to FOMC minutes increased. For instance, the response of the Euro-US Dollar exchange rate and 10-years bonds to the path surprise increased about three-fold. This is consistent with the argument (Rajan (2015)) that after the recent financial crisis the US dollar has become more influential in the financial world. With the quantitative easing policy the Fed increased its balance sheet fourfold and the value of US dollar depreciated against the

international currency basket. This means that international capital flowing from the US to the rest of the world increased and the world's financial market have heavily relied on the US dollar. Therefore, these results support that any new information related to the value of USD affects the exchange rate market even if this information set is three weeks lagged. Similarly, the responses of stock market and 3-Month interest rate five-fold and two-fold, respectively.

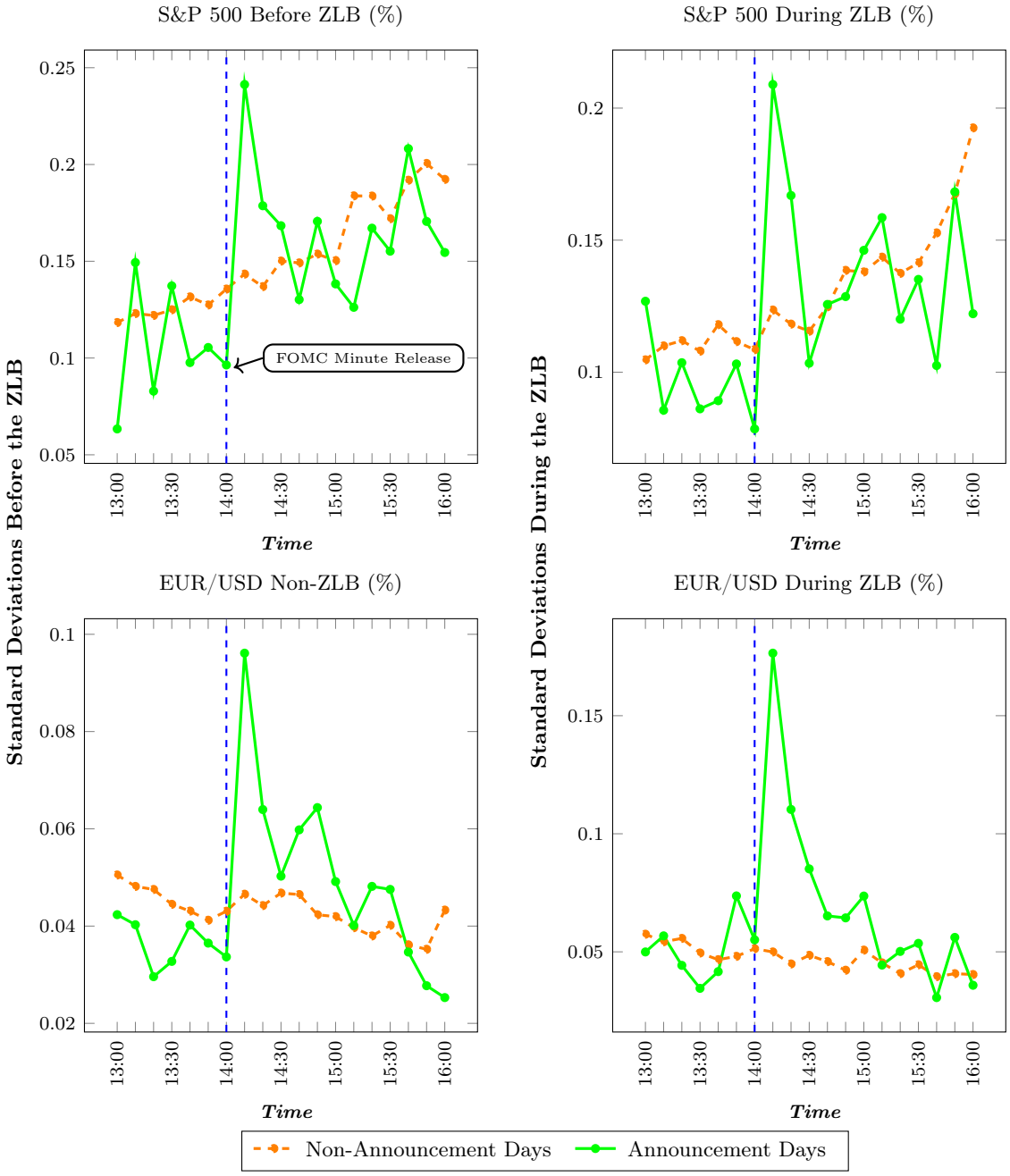
Table 6. The Responses of the Financial Markets to FOMC Minutes

(A)	Monetary Policy Surprises for Non-ZLB (2004-2008)							
	Target	SE	Path	SE	Cons	SE	Obs	R-Sq
S&P500 (%)	-1.51	(0.90)	-0.95***	(0.27)	-0.04	(0.04)	46	0.22
EUR (%)	0.75	(0.80)	0.78**	(0.34)	-0.05*	(0.02)	46	0.11
10-Year (bps)	28.46	(21.48)	12.87**	(4.89)	0.10	(0.81)	46	0.18
3-Month (bps)	13.05	(12.64)	8.09	(4.85)	0.39	(0.57)	46	0.10
(B)	Monetary Policy Surprises for during ZLB (2008-2015)							
	Target	SE	Path	SE	Cons	SE	Obs	R-Sq
S&P500 (%)	-8.04**	(3.88)	-0.61	(0.41)	0.02	(0.04)	57	0.14
EUR (%)	1.12	(3.39)	2.53***	(0.80)	-0.02	(0.03)	57	0.16
10-Year (bps)	25.82	(79.93)	31.33***	(8.52)	1.76**	(0.73)	57	0.23
3-Month (bps)	29.62	(18.82)	-1.16	(2.01)	0.11	(0.17)	57	0.05

Notes: Table shows responses of asset prices to the surprise of FOMC minutes. The sample period includes FOMC minutes from December 2004 to November 2017 which is total 103 FOMC minutes announcements. Interest rates are in the bps unit, and S&P 500 and exchange rates are in percentage change. Robust standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

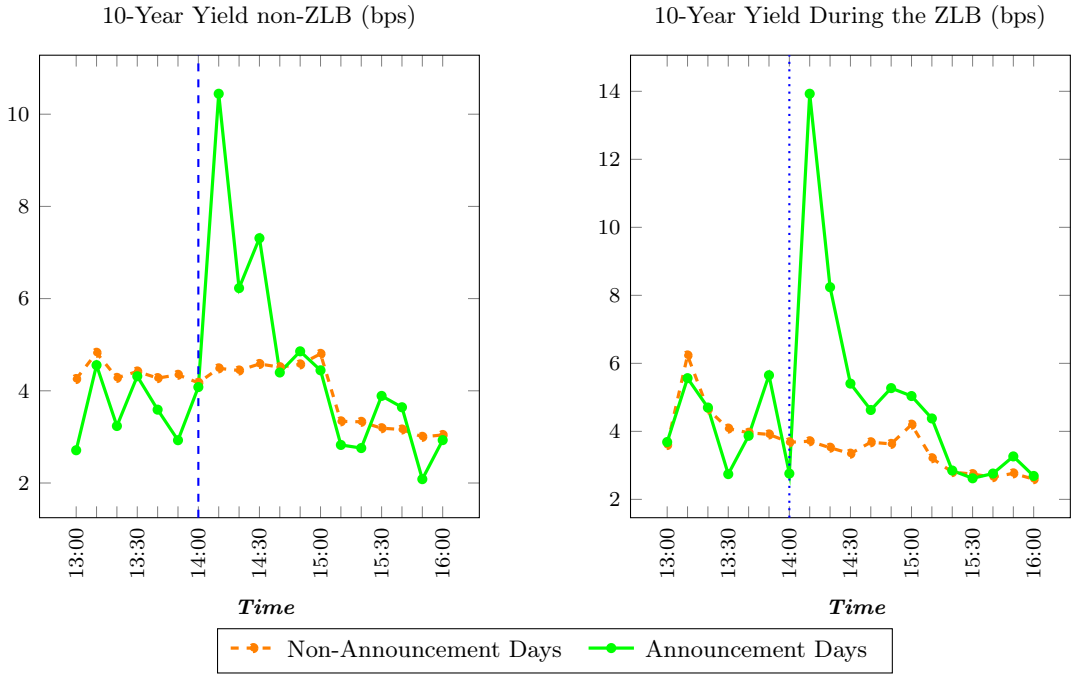
In this respect, Figure-3 and 4 plot (i) the standard deviation of ten-minute asset price returns around FOMC minutes release with a solid line, and (ii) the standard deviation of ten-minute asset price returns on non-announcement days (control days) and hours with a dashed line. Graphs on the left-hand side represent the volatility before the ZLB and graphs on the right-hand side represent the volatility during the ZLB period. The figures indicate that the overall level of volatility on the days of FOMC minutes announcement has increased and non-announcement days has remained during the zero lower bound period. For example, the volatility of 10-Year Treasury yields on the announcement days before the ZLB is about two times greater than the one on non-announcement days. However, with the ZLB period, this difference became five times greater.

Figure 3. Asset Price Volatility Before and During the ZLB Period



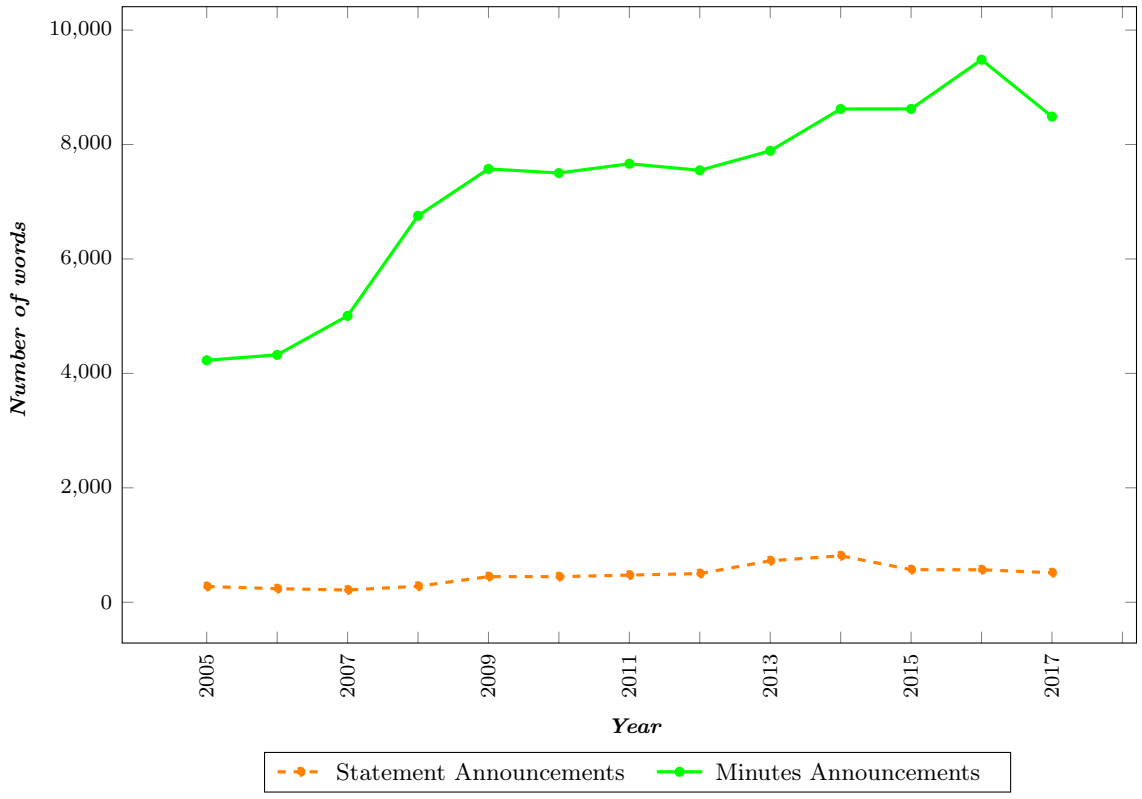
Notes: This figure plots (i) the standard deviation of ten-minute asset price returns around FOMC minutes release on FOMC announcement days with with a [green] solid line, and (ii) the standard deviation of ten-minute asset price returns on control days (non-announcement days) with a [orange] dashed line. Returns are ten-minute percentage changes for exchange rates and stock index. The first period (before the ZLB) covers from December 2004 to December 2008 while the ZLB period is December 2008–December 2015. The interval spans from one hour before (13:00) and two hours after (16:00) the event time (FOMC Minutes is announced at 14:00 ET.). The vertical [blue] dashed line is placed at the release time of FOMC minutes which is 14:00 ET. The volatility of NASDAQ-100, DJIA, GBP/USD, and JPY/USD can be seen at Figure-**??** in Appendix.

Figure 4. Asset Price Volatility Before and During the ZLB Period



Notes: This figure plots (i) the standard deviation of ten-minute asset price returns around FOMC minutes release on FOMC announcement days with with a [green] solid line, and (ii) the standard deviation of ten-minute asset price returns on control days (non-announcement days) with a [orange] dashed line. Returns are ten-minute based on basis point change for Treasury yields. The first period (before the ZLB) covers from December 2004 to December 2008 while the ZLB period is December 2008–December 2015. The interval spans from one hour before (13:00) and two hours after (16:00) the event time (FOMC Minutes is announced at 14:00 ET.). The vertical [blue] dashed line is placed at the release time of FOMC minutes which is 14:00 ET. The volatility of NASDAQ-100, DJIA, GBP/USD, and JPY/USD can be seen at Figure-**??** in Appendix

Figure 5. The Average Number of Words for Statement and Minutes Announcements



Notes: .

There might be many different potential interpretations of this finding. First, the size of minutes content can play a role in this, since the size and the number of Fed communications have been increasing for last two decades. In this regards, the Figure-5 show the annual average of the number of words for each announcements. For example, the average number of words in minutes for FOMC meetings 2005 is 4229 while the average number of minutes of FOMC meeting in 2016 is 9482 words which is more than two times greater. Larger content might bring more information, thus, gives more surprise. Second, during the ZLB period surprises might not come from interest rate change reported through FOMC statement announcement but other concerns. For example, again FOMC statement for the meeting on January 25, 2012 has only 420 words and no surprise for the target rate policy. However, the minutes of this meeting has 10,651 words and much new information other than interest rate changes such as the Fed growth rate expectation, the size of quantitative easing, and the potential inflation rate in the near future. Information regarding these topics can be found in minutes.

In this regards, we test whether there is relationship between the number of words and its

surprise component. Also we tested whether there is negative surprise trend over the time. For example, the increase of the number of words over time might affect the surprise component. Hence we run two regression on surprises for the number of words and announcements over the time.

$$AbsPS_{statement} = \alpha + \beta Announcement\ ID \tag{33}$$

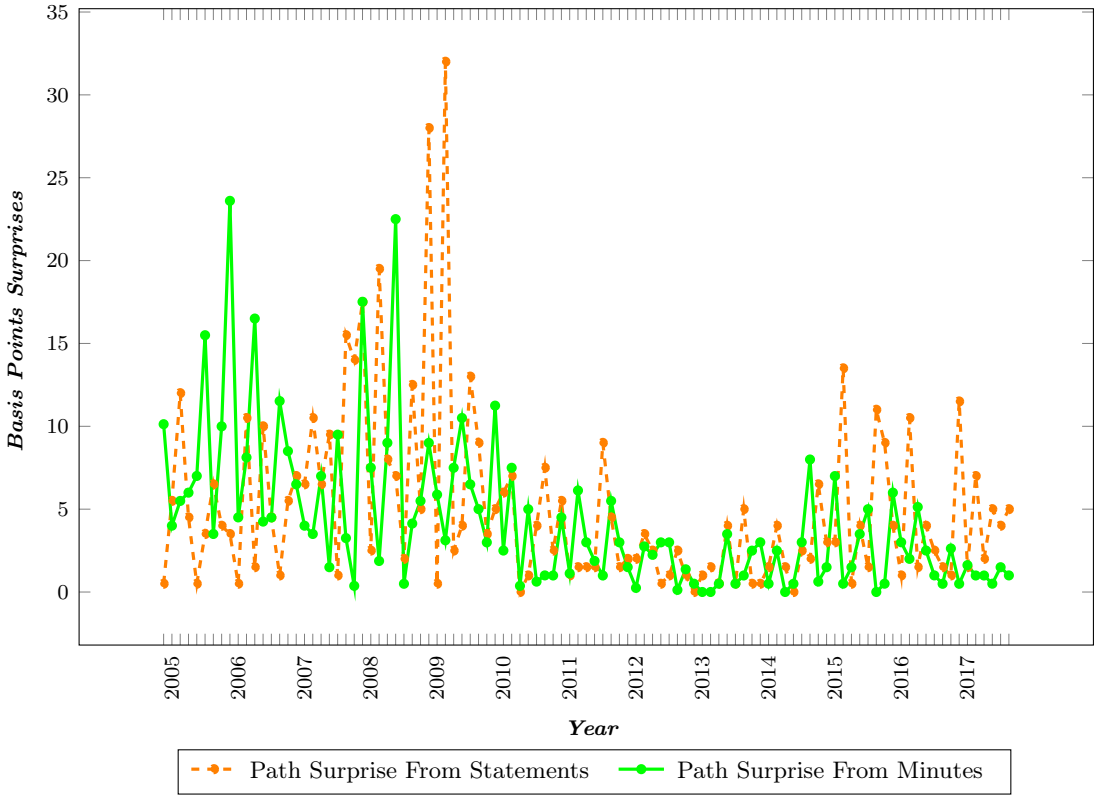
$$AbsPS_{minutes} = \alpha + \beta Announcement\ ID \tag{34}$$

$$AbsPS_{statement} = \alpha + \beta(Number\ of\ words\ in\ Statement) \tag{35}$$

$$AbsPS_{minutes} = \alpha + \beta(Number\ of\ words\ in\ Minutes) \tag{36}$$

where $AbsPS_{statement}$ $AbsPS_{minutes}$ are the path surprise surprise from statement announcement and minutes announcement days, respectively. $Announcement\ ID$ represent each FOMC meeting over the time. For example it is 1 for December 2004 meeting while it is 103 for the meeting on November 2017. Lastly $Number\ of\ words\ in\ Statement$ and $Number\ of\ words\ in\ Minutes$ are the number of words which statement and minutes announcements have for each meeting.

Figure 6. Path Surprises for Each Statement and Minutes Announcement Over the Time



Notes: .

Table 7 shows these relationship. According to table.....the Fed explains more and more to decrease uncertainty.... [NEED MORE DISCUSSION]

To sum up, even though there is no interest rate change during the ZLB period, the minutes of FOMC meetings are seen as a source of other economic information and all these new information might increase the volatility of the financial market.

The volatility of FOMC statement announcement days was also controlled. To gauge the order of magnitude of effects of FOMC statements, FOMC minutes and non-announcement days, a comparison of the volatility of stock market and exchange rates attributed to FOMC minutes was made with that induced by the release of FOMC statement and non-announcement days. Figure-7 represents these comparisons. The dotted [blue] line denotes the volatility of the release of FOMC statement and FOMC minutes and non-announcement days are the same as before, which are represented by the solid line and dashed line, respectively. According to Figure FOMC statements indicate the most greatest volatility in asset price. For example, S&P 500 stock prices are at least four times more volatile on FOMC statement announcement days compared with non-announcement

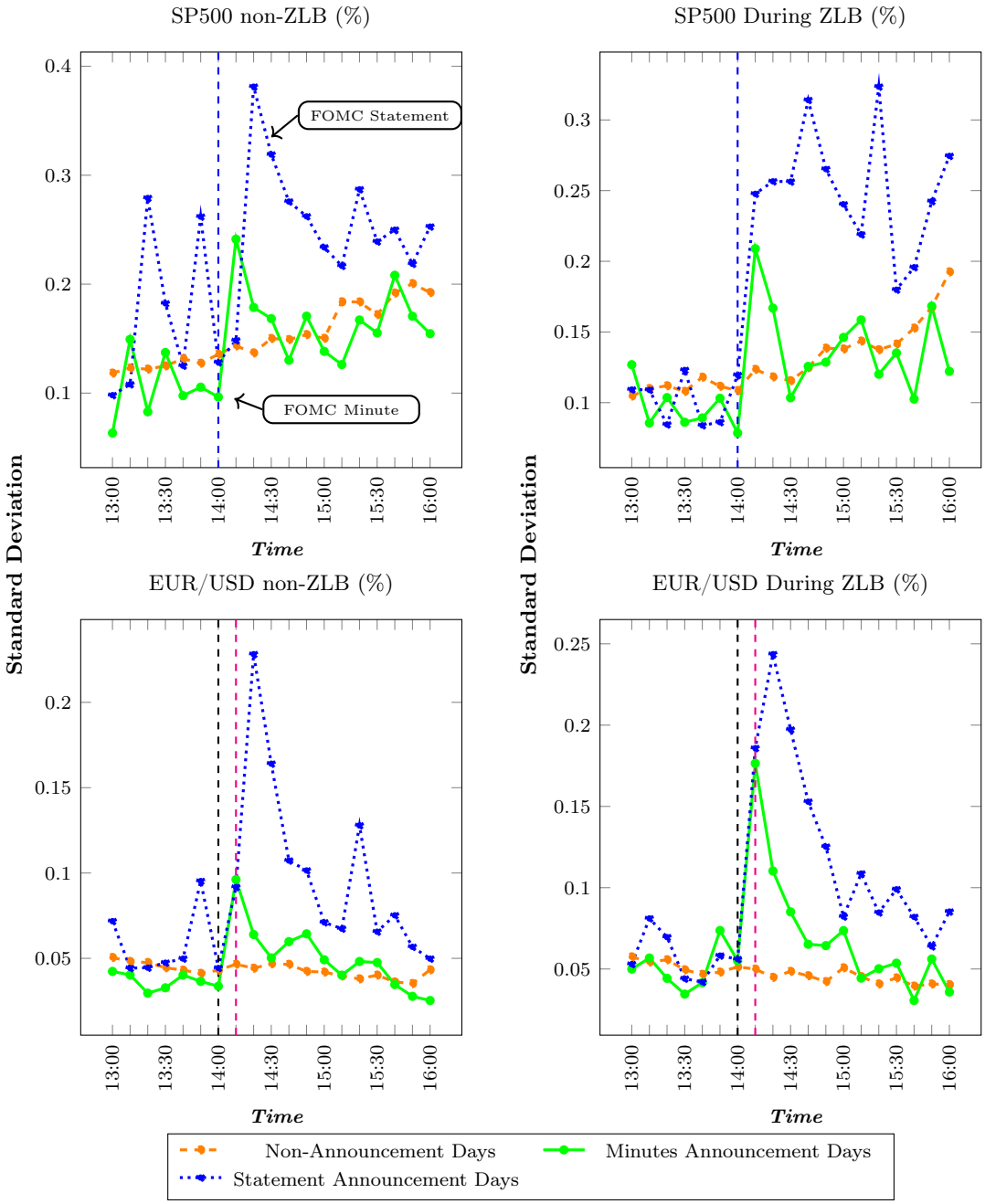
Table 7. The Number of Words and Surprises

VARIABLES	(1) AbsPS Sta	(2) AbsPS Min	(3) Abs PS Sta	(4) Abs PS Min	(5) # WordsSta	(6) # WordsMin
Announcement ID	-0.043**	-0.082***			4.636***	47.76***
	(0.018)	(0.013)			(0.395)	(5.367)
# Words Sta			-0.01***			
			(0.003)			
# Words Min				-0.001***		
				(0.0002)		
Constant	7.305***	8.553***	9.539***	10.87***	227.9***	4,769***
	(1.060)	(0.761)	(1.422)	(1.429)	(23.66)	(321.5)
Observations	103	103	103	103	103	103
R-squared	0.054	0.291	0.100	0.185	0.577	0.439

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

days when they are two times higher than FOMC minute announcement days.

Figure 7. FOMC Statement vs FOMC Minutes (Before and During the ZLB Period)



Notes: This figure plots (i) the standard deviation of ten-minute asset price returns around FOMC minutes release on FOMC announcement days with with a [green] solid line, (ii) the standard deviation of ten-minute asset price returns on control days (non-announcement days) with a [orange] dashed line, and (iii) the standard deviation of ten-minute asset price returns around FOMC statement release on FOMC announcement days with with a [blue] dotted line. Returns are ten-minute based on basis point change for Treasury yields. The first period (before the ZLB) covers from December 2004 to December 2008 while the ZLB period is December 2008–December 2015. The interval spans from one hour before (13:00) and two hours after (16:00) the event time (FOMC Minutes and Statement are announced at 14:00 and 14:15 ET respectively). The vertical [blue] dashed line is placed at the release time of FOMC minutes which is 14:00 ET.

9 Conclusion

This research, at first, has examined the extent to which FOMC minutes has some surprise information for financial market participants during the period from December 2004 to November 2017, by considering 103 FOMC minutes announcements and 103 FOMC statement announcement. This investigation is an important topic for several reasons. From a policy maker's perspective, this line of investigation sheds further light on the effect of monetary policy communication on the markets. Two different components of monetary policy surprise were constructed; namely, the target and path surprise with high-frequency data. Thereafter, using the event study method with intra-daily it was found that FOMC minutes have *new* and relevant information for the financial markets.

In summary, we investigate the financial market effects of FOMC minutes on stock markets, fixed income markets and exchange rates prices and compares conventional and unconventional (the zero lower bound) periods using an intra-daily event-study method. A summary of the main findings of this research is outlined below. First, an investigation into the financial market volatility caused by the release of FOMC minutes on the asset prices (exchange rates, stock prices, and Treasury yields) was undertaken. The release of FOMC minutes is indicated to induce *higher than normal* volatility across different asset classes. For example, the volatility of the EURO/USD exchange rate and 10-year Treasury yields is approximately three times larger on event days than non-announcement days. These findings suggest that FOMC minutes contain market-relevant information and this is not a completely ex-ante information. The findings of this section are consistent with the results of Rosa (2013) which also showed the volatility is higher than normal on announcement days. Second, in contrast to Jubinski and Tomljanovich (2013) (and in addition to Rosa (2013)) it was found that financial markets respond quickly and significantly to the release of FOMC minutes, and these reactions are heterogeneous across the financial markets. For example, only the stock market responds negatively and significantly to the target surprise while exchange rate and ten-year interest rate respond positively and significantly to the path surprise, and further, that three-month interest does not respond significantly. Therefore, it concludes that the release of FOMC minutes receives the attention of the market and this attention is mostly significant. This suggests that FOMC minutes should be considered an important announcement as similar to the actual FOMC interest-rate decisions. Third, we compare all these reactions with the ones to the FOMC statement and find that reactions to FOMC minutes are lower than the reactions to FOMC statement but it significantly larger than non-announcement days. Finally, further investigation has been conducted by splitting the dataset into two parts in order to examine whether the asset price response and

volatility to the release of FOMC minutes change before and during the zero lower bound period. It was found that the volatility increased and responses to FOMC minute became stronger. The potential interpretation of these findings is that since there was no policy change expectation, the markets do in fact react to the release of FOMC minutes as a source of information on the future path of the monetary policy stance.

This information allows policy makers to evaluate whether and to what extend financial agents respond in accordance with the policy makers' intentions. Information about the likely market reaction to monetary policy, therefore, enables the Fed to assess the immediate success of any action that has been taken. This is important as expectations play a crucial role in the determination of investment and consumption preferences so and, thus, for real economic output in the future. Hence, the measurement of monetary policy surprises and their effects on markets has become an important task for policy makers and economists. This research primarily deals with questions such as how such unexpected occurrences in monetary policy and their sources are determined and how these minutes annoincements affect financial markets.

Appendix

A Derivation of the Target Surprise

$$ff^m_{d,t} = \mathbb{E}_{d,t}[r_{t+m}] + \eta^m_{d,t} \tag{37}$$

$$ff_{d_0-1,t} = \frac{d_0}{D_0} r_0 + \frac{D_0 - d_0}{D_0} \mathbb{E}_{d_0-1,t}(r_1) + \eta_{d_0-1,t} \tag{38}$$

where $ff_{d_0-1,t}$ is the closing-contract price on one-day before $(d_0 - 1)$ FOMC announcement day (d_0) in month t. By evaluating the equations-38 one-day ahead which is at the end of day d_0, we can reach:

$$ff_{d_0,t} = \frac{d_0}{D_0} r_0 + \frac{D_0 - d_0}{D_0} (r_1) + \eta_{d_0,t} \tag{39}$$

where $ff_{d_0,t}$ is the contract price at the end of FOMC announcement day in month t. Note that in both equations- 38 and 39, m is zero and so $ff_{d_0,t}$ equals $ff^0_{d_0,t}$ but for the simplicity we do not prefer to denote.

Differencing the equation-39 from the 38 :

$$ff_{d_0-1,t} - ff_{d_0,t} = \left(\frac{d_0}{D_0} r_0 - \frac{d_0}{D_0} r_0\right) + \frac{D_0 - d_0}{D_0} \Big(\mathbb{E}_{d_0-1,t}(r_1) - (r_1) \Big) + \Big(\eta_{d_0-1,t} - \eta_{d_0,t} \Big) \tag{40}$$

$$\Delta ff_{d_0,t} = \frac{D_0 - d_0}{D_0} \Big(\mathbb{E}_{d_0-1,t}(r_1) - (r_1) \Big) + \Delta \eta_{d_0,t} \tag{41}$$

where $\Delta ff_{d_0,t} \equiv ff_{d_0,t} - ff_{d_0-1,t}$ and $\Delta \eta_{d_0,t} \equiv \eta_{d_0,t} - \eta_{d_0-1,t}$

$$\Big(\mathbb{E}_{d_0-1,t}(r_1) - (r_1) \Big) = \Big(\Delta ff_{d_0,t} - \Delta \eta_{d_0,t} \Big) \frac{D_0}{D_0 - d_0} \tag{42}$$

where $\Delta \eta_{d_0,t} \equiv 0$ and tha target surprse is

$$TS_{d_0,t} = \mathbb{E}_{d_0-1,t}(r_1) - (r_1) \tag{43}$$

simply;

$$TS_{d_0,t} = \frac{D_0}{D_0 - d_0} \Delta ff_{d_0,t} \tag{44}$$

where $\frac{D_0}{D_0 - d_0}$ is the *scaling factor* and $TS_{d_0,t}$ is the target surprise. Kuttner (2001) and Gürkaynak (2005) are followed in scaling for the concurrent month, $\Delta ff_{d_0,t}$ up by the ratio of the number of days in the month, D_0, over the number of days remaining after the meeting,$D_0 - d_0$. One problem might arise with this scaled measure in case of FOMC meetings that occur very late in the month. For example in the last seven days of the month, the scaling factor becomes very large at the end of the month for example, if FOMC meeting takes place on December 30 then the scaling factor becomes 31 ($D_0 = 31$, $d_0 = 30$).

Thus, following Kuttner (2001) and Gürkaynak (2005) the unscaled change is used in the next-month fed funds futures contract to avoid multiplying by a very large scale factor in equation-10. In that case, $TS_{d_0,t} = \Delta ff^1_{d_0,t} = ff^1_{d_0,t} - ff^1_{d_0-1,t}$. Thus, no scaling is involved since the policy action affects the expected rates in the entire subsequent month contract.

B Derivation of the Path Surprise

Let ff denotes the futures contract rate for the month containing the second FOMC announcement. Then

$$ff_{d_0-1,t} = \frac{d_1}{D_1} \mathbb{E}_{d_0-1,t}[r_1] + \frac{D_1 - d_1}{D_1} \mathbb{E}_{d_0-1,t}[r_2] + \eta_{d_0-1,t} \tag{45}$$

where d_1 and D_1 are the day of that second FOMC announcement and the number of days in the month containing this second FOMC meeting. Similarly, $\eta_{d_0-1,t}$ reflects the risk premium as same as before. r_1 is the interest rate after the first FOMC meeting and r_2 is the interest rate after the second FOMC meeting. By evaluating the above equations ahead one day :

$$ff_{d_0,t} = \frac{d_1}{D_1}[r_1] + \frac{D_1 - d_1}{D_1} \mathbb{E}_{d_0,t}[r_2] + \eta_{d_0,t} \tag{46}$$

Differencing the equation-45 from the 46:

$$\Delta ff_{d_0,t} = \frac{d_1}{D_0} \Big(\mathbb{E}_{d_0-1,t}(r_1) - (r_1) \Big) + \frac{D_1 - d_1}{D_1} \Big(\mathbb{E}_{d_0-1,t}(r_2) - \mathbb{E}_{d_0,t}(r_2) \Big) \tag{47}$$

again same as equation-42 ; $\Delta ff_{d_0,t} \equiv ff_{d_0,t} - ff_{d_0-1,t}$ and $\Delta \eta_{d_0,t} \equiv 0$ and we have seen on

equation-43 that $TS_{d_0,t} = \mathbb{E}_{d_0-1,t}(r_1) - (r_1)$ and similarly the path surprise is

$$PS_{d_0,t} \equiv \mathbb{E}_{d_0-1,t}(r_2) - \mathbb{E}_{d_0,t}(r_2) \tag{48}$$

then we put $TS_{d_0,t}$ and $PS_{d_0,t}$ into equation-48

$$\Delta ff_{d_0,t} = \frac{d_1}{D_0} TS_{d_0,t} + \frac{D_1 - d_1}{D_1} PS_{d_0,t} \tag{49}$$

then we can reach the path surprise;

$$PS_{d_0,t} = \left(\Delta ff_{d_0,t} - \frac{d_1}{D_1} TS_{d_0,t}\right) \frac{D_1}{D_1 - d_1} \tag{50}$$

On the other hand, one can argue that a change in near-term (one-year) interest rates may be due to a surprise change in the target rate so Path surprise can also contain the effect of target surprise which violates our argument. Even though this argument is not persuasive since target surprise is proxied by one-month future contract while path surprise by one year Eurodollar which is entirely different maturity. However, to deal with this argument, we used two measures of the path surprise. Path Surprise I is the change in one-year-ahead Eurodollar interest rate futures in a one-day or 40 minutes window around the Fed events. To remove the effect of the target rate surprise from the change in the near-term interest rate, following Hausman and Wongswan (2011) and Gürkaynak et al. (2005) we defined Path Surprise II as the component of the change in one-year-ahead Eurodollar interest rate futures that is uncorrelated with the target surprise. In other words, we orthogonalised path surprises with respect to the target surprises to isolate the separate effects of target and long-term path surprises.

Thus, path surprise II represents news that financial agents have learned only from FOMC announcement about the predicted future path of policy which is over and above what they have learned about the level of the target rate(Hausman and Wongswan, 2011). To derive path surprise II, following Hausman and Wongswan (2011) and Gürkaynak et al. (2005) it is run a regression of path surprise I on a constant and the target surprise. The innovation from this regression is Path Surprise II:

$$\text{Path Surprise}I_d = w_0 + w_1 * TS_d + PS_d^{II} \tag{51}$$

where PS_d^{II} (path surprise II) is the error term and uncorrelated with the target surprise. $PathSurpriseI_d = -.551 + .679 * TS_d + PS_d^{II}$ adjusted R-sq. is 0.23.

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