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Financial Crisis and the Global Transmission of U.S. Monetary Policy Surprises

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1 Introduction

When the U.S. sneezes, the world catches a cold.

| Anonymous

As global capital markets integrate, U.S. monetary policy is more likely to affect the economies of other countries. As a result, finance ministers in emerging markets often worry that their economies are influenced by U.S. monetary policy. For example, the Federal Reserve's reduction of the Fed Funds rate to its effective lower bound on December 16, 2008, led to a decrease in government bond yields and an appreciation of local currencies in more than 30 countries for one day. This is why global financial markets pay attention to Fed announcements on the day the Federal Open Market Committee (FOMC) meets.

In this paper, I investigate whether the 2007-2008 U.S. financial crisis changed the influence of the Fed's surprising decisions on foreign financial markets. Specifically, I focus on how the Fed's dependence on unconventional monetary policy after the financial crisis and its return to conventional policy in 2015 affected the global influence of U.S. monetary policy surprises. Using daily variations in government bond yields and foreign exchange spot rates for 46 sample countries on FOMC meeting days, I find that the global influence of U.S. monetary policy surprises intensified after the financial crisis: The widening gap in interest rates between the U.S. and the rest of the world rendered foreign financial markets more sensitive to Fed decisions after the crisis.

The financial crisis led to a global economic downturn and a European debt crisis. The Fed responded aggressively to the crisis by lowering the Fed Funds rate to a range between 0 and 0.25 percent, the lowest in its history. Also, the Fed adopted unconventional policies: forward guidance on future interest rates and quantitative easing (QE) with large-scale asset purchases (LSAP). The Fed eventually escaped the zero lower bound (ZLB) in December 2015 by raising the Fed Funds rate for the rst time since 2006. As of November 2017, the Fed has raised the target range for the Fed Funds rate to between 1.00 and 1.25 percent. I design an empirical model that employs data covering all FOMC meetings from August 2001 to September 2017. I divide this sample into future path of expected interest rates contained in the Fed's announcement.

I measure the responses of foreign financial markets to U.S. monetary policy surprises by daily variations in government bond yields and foreign exchange spot rates in 46 countries on FOMC days. I examine how short-term (2-year), midterm (5-year), and long-term (10-year) sovereign bond yields respond to U.S. monetary shocks in pre-crisis, crisis, and post-crisis periods. My estimates indicate that the response of sovereign bond yields to U.S. monetary policy surprises differs not only

monetary policy in several ways. The first contribution is showing that the financial crisis affected the influence of U.S. monetary policy surprises. The Fed's dependence on QE in the financial crisis led to a voluminous literature on how unconventional U.S. monetary policy affects global economies (Banerjee, Devereux, and Lombardo (2016); Gilchrist, López-Salido, and Zakrajšek (2015); Chen et al. (2016); Gagnon et al. (2017); Meinusch and Tillmann (2016); Bowman, Londono, and Sapriza (2015); Bauer and Neely (2014); Neely (2015); Swanson and Williams (2014)). Banerjee, Devereux, and Lombardo (2016) show that unexpected U.S. monetary policy tightening leads to a fall in GDP, rise in interest rates, and depreciation in exchange rates in emerging market economies. Meinusch and Tillmann (2016) empirically find that QE is associated with higher output and inflation and policy has a bigger effect on short- and long-term interest rates for developed economies relative to emerging markets. However, Chen et al. (2016) show that emerging markets are more likely to respond to QE when using monthly data between 2007 and 2013. I add empirical evidence that the responses of developed economies to a U.S. monetary policy surprise became stronger than those of emerging markets after the financial crisis.

The remainder of the paper is organized as follows. Section 2 discusses the background of the study. Section 3 describes the data and methodology. Section 4 presents the results for spillover estimates of U.S. monetary policy surprises. Section 5 tests the robustness of the results, and Section 6 concludes.

2 Background

2.1 Global transmission channels of U.S. monetary policy

Uncovered nominal interest parity explains how exchange rates respond to changes in interest rates caused by monetary policy. The theory states that expected changes in the exchange rate depend on interest rate differentials:

$$E_t s_{t+1} - s_t = i_t - i^*_t \quad (1)$$

where s_t is the nominal exchange rate between two currencies at time t, $E_t s_{t+1}$ is an expected value of s_{t+1} with the information available at time t, and i_t is the nominal interest rate in the home country (similarly, i^*_t is for the foreign country).[2] If the home country has a higher nominal interest rate (i.e., $i_t > i_t$), its currency is expected to depreciate (i.e., a rise in s) to equalize returns in the two countries. Under rational expectation, the exchange rate at t + 1 can be expressed as the sum of the expected value of the exchange rate and a forecast error ($'_t$):

$$s_{t+1} = E_t s_{t+1} + '_t \tag{2}$$

June 19, 2013, the Fed announced a tapering of quantitative easing (QE) policies by scaling back its bond purchases. On this day, the global financial market interpreted the announcement as a signal that the Fed would raise the Fed Funds rate in the future. As a result, government bond yields increased and local currencies depreciated in 34 countries for one day, as shown in Figure 2.

Several other channels may also affect spillover of U.S. monetary policy (Rey (2016); Borio and Zhu (2012)). For example, according to the credit channel, when the Fed relaxes its monetary policy, nominal interest rates drop, and this leads to an increase in the equity price. As a result, the net worth of borrowers rises and global banks' lending increases. This could explain the positive correlation between short-term rates in foreign countries and the Fed Funds rate. The risk-taking channel has a similar mechanism. Relaxation of U.S. monetary policy leads to drops in nominal interest rates. As the returns from safe assets decrease, banks apply relatively low credit standards. Accordingly, the global credit supply goes up and short-term rates in foreign countries move downward. Lastly, the balance sheet channel shows that even advanced economies cannot be free from the influence of U.S. monetary policy. When the Fed tightens its monetary policy, a foreign country's domestic currency depreciates. This helps increase the foreign country's exports. However, as banks become more cautious of the rising (dollar-denominated) value of foreign debt, interest rates rise and bank loans may decrease.

The empirical question is whether we can extend the response of foreign government bond yields and exchange rates to the Fed's decision to all FOMC meetings. If so, how much does U.S. monetary policy influence the movement in foreign government bond yields and exchange rates?

2.2 The nancial crisis and monetary policy regime

As shown in Figure 3, the 2007-2008 nancial crisis was a huge turning point in the Fed's history. Before the crisis, the Fed managed the Fed Funds rate as a key instrument for its monetary policy. For example, on June 25, 2003, the Fed cut the Fed Funds rate by a 0.25 percentage point to 1 percent, the lowest level in 45 years, to overcome the 2001 recession. The very low interest rates led to a housing boom, solid pace of economic expansion, and improved labor market conditions. As a result, the Fed raised the Fed Funds rate to 1.25 percent on June 30, 2004, which was the rst increase since 2000.

However, the 2007-2008 nancial crisis, triggered by the bursting of the subprime mortgage bubble and the collapse of Lehman Brothers, dramatically changed the Fed's policy regime, as shown in Table 1. On December 16, 2008, the Fed responded aggressively to the crisis by dramatically lowering the Fed funds rate to \between 1/4 points and zero," the lowest rate in its history. Facing the ZLB, the Fed had no room for additional moves in the Fed Funds rate if the economy did not improve soon. As a result, instead of adjusting the Fed Funds rate, the Fed adopted unconventional policies, such as forward guidance on future interest rates and QE with LSAP to stimulate the economy and keep market rates low. It tried to in uence expectations for the future path of Federal Funds rates through the FOMC statement, a press release, and the chairperson's public speech. The Fed also cooperated with other central banks to prevent further deepening of the global credit crisis. For example, on October 8, 2008, the Federal Reserve and the central banks of the E.U., U.K., Canada, Sweden, and Switzerland cut their rates by one-half point. One week later, the U.S., E.U., and Japan also adopted a coordinated policy to prevent banks from failing. The unconventional monetary policy regime ended in December 2015, when the Fed raised the Fed Funds rate for the rst time since 2006. This action o cially marks \the end of an extraordinary seven-year period during which the Federal Funds rate was held near zero to support the recovery of the economy from the worst financial crisis and recession since the Great Depression."[4] Since then, as of November 2017, the Fed has raised the Fed Funds rate three times to the range of 1.00 to 1.25.

The question is how has the Fed's dependence on unconventional monetary policy after the financial crisis, and its return to conventional policy in 2015, affected the global influence of U.S. monetary policy? To address this question, I divide the sample into three phases: pre-crisis, crisis, and post-crisis. I assume that the financial crisis period began when the Fed's LSAP-I plan was

$$f_{t;-10} = \frac{d(\text{Realized}) + (D-d)(\text{Expected}_{t;-10})}{D} \tag{4}$$

where Realized is the effective Fed Funds rates during the past d days of the relevant month and $\text{Expected}_{t;-10}$ is the expectation of the Fed Funds rate for upcoming $D-d$ days of the month 10 minutes before the FOMC announcement. In equation (4), I solve for $\text{Expected}_{t;-10}$ to factor out the market's expectation for the Fed's decision before the announcement:

$$\text{Expected}_{t;-10} = \frac{D}{D-d}(f_{t;-10}) - \frac{d}{D-d}(\text{Realized}) \tag{5}$$

Similarly, I calculate the expected value $\text{Expected}_{t;+20}$ for the Fed Funds rate for forthcoming $D-d$ days of the month 20 minutes after the FOMC announcement:

$$\text{Expected}_{t;+20} = \frac{D}{D-d}(f_{t;+20}) - \frac{d}{D-d}(\text{Realized}) \tag{6}$$

where $f_{t;+20}$ (the Fed Funds future rate 20 minutes after the FOMC announcement) reflects how the financial markets interpreted the Fed's decision ex post.

I define a Fed Funds futures surprise, FF_t, by changes in the expectation for the Fed Funds rate between 10 minutes before ($\text{Expected}_{t;-10}$) and 20 minutes after ($\text{Expected}_{t;+20}$) the FOMC announcement from equations (5) and (6):

$$FF_t = \frac{D}{D-d}(f_{t;+20} - f_{t;-10}) \tag{7}$$

Within a 30-minute window, the Fed Funds futures surprise (FF_t) measures the unanticipated component of the Fed's decision on the current Fed Funds rate target (Kuttner (2001); Gertler and Karadi (2015)). If there is no surprise in the Fed's decision, FF_t is zero, because $f_{t,-10}$ and $f_{t,+20}$ have the same value.

However, when the Fed Funds rate dropped to its ZLB in the financial crisis period, changes in the current Fed Funds future rate might be restricted. To address this problem, I employ 10-year Treasury futures that reflect a future path for monetary policy contained in the FOMC holds irregular intermeetings as needed. In meetings, the FOMC makes decisions on a target level for the Federal Funds rate and growth of the U.S. money supply. Each decision includes the future direction of U.S. monetary policy. This study covers all FOMC announcements from 130 scheduled

3.2 Government bond yields and foreign exchange rates

For each FOMC meeting and irregular event in the dataset, I collect daily variations in government bond yields and foreign exchange rates for 46 countries. As shown in Table 2, the sample countries in my dataset include both developed economies and emerging markets. Changes in an n-year bond yield for country i on FOMC meeting day t within a 1-day period are calculated as

$$y_{i;t}(n) = y_{i;t}(n) \quad y_{i;t \quad 1}(n) \tag{9}$$

Figure 6 depicts the time zone of sample countries. Asian and European markets are closed at the time of the scheduled FOMC announcement. I use the 1-day window between t and t + 1 for these markets to address a time lag.

The dataset on foreign government bond yield consists of 2-, 5-, and 10-year maturities. I investigate how short-term (2-year), midterm (5-year), and long-term (10-year) yields respond differently to U.S. monetary policy surprises. This allows me to compare the different movements at the short and long ends of the yield curve. To test whether the effects of U.S. monetary policy surprises are different across advanced and non-advanced economies, I divide the samples into two groups, developed economies and emerging markets, as shown in Table 3.

I calculate changes in the foreign exchange spot rate for country i on FOMC meeting day t as follows:

$$s_{i;t+1} = \frac{s_{i;t+1} \quad s_{i;t}}{s_{i;t}} \quad 100 \tag{10}$$

where $s_{i;t}$ is the percentage changes in the foreign exchange rate (in dollars per unit of non-U.S.

currency) within a 1-day window.

The exchange arrangement in each country plays an important role in the responses of exchange rates to U.S. monetary shocks. For example, when a country opens its financial markets to foreign investors, it can experience sudden inflows and stops of foreign funds (Edwards (2007)). A country may fear a floating exchange regime that can magnify their vulnerability to the sudden outflow or inflow of foreign funds. This explains why some countries (mostly emerging markets) are inclined to peg their currency to the U.S. dollar, which may reduce the spillover of U.S. monetary policy surprises. In order to analyze how U.S. monetary policy surprises affect foreign exchange rates under different exchange rate regime, I categorize sample countries into four groups: hard pegs, soft pegs, managed floating, and free floating, as shown in Table 4. While most developed economies in my dataset adopt a fully floating exchange regime, many emerging market economies run managed float regimes or limited-flexibility regimes.[6]

3.3 Empirical methodology

U.S. monetary policy surprises on FOMC meeting days play a role as exogenous shocks to financial markets in foreign countries. I evaluate the global transmission of U.S. monetary policy surprises to foreign government bond yields and exchange rates using the following panel regression:

$$\begin{aligned} \Delta y_{i,t+1} = {} & \beta_0 + \beta_1 FF_t + \beta_2 TYF_t + \beta_3 CRISIS + \beta_4 POST + \beta_5 FF_t \times CRISIS \\ & + \beta_6 TYF_t \times CRISIS + \beta_7 FF_t \times POST + \beta_8 TYF_t \times POST + \alpha_i + \varepsilon_{it} \end{aligned} \qquad (11)$$

In equation (11), I regress the daily change in country i's financial variables ($\Delta y_{i,t+1}(n)$ for government bond yields and $\Delta s_{i,t+1}(n)$ for exchange rates) around FOMC meeting day t on the

[6] The exchange rate regime is measured by IMF's Annual Report on Exchange Arrangement and Exchange Restrictions.

Along with the net effect in equation (13), the total effect of FF_t on $y_{i;t+1}(n)$ in each period is calculated by

$$E[\ y_{i;t+1} \mid FF_t \neq 0; CRISIS = 1; POST = 0] = {}_0 + {}_1 + {}_3 + {}_5 \quad (14)$$

$$E[\ y_{i;t+1} \mid FF_t \neq 0; CRISIS = 0; POST = 1] = {}_0 + {}_1 + {}_4 + {}_7 \quad (15)$$

In equation (14), a positive value of ${}_0 + {}_1 + {}_3 + {}_5$ implies that a change in the Fed Funds futures surprise (FF_t) is positively associated with a daily change in foreign government bond yields ($\ y_{i;t+1}(n)$) in the crisis period.

4 Results

Table 5 shows that the response of sovereign bond yields to U.S. monetary policy surprises differs not only across maturities of bonds, but also across periods. For a decrease in the Fed Fund futures surprise of 100 basis points, yields on short-term sovereign bonds in the crisis period would be expected to decline by 80 basis points more than bond yields in the pre-crisis period. A surprise cut in the Fed Fund futures and Treasury futures surprise has a stronger positive association with movement of midterm and long-term sovereign bond yields in the post-crisis period compared to the pre-crisis period. For example, a rise in the Fed Funds futures surprise of 100 basis points leads to an increase of 120 additional basis points in long-term foreign government bond yields in the post-crisis period relative to the pre-crisis period. The Treasury futures surprise also begins to influence the movement of 5-year and 10-year government bond yields in the post-crisis period. For an unanticipated increase in Treasury futures by 100 basis points, foreign government bond yields increase by 5 to 6 additional basis points in the post-crisis period relative to the pre-crisis period. Column (4) in Table 5 shows the relationship between foreign exchange spot rates and U.S. monetary policy surprises. My estimates indicate that a decline in the Fed Funds futures surprise of unanticipated decrease in the Fed Fund futures of 100 basis points is associated with an additional 80 basis points decrease in short-term bond yields in the crisis period, compared to the pre-crisis period. In the post-crisis period, a rise in the Fed Fund futures surprise by 100 basis points is connected to marginal increases in midterm and long-term foreign bond yields, compared to the pre-crisis period. However, only the response of midterm bond yields shows a statistical significance.

The results suggest that developed economies' responses to U.S. monetary policy surprises became stronger than those of emerging markets after the financial crisis. This finding is consistent with those reported by Gilchrist, Yue, and Zakrajsek (2018) and Neely (2015). Central banks exert greater control over short-term bond yields by their own benchmark interest rates (Caceres et al. (2016)). Monetary policy coordinations on short-term interest rates among developed economies during the financial crisis may explain why the response of 2-year bond yields is greater than those of 5- and 10-year bond yields in the crisis period. On the other hand, long-term bond yields are relatively free to respond to external shocks. For example, the Fed managed to put downward pressure on interest rates under ZLB by purchasing long-term securities. In the post-crisis period, central banks in developed economies are reluctant to raise their short-term target interest rates. This may lead to a larger effect of U.S. monetary policy surprises on the long end of the yield curve in developed economies rather than the short end.[7]

Table 7 shows how the influence of U.S. monetary policy surprises on foreign exchange rates depends on exchange rate arrangements in specific countries. First, there is no exchange rate response to U.S. monetary policy surprises in hard-peg counties. Hard-peg countries, such as Hong Kong, Bulgaria, and Lithuania, have fixed their exchange rates to minimize the vulnerability of their currency to exogenous shocks.[8] In contrast, exchange rates in other regimes significantly

[7] See Appendix A for country-level regressions.

[8] However, a hard-peg country must keep its monetary policy and interest rates in line with the other country. For

5 Robustness

5.1 Clustering standard errors

In my empirical model, government bond yields ($\Delta y_{i;t+1}$) and foreign exchange rates ($\Delta s_{i;t+1}(n)$) change at the country level (i). However, U.S. monetary policy surprises, such as FF_t and TYF_t, vary at the aggregate level, as follows:

$$\begin{aligned}\Delta y_{i;t+1} = {} & \beta_0 + \beta_1 FF_t + \beta_2 TYF_t + \beta_3 CRISIS + \beta_4 POST + \beta_5 FF_t \times CRISIS \\ & + \beta_6 TYF_t \times CRISIS + \beta_7 FF_t \times POST + \beta_8 TYF_t \times POST + \alpha_i + \varepsilon_{it}\end{aligned} \tag{16}$$

As a result, I may not assume independence of error terms across countries for each FOMC meeting. The correlation within each FOMC meeting comes from a common error component(ν_t):

$$\varepsilon_{it} = \nu_t + \eta_{it} \tag{17}$$

The nonindependence of error terms (i.e., $E[\varepsilon_{it}\varepsilon_{jt}] = \rho_\varepsilon \sigma_\varepsilon^2 \neq 0$) may underestimate standard errors with

$$\rho_\varepsilon = \frac{\sigma_\nu^2}{\sigma_\nu^2 + \sigma_\eta^2} \tag{18}$$

which is called a Moulton problem (Moulton (1986)).

I address the possible Moulton problem by clustering standard errors with a block-diagonal in $\hat{\Omega}$:

$$Var(\hat{\beta}) = (X'X)^{-1} X' \hat{\Omega} X (X'X)^{-1} \tag{19}$$

by ordering observations by group.

Table 9, with clustering of standard errors, confirms that the global influence of U.S. monetary policy surprises intensified after the financial crisis. A surprise 100 basis point decrease in the Fed Funds futures leads to a drop in government bond yields by 40 to 70 additional basis points across maturities of bonds in the crisis period, compared to the pre-crisis period. In the post-crisis period, Then, I estimate the effects of FF_t and $\widehat{Residual}_t$ on changes in foreign government bond yields $((\Delta y_{i;t+1}))$ and exchange rates $((\Delta s_{i;t+1}))$, as follows:

$$\Delta y_{i;t+1} = \beta_0 + \beta_1 FF_t + \beta_2 \widehat{Residual}_t + \beta_3 CRISIS + \beta_4 POST + \beta_5 FF_t \; CRISIS \qquad (21)$$

government bond yields and exchange rates. My results showed that developed economies became more sensitive to U.S. monetary policy surprises than emerging markets after the crisis.

Overall, my results demonstrate the consequences of the chasm between U.S. monetary policies and those of other countries. While the Fed departed from the ZLB by raising the Fed Funds rate in 2015, central banks in many countries maintained low interest rates and dependence on QE. The global monetary policy divergence forced foreign nancial markets to respond elastically to changes in the Fed Funds rate. My ndings can help foreign policymakers account for the strengthened in uence of post-crisis U.S. monetary policy shocks as they attempt to stabilize their economies.

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7 Figures

Figure 1: Changes in foreign governement bond yields and exchange rates on Dec 16, 2008

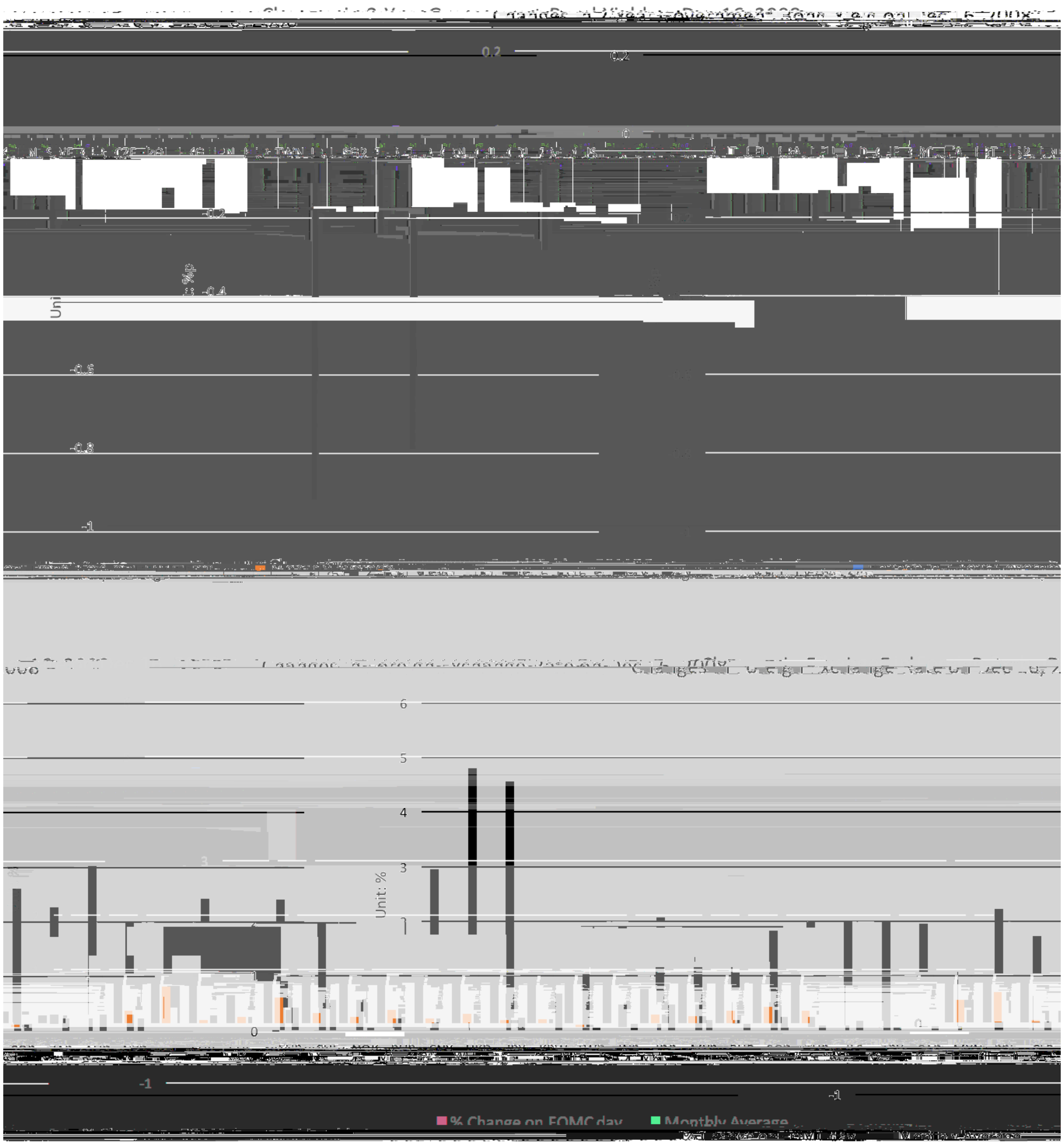

Figure 2: Changes in foreign governement bond yields and exchange rates on June 19, 2013

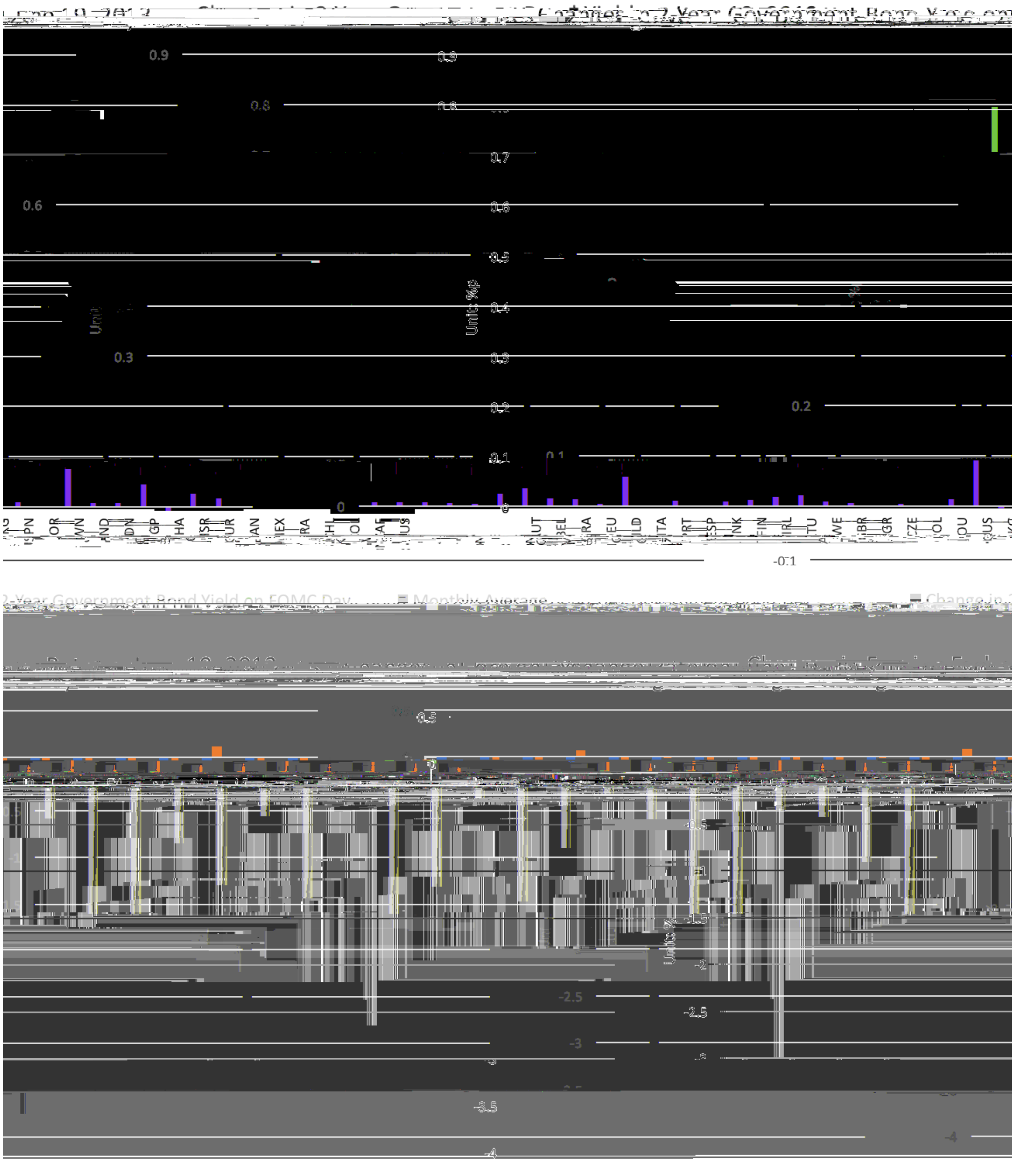

Figure 3: Movement of effective Fed Funds rate

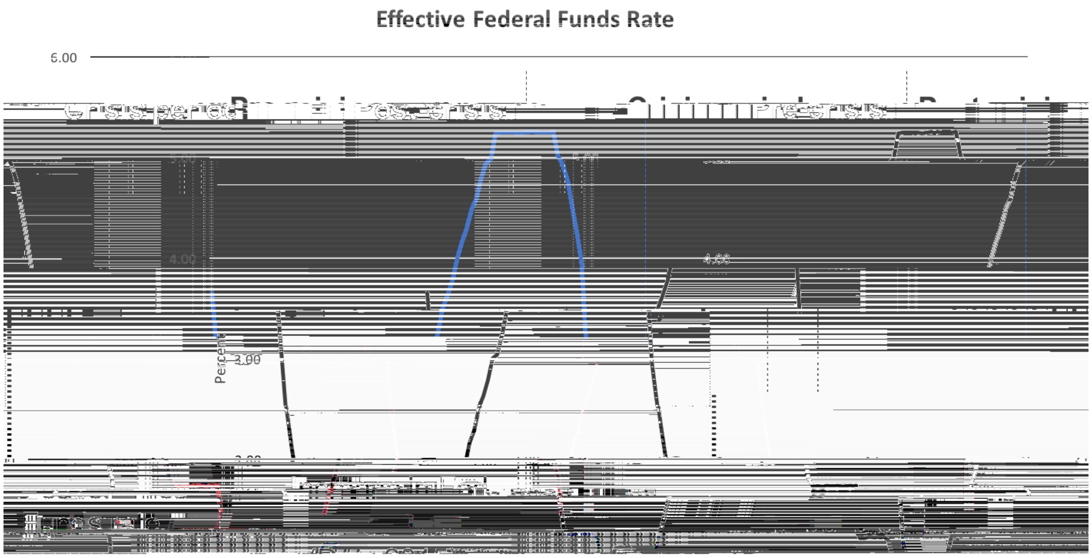

Figure 4: Fed Funds Future surprise (Aug, 2001 - September, 2017)

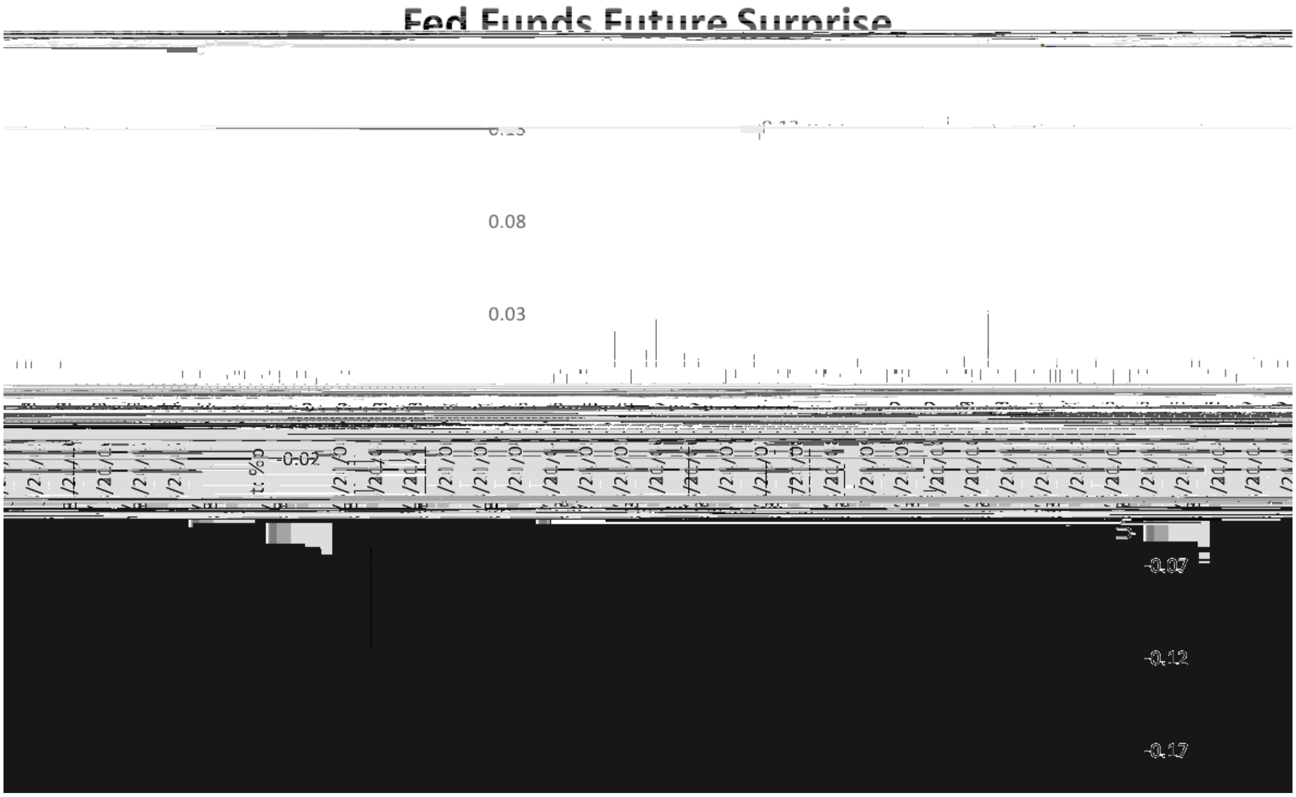

Figure 5: Treasury Future surprise (Aug, 2001 - September, 2017)

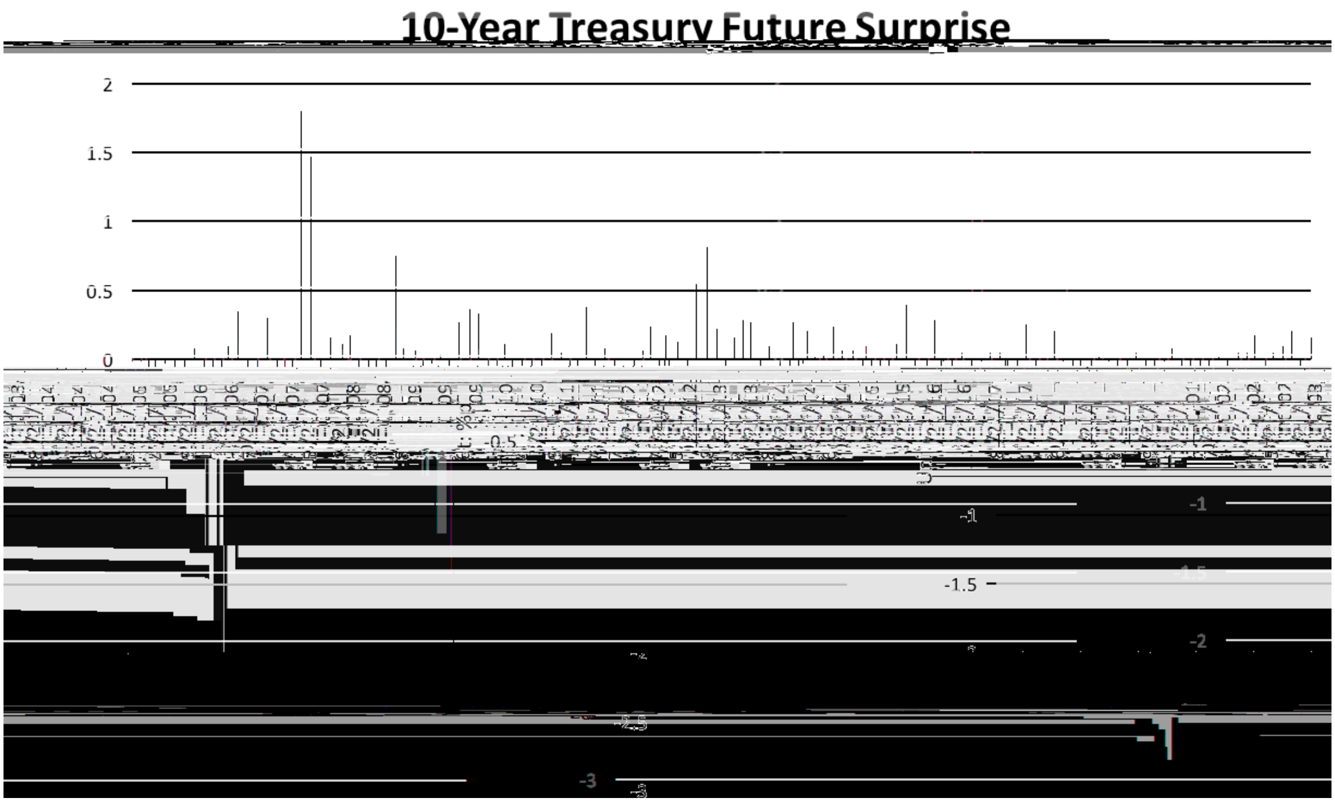

Figure 6:

8 Tables

Table 1: Time line of the nancial crisis

Time	Event
[illegible]	[illegible]

Table 2: The sample countries

	Division	Country
Europe ([illegible])	Eastern Europe ([illegible])	[illegible] Czech Republic, [illegible] Poland, Romania, Russia
	Northern Europe (7)	Denmark, Finland, [illegible]
	Sothern Europe (4)	Greece, Italy, Portugal, Spain
	Western Europe (6)	Austria, Belgium, France, Germany, Netherland, Switzerland
Asia ([illegible])	East Asia (5)	China, Hong Kong, Japan, South Korea, Taiwan
	South and Southeast Asia (6)	India, Indonesia, Malaysia, Philippines, Singapore, Thailand
	Western Asia (2)	Israel, Turkey
America (7)	North America (2)	Canada, Mexico
	Central and South America (5)	Brazil, Chile, Colombia, Costa Rica, Venezuela

Table 3: The division of groups

	Country	Country
Developed	AUT, BEL, NLD, CHE, [illegible]	CAD, DEU, FRA, GBR, ITA, JPN, [illegible]
	[illegible] CZE, HUN, POL, KOR, [illegible]	[illegible] DNK, FIN, IRL, NOR, SW[illegible]
Developing	[illegible] UK, MEX, CHL, AUS, NZ [illegible]	[illegible]
[illegible]	[illegible]	[illegible]

Table 4: Exchange rates arrangement

	Country
Hard Pegs	LTU, BGR, HKG
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	AUS, NZL

Table 5: Response of government bond yields and exchange rates to U.S. monetary policy surprises

	(1)	(2)	(3)	(4)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	(0.0162)	(0.124)	(0.0202)	(0.0158)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 6: Comparison of responses to U.S. monetary policy surprises

[illegible]

Table 7:

Table 8: Response of government bond yields to U.S. monetary policy surprises by exchange rate regime

[illegible]

Table 9: Clustering and the responses to U.S. monetary policy surprises

[illegible]

Table 10: Residual surprise and the responses to U.S. monetary policy surprises

Table A1 (Continued): Response of 2-year government bond yield to U.S. monetary policy surprises

[illegible]	(0.175)	(0.573)	(0.158)	(0.170)	(0.211)	(0.171)	[illegible]	[illegible]	(0.182)	(0.225)	(0.170)	[illegible]

[redacted]

Table A1 (Continued):

Table A1 (Continued): Response of 2-year government bond yield to U.S. monetary policy surprises

Table A2: Response of 10-year government bond yield to U.S. monetary policy surprises

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table A2 (Continued): Response of 10-year government bond yield to U.S. monetary policy surprises

Table A2 (Continued): Response of 10-year government bond yield to U.S. monetary policy surprises

Table A2 (Continued): Response of 10-year government bond yield to U.S. monetary policy surprises

(8)	(9)	(10)		(1)	(2)	(3)	(4)	(5)	(6)	(7)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]