

The short-term spillover effects of the Fed on Chinese financial market

The overshooting model or the portfolio balance theory

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Abstract

Under the framework of overshooting model and portfolio balance theory, this paper analyses the short-term spillover effect of Fed's QE on asset prices in China. Policy shocks "overall events" have a significant impact on China's financial market. China's debt full price index, Shanghai-Shenzhen 300 and Nan-Hua Futures Composite Index have increased significantly, while the "single event" issuance has no notable impact. Further research shows that the interest rate transmission mechanism has a striking impact on bonds, the exchange rate transmission mechanism has a remarkable impact on stocks, and the expected transmission mechanism has a notable impact on futures. China should comprehensively use interest rate, exchange rate and expected management tools to avoid the accumulation of financial bubbles.

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Keywords: overshooting model, portfolio balance theory, Fed's QE, Exchange rate channel, Interest rate channel, expectations channel.

1 Introduction

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Between 2008 and 2013, the Federal Reserve launched three rounds of quantitative easing monetary policy (QE). The introduction of QE has made a great contribution to alleviating the deflationary state of the United States and boosting the economic development of the country (Yellen, 2017). At the same time, it also has significant spillover effects on asset prices in other countries and regions (Anay et al., 2017; Fratzscher et al., 2013; Rogers et al., 2014; Lombardi & Zhu, 2014; Chen et al., 2015). The QE also had a notable impact on China's financial market price index. The CNY central parity rate and short-term interest rate of the RMB dropped significantly, and the stock market price index rose significantly. This paper aims to explore the spillover effect and transmission mechanism of the Federal Reserve's QE on China's financial market asset prices.

In the theoretical study of international policy transmission mechanism, Mundell and Fleming Model (MF) focus on analyzing the impact of a country's macroeconomic policies on macroeconomic variables such as domestic production and prices. Purchasing power parity, interest rate parity, and balance of payments theory are based on price, interest rate, and balance of payments respectively, paying attention to the role of the three markets in exchange rate decisions. Portfolio balance theory (Branson, 1977) and overshooting model (Dornbusch, 1976) concentrate on the asset market and make different assumptions on the international policy transmission mechanism and efficiency from long-term and short-term period. These two model can not only be used to analyze the influence of a country's policy on the economic variables of other countries in the short-term and long-term, but also can be used to describe the transmit process of other countries' asset market variables from short-term to long-term. They are relatively systematic analysis model of international policy transmission mechanism. In the theoretical framework of overshooting model and portfolio balance theory, this paper studies the short-term spillover effects of the Federal Reserve's QE by using vector auto-regression model (VAR) and event study method.

Scholars divide the Fed's international transmission path of QE into "Signaling Channel Effect" and "Portfolio Rebalance Effect" (Bernanke, 2013; Bauer & Neely, 2014; D'Amico & King, 2013; Neely, 2011). From signaling channel effect, many scholars have analyzed the immediate spillover effects of the Federal Reserve's QE on global financial markets. After comparing the effects of the two transmission mechanisms on bond yields in different countries, Bauer and Neely thought that signaling mechanism has a more significant impact on the United States and Canada, and the portfolio rebalance effect has a more significant impact on Germany and Australia, while Japan is relatively less affected by the both transmission mechanisms. From portfolio rebalance effect, some scholars have studied the impact of the Fed's adjustment of its balance sheet on global

financial markets. Neely (2011) employed the portfolio model and the uncovered interest rate parity to study the efficiency of the portfolio rebalance effect. He pointed out that the portfolio model can explain the direction of changes in the international bond interest rate, but it will underestimate the change of the US dollar index. The uncovered interest rate parity makes a correct prediction of the direction of the US dollar exchange rate, but the actual change of the US dollar exchange rate is much lower than the model's prediction. Some scholars have analyzed the unconventional monetary policies of the Federal Reserve from the perspective of currency liquidity, which has affected the financial markets of various countries by means of capital flows, exchange rates and credit (Rajan, 2013). Based on the above three transmission mechanisms, this paper analyzes the impact of the Federal Reserve's QE on the asset prices of China's financial market by means of exchange rate, interest rate and expectation transmission mechanism.

The Fed's QE has a significant impact on the price and risk structure of other countries' financial markets. Many scholars use the VAR or the least squares method as the benchmark model of the event analysis method to analyze the subtle changes in the economic and financial variables of other countries at the specific moment of the release of the QEs (Glick & Leduc, 2012; Bauer & Neely, 2014; Wright, 2012; Rogers et al., 2014). Glick & Leduc (2012) used the abnormal change in the price of US Treasury futures at the time of policy release as a proxy variable for the Federal Reserve's QE to analysis the impact of the Fed's first round of large-scale asset purchase policies on global financial market. In a similar way, Wright (2012) examined the different effects of the Fed's large-scale asset purchase policy on the price of bond futures in the US Treasury futures market. Bauer & Neely (2014) explored the VAR as a benchmark estimation equation to analyze the spillover effects of the Fed's large-scale asset purchases on the US, Canada, Germany, and Japan bond markets. However, using VAR and least squares as the benchmark estimation equation to simulate the price of financial assets has great limitations because of the possible unit root and heteroscedasticity. Bauer & Neely (2014) adopted the methods of ordinary least squares, random walk, and unit root to correct the VAR model residuals. The results show that the spillover effect of the Federal Reserve's QE on asset prices in other countries' financial markets is still significant.

Under the framework of overshooting model and portfolio balance theory, this paper analyses the short-term spillover effect of Fed's QE on asset prices in China. The Shadow Short Rate (SSR) used as the proxy variable of the Federal Reserve's unconventional monetary policy, this paper analyzes the impact of the Federal Reserve's QE on China's stock market, bond market and futures market price index from 2008 to 2013. At the same time, this paper sorts out the 15 policy

release events during the three rounds of QEs, and analyzes the immediate effects of the virtual variables of policy events on China's financial asset price index. On this basis, this paper further explores the transmission path of the Fed's QE, and studies the impact of interest rate, exchange rate and expectation shock on China's Shanghai and Shenzhen Composite Index, China Bond Full Price Index and Nan-Hua Futures Composite Index. In order to verify the credibility of the empirical results, this paper also uses the Unit Root Model (UR), Generalized Auto-Regressive Conditional Heteroscedasticity Model (GARCH) and two-stage least squares (Two Stage) as the robustness test.

The contribution of this paper lies in the analysis of the spillover effect of the QE from the perspective of the immediate effect of policy release. Based on this, this paper further studies the impact of exchange rate, the China-US interest rate spread and RMB appreciation expectation on China's stock, bond and futures price indices. The shortcoming of this paper is that the research content is limited to the introduction process of the policy, and the analysis of exit mechanism is lacking.

2 Theory and Assumptions

2.1 Overshooting model

Overshooting model was first proposed by American economist Dornbusch in 1976 (Dornbusch, 1976). It divides a country's market into a money market, a product market, a labor market, and a foreign exchange market. The price adjustment of the money market is faster than the product market and the labor market.

According to the Overshooting model, the Federal Reserve's QE will inject a lot of liquidity into the country's economy, which will affect the country's macroeconomic variables and ultimately affect China's financial market. Under the assumption that the short-term currency is non-neutral, the Fed's QE will increase the country's money supply, thus the country's interest rate will fall, and the China-US interest rate spread will rise. Since the interest rate of China's bond market does not change, the price index of China's bond market does not change. As China-US interest rate spread rises, the RMB will appreciate and the expectation of RMB appreciation will further increase on the premise that interest rate parity holds. Under the premise that the domestic market interest rate does not change, the net export will reduce because of the appreciation of the renminbi, and the price index of China's stock market will fall. China's futures market price index is affected by the comprehensive effects of interest rates, exchange rates and expectations, and the direction of change is uncertain.

2.2 Portfolio balance theory

Portfolio balance theory was proposed by American professor Bronson (Branson, 1977). Under the premise that the currency can be freely exchanged, he distributes a country's wealth in the domestic currency market, the domestic bond market, and the foreign asset market. The three markets are sensitive to both exchange rate and interest rate changes. The domestic money supply and bond supply are determined by the country, and the supply of foreign bonds is determined by the current account surplus. According to the theory of portfolio balance, there is a short-term and long-term equilibrium in the economy, and the fundamental difference is whether the current account is in balance.

According to the theory of portfolio balance, the Federal Reserve's QE will change the supply of assets in the country's financial market. It will not only reduce the supply of financial assets in its domestic market, but also reduce the risk exposure of financial markets. On the one hand, the reduction in bond supply in the foreign bond market has led to a decline in China's holdings of wealth, and domestic demand for Chinese bonds and currencies has fallen. Under the floating exchange rate, the RMB depreciated and the short-term equilibrium interest rate remained unchanged. On the other hand, due to the decline in the risk of foreign assets, the demand for foreign assets of Chinese residents has risen, and the demand for domestic assets has fallen. Thus the RMB has depreciated, and China's short-term equilibrium interest rate has risen. In summary, the Fed's quantitative easing policy will cause China's RMB to depreciate, short-term equilibrium interest rates rise, and asset market price indices fall.

2.3 Overshooting model or portfolio balance theory?

For the short-term spillover effects of the Federal Reserve's QE on China's macroeconomic variables, the conclusions drawn from the two research frameworks of the overshooting model and the portfolio balance theory are somewhat different. Both believe that the Fed's QE will increase China-US interest rate spread. The difference is that the overshooting model believes that China's market interest rate will not change, the RMB will appreciate, and the expectation of RMB appreciation will be further enhanced. The portfolio balance theory believes that China's interest rate rises, the RMB depreciation, and the RMB appreciation is uncertain. This paper takes the conclusions of the portfolio balance theory as the null hypothesis, and empirically tests the short-term spillover effects of the Federal Reserve's QE on China's interest rate, exchange rate and RMB appreciation expectations.

Proposition 1: In the short term, China's market interest rate rises. China-US

interest rate spread will rise, and the RMB depreciates. Whether the RMB will appreciate is uncertain.

Both the overshooting model and the portfolio balance theory believe that the QE will lower the stock price index of China. The difference is that the former believes that China's bond market price index will not fluctuate significantly, and the futures market price index changes uncertainly; the latter believes that both bond and futures market price indices will decline.

Proposition 2: In the short term, China's bond, stock and futures market price indexes will all fall to varying degrees.

The reason for the difference between the overshooting model and the portfolio balance theory is the theoretical assumptions of the two. The latter does not consider the product market and the labor market, and simply considers the stock, bond and futures markets to be unified as domestic asset markets, and does not need to consider the impact of exchange rates and expectations on different market price indices. In fact, the latter assumed that uncovered interest rate parity was not established and set the expectation of RMB appreciation to zero, which has ruled out the impact of QE on China's financial market through the expected transmission path. The former considers the product, labor, currency and foreign exchange markets at the same time, so the change of the exchange rate will have an impact on bonds, stocks and futures. At the same time, the former assumes that the uncovered interest rate parity is established, so the appreciation of the RMB is expected to influence China's financial market. Therefore, simply testing the impact of QE on China's financial market price index does not fully compare the explanatory power of the two theoretical frameworks. Thusly this paper further examines the correlation between China's financial market price index and China-US interest rate spread, RMB exchange rate and RMB appreciation expectations during QE.

Proposition 3: In the short term, the Fed's QE mainly relies on the interest rate transmission mechanism to have a spillover effect on China's financial market price index, and the exchange rate and expectation transmission mechanisms are not significant.

3 Model and data

3.1 Empirical model

3.1.1 The shock of the Federal Reserve's QE on the asset prices of China's financial market

Bauer & Neely (2014) explored the event study method and used VAR as the benchmark estimation equation to analyze the spillover effects of the Fed's

large-scale asset purchases on the bond markets of US, Canada, Germany, and Japan, just as equation (1) shown. Considering that the bond market's short-term interest rate and risk premium are highly sustainable, Bauer and Neely use six methods, such as least squares, random walk, and unit root to correct the parameters.

In order to test whether Proposition 2 is established, this paper uses event study method to analyses the changes of China's stock, bond and future market price indices after the announcement of the Fed's large-scale asset purchase plan. This paper believes that in the short term, China's financial market price index is determined by its past price level, its own risk factors, financial market risk status, monetary policy measures and foreign market policy shocks and random factors. Therefore, this paper adds historical volatility (Yhv), Shanghai Interbank Offered Rate (shibor1m), SSE A-share average P/E (pe), RMB deposit benchmark interest rate (sr), large financial institution deposit reserve ratio (rs), Fed asset purchase policy (QE) and other factors, as equation (2) shown.

$$X_{t+1} = \mu + \varphi X_t + \sum \varepsilon_{t+1} \quad (1)$$

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 Yhv_{t-1} + \alpha_3 shibor1m_t + \alpha_4 pe_t + \alpha_5 rs_t + \alpha_6 sr_t + \gamma_j QE_{jt} + e_t \quad (2)$$

This paper analyzes the impact of the Federal Reserve's QE on China's financial market price index from the "single event" and "global events". On the one hand, this paper sorts out 15 policy release events during the Fed's three rounds of QEs, and analyzes the spillover effect of "single event" as a dummy variable. On the other hand, this paper uses "shadow interest rate" as a proxy variable to analyze the impact of the "global incident" of the Federal Reserve's QE on China.

3.1.2. The shock of the Federal Reserve's QE on China-US interest rate spread, RMB exchange rate and RMB appreciation expectations

This paper sorts out the transnational transmission channels of policy shocks in the overshooting model and portfolio balance theory, and believes that the asset rebalancing effect will eventually take effect through interest rates and exchange rates. Therefore, this paper argues that the spillover effect of the Fed's large-scale asset purchase on China's financial market asset prices is mainly accomplished by means of China-US interest rate spread, exchange rates and RMB appreciation expectations.

In order to study the respective roles of China-US interest rate spread, exchange rates and RMB appreciation expectations, this paper first quantifies the impact of the release of the Fed's large-scale asset purchase on China-US interest

rate spread, exchange rate and RMB appreciation expectations. Wright (2012) used the change of interest rate futures price at the time of the release of the Fed's monetary policy as a proxy variable for policy shocks, and studied the effectiveness of monetary policy near zero interest rates. Specifically, he used the time point of the Fed policy release as the origin of the event, and used (-15min, 105min) as the event window to examine the price fluctuations of bond futures with different maturities in the US Treasury futures market. Based on Wright (2012), Glick & Leduc (2012) further expanded the research to the commodities, foreign exchange, stock and bond markets, and analyzed the short-term impact of the Federal Reserve and the Bank of England's QE on global financial markets. Glick and Leduc compare the price indices before and after the event, and use the difference as an indicator to measure the impact of QE. This article takes the day of the Fed's QE as T_0 , and examines the difference between the actual value and the predicted one of target variable at time T_0 , so as to obtain the impact of QE on the target variable. In order to enhance the accuracy of the prediction value estimation, two methods are adopted in this paper. On the one hand, the value of the previous trading day of the target variable event is used as the predicted value, just as equation (3) shown. On the other hand, this article uses the previous trading day value of the target variable as the explanatory variable to get the predicted value of the target variable, just as equation (4) shown.

$$Y_shock_t = Y_t - Y_{t-1} \quad (3)$$

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + e_t \quad (4)$$

$$Y_surprise_t = Y_t - \tilde{Y}_{t-1} = Y_t - \alpha_0 - \alpha_1 Y_{t-1} \quad (5)$$

3.1.3. Transmission Mechanism of Short-term Spillover Effect of Federal Reserve's QE.

In the short term, the Fed's QE will have an impact on China's financial market price index through China-US interest rate spreads, exchange rates and expectation transmission mechanisms. In order to test whether Proposition III is established, this paper focuses on the impact of the above three policy indicators on China's financial market.

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 Y_{hv_{t-1}} + \sum_i \beta_i X_{it} + \gamma_1 drfshock_t + \gamma_2 exshock_t + \gamma_3 expshock_t + \varepsilon_t \quad (6)$$

This paper argues that in the short term, China's financial market prices are determined by its past price levels, its own risk factors, macro fundamentals, foreign market policy shocks and random factors. Therefore, China's financial

market price index Y_t can be roughly expressed as linear combination of its lag period price index Y_{t-1} , lag period historical volatility Yhv_{t-1} , China's macro fundamental factors X_{it} , foreign market policy shocks, and random variables ε_t , as shown in equation (6). The impact of the Fed's large-scale asset purchase policy can be further decomposed into policy shocks arising from the China-US interest rate spread, exchange rates and RMB appreciation expectations, respectively expressed by $drfshock_t$, $exshock_t$, $expshock_t$. If the coefficient $\gamma_1(\gamma_2, \gamma_3)$ is significant, the Fed's large-scale asset purchase has an impact on China's financial market price index through the interest rate (exchange rate, expectation) transmission mechanism.

3.2 Data

3.2.1. Federal Reserve's QE

In 2008-2013, the Federal Reserve launched three rounds of unconventional monetary policy measures. These policy measures can be broadly classified into three categories, such as providing liquidity to specific financial institutions or credit markets, large-scale asset purchases (LSAPs), and providing currency swaps to specific countries. This article only studies the short-term spillover effects of the Fed's large-scale asset purchases on China's financial markets.

The policy events in this article are taken from the official website of the Federal Reserve, such as the Open Market Operations Committee (FOMC) policy announcement, news events, and public speech by Federal Reserve Chairman Bernanke. In order to lock the research into the LSAP introduction phase, this article will remove the news about the LSAP exit phase. This article converts the New York time of the policy events into Beijing time, and takes relevant data corresponding to Beijing time. On January 29, 2009 (Beijing time), the Federal Reserve's Open Market Operations Committee (FOMC) announced that it was preparing to expand its asset purchases, which coincided with the Chinese Lunar New Year, so we took the data of the first trading day after the release of the policy event on February 2, 2009. On September 21, 2010 (Beijing time), FOMC showed the necessity of policy adjustment, which coincided with the traditional Mid-Autumn Festival holiday in China, This paper took the relevant data of the first trading day after the release of the policy event on September 27, 2010.

Table 1: Timetable for the release of the Fed's large-scale asset purchase policy

New York time	Beijing time	Federal Reserve's large-scale asset purchase policy
2008.11.25	2008.11.25	The Fed announced to buy \$500 billion in

8:15	(2008.11.26)	mortgage-backed securities and \$100 billion in agency bonds.
2008.12.1 13:45	2008.12.2	The Chairman of Federal Reserve Bernanke announced to start the Treasures purchase plan.
2008.12.16 14:15	2008.12.17	The Federal Reserve's Open Market Operations Committee (FOMC) was considering expanding agency bonds purchases and launching the Treasury securities purchase program.
2009.1.28 14:15	2009.1.29 (2009.2.2)	FOMC was preparing to expand the purchase of agency bonds, mortgage backed securities and long term treasuries.
2009.3.18 14:15	2009.3.19	FOMC would continue to purchase \$750 billion in agency MBS, \$100 billion in agency debt and \$30 billion in Treasury securities.
2010.8.10 14:15	2010.8.11	FOMC announced that it will reinvest the principal of the expired government bonds.
2010.8.27 10:00	2010.8.27	Bernanke suggested that FOMC would further purchase long-term securities.
2010.9.21 14:15	2010.9.22 (2010.9.27)	The FOMC believed that the inflation rate will remain in a downturn for some time, and it was necessary to adjust the policy to achieve the desired goal.
2010.10.15 8:15	2010.10.15	Bernanke pointed out that the Fed might increase the necessary asset purchase policy to revive the economy.
2010.11.3 14:15	2010.11.4	FOMC announced to purchase Treasury securities.
2011.8.26 10:00	2011.8.26	Bernanke suggested that QE3 will not be implemented in the short term.
2011.9.21 14:15	2011.9.22	The FOMC decided to extend the average maturity of its purchased bonds. As of June 2012, the Fed would complete the replacement of the equivalent amount of Treasury bonds with a remaining maturity of less than three years from Treasury Securities with a remaining maturity of six to 30 years.
2012.6.20 14:15	2012.6.21	The FOMC would continue to purchase Treasury securities with a remaining maturity of 6 to 30

		years at the current frequency and sell an equivalent amount of Treasury bonds with a remaining maturity of 3 years or less.
2012.9.13 14:15	2012.9.14	The FOMC decided to increase its purchase of mortgage-backed securities (MBS) by \$40 billion a month.
2012.12.12 14:15	2012.12.13	The FOMC decided to increase the purchase of Longer-term Treasury Securities by \$45 billion a month, while terminating the purchase of \$40 billion in monthly mortgage-backed securities.

3.2.2. The shock of LSAP to China-US interest rate spread, exchange rate and RMB appreciation expectation

According to Wright (2012) and Glick & Leduc (2012) on the treatment of policy shocks, the impact of the Fed's large-scale asset purchase policy announcement on the China-US interest rate spread, exchange rates and RMB appreciation expectations is just as table 2 shown. The release of the Fed's large-scale asset purchase policy has had a certain impact on the China-US interest rate spread, RMB exchange rates and RMB appreciation expectations. For the RMB exchange rate, those events involving the formal introduction of large-scale asset purchase policies will cause the US dollar to depreciate against the RMB, and those policy events that only affect market expectations and those only involve the conversion of maturity will not. For the expectation of RMB appreciation, those policy events that are unexpected to the market can cause the expectation of the RMB to appreciate against the US dollar. This paper argues that Bernanke's large-scale asset purchase policy in the three speeches of 2010-2011 has a lower probability of launching the policy or the implementation of the policy is lower than the market expectation, so there is an abnormal phenomenon of RMB depreciation against the US dollar.

Table 2: Impact on spreads, exchange rates and expectations on the day the Fed's large-scale asset purchases

Beijing time	ex-shock	ex-surprise	expect-shock	expect-surprise	drf-shock	drf-surprise
2008.11.26	-0.0020	-0.0015	—	—	0.0292	-0.0027
2008.12.2	0.0022	0.0027	—	—	0.0441	-0.0197
2008.12.17	-0.0080	-0.0075	—	—	-0.0209	-0.0964
2009.2.2	0.0017	0.0022	-0.0037	-0.0037	-0.1312	-0.2149
2009.3.19	-0.0018	-0.0013	0.0015	0.0015	0.0121	-0.0753
2010.8.11	0.0023	0.0028	0.0045	0.0045	0.0130	-0.0409
2010.8.27	-0.0040	-0.0035	-0.0036	-0.0036	0.3246	0.2788
2010.9.27	0.0101	0.0106	0.0169	0.0169	-0.0846	-0.1218
2010.10.15	-0.0085	-0.0080	-0.0056	-0.0055	-0.0362	-0.0826
2010.11.4	-0.0110	-0.0105	0.0016	0.0017	-0.0046	-0.0537
2011.8.26	0.0014	0.0020	-0.0006	-0.0004	-0.1242	-0.0797
2011.9.22	0.0036	0.0042	-0.0160	-0.0158	-0.2304	-0.1658
2012.6.21	0.0036	0.0043	0.0053	0.0055	0.3025	0.3412
2012.9.14	-0.0021	-0.0014	0.0040	0.0042	-0.0201	-0.0112
2012.12.13	0.0004	0.0011	-0.0004	-0.0002	0.0247	0.0115

4 Empirical analysis and results

4.1 Short-term spillover effects of the Federal Reserve's quantitative easing policy on China's financial market

According to equation (2), this paper establishes a VAR model with a lag order of 2, and examines the spillover effects of the “global events” and “single events” of the Federal Reserve's QE on China's financial market price index. The VAR model is shown in equation (7), where QE_{jt} , $j = 0, 1, 2, \dots, 15$ represent the Fed's QE “whole event” and 15 “single events” respectively.

$$\begin{pmatrix} bond_t \\ stock_t \\ future_t \end{pmatrix} = \alpha_0 + \sum_{i=1}^2 \alpha_i \begin{pmatrix} bond_{t-i} \\ stock_{t-i} \\ future_{t-i} \end{pmatrix} + \beta_1 \begin{pmatrix} bondhv5_{t-1} \\ stockhv5_{t-1} \\ futurehv5_{t-1} \end{pmatrix} + \gamma_j QE_{jt} \\
 + \beta_2 shibor1m_t + \beta_3 pe_t + \beta_4 rs_t + \beta_5 sr_t + e_t \quad (7)$$

Table 3: The spillover effect of the Federal Reserve's QE on China's financial market price index

Beijing time	bond	stock	future	Beijing time	bond	Stock	Future
LSAP	-0.01*	-9.03***	-1.34**	2010.10.15	0.03	125.22***	8.68
	(-1.66)	(-4.80)	(-2.46)	LSAP09	(0.22)	(2.94)	(0.71)
2008.11.26	0.58***	2.90	7.00	2010.11.4	-0.08	88.43**	28.83**
LSAP01	(4.62)	(0.07)	(0.55)	LSAP10	(-0.69)	(2.07)	(2.34)
2008.12.2	0.25**	-34.50	-27.22**	2011.8.26	-0.02	-5.22	3.25
LSAP02	(1.97)	(-0.79)	(-2.18)	LSAP11	(-0.16)	(-0.12)	(0.26)
2008.12.17	0.73***	-15.46	0.86	2011.9.22	0.11	-88.40**	-35.83***
LSAP03	(6.01)	(-0.36)	(0.07)	LSAP12	(0.89)	(-2.07)	(-2.92)
2009.3.19	0.05	36.30	11.59	2012.6.21	0.09	-19.92	-13.95
LSAP05	(0.39)	(0.85)	(0.94)	LSAP13	(0.73)	(-0.47)	(-1.14)
2010.8.11	0.05	24.49	-5.68	2012.9.14	-0.26**	8.73	33.35**
LSAP06	(0.41)	(0.57)	(-0.46)	LSAP14	(-2.09)	(0.20)	(2.72)
2010.8.27	0.03	19.56	8.38	2012.12.13	0.03	-32.76	-5.35
LSAP07	(0.23)	(0.46)	(0.68)	LSAP15	(0.22)	(-0.77)	(-0.44)

Note: The t-test values is in parentheses, ***, **, and * represent significant levels at 5%, 5%, and 10% respectively.

The “overall event” of the Federal Reserve’s QE has had a significant impact on China's financial market price index (Table 3). For every 0.01 drop in the Fed’s “shadow interest rate”, China Bond Full Price Index, Shanghai Composite Index and Nan-Hua Futures Commodity Index rose by 0.01, 9.03 and 1.34 units respectively.

The impact of the “single incident” release of the Federal Reserve’s QE on China’s financial market price index is not very significant. LSAP01, LSAP02 and LSAP03 have significantly improved the full price index in China's bond market. LSAP14 significantly reduced the China Bond Full Price Index. For the China Bond Full Price Index, only the release of asset purchase policies which can truly change the liquidity of foreign markets will cause fluctuations in the price index, and those that adjust the financial market only by changing public expectations cannot. LSAP09 and LSAP10 significantly increased Shanghai and Shenzhen 300 Index, while after LSAP12, it decreased significantly. After the LSAP02 and LSAP14 policy shocks, China's Nan-Hua Futures Composite Index increased significantly, while LSAP10 and LSAP12 decreased. Whether the Fed affects market expectations, convert the deadline, or real asset purchase policies may have a significant impact on China's stock and futures market price indices.

4.2 The conduction of short-term spillover effects of the Federal Reserve's QE.

Tables 4, 5 and 6 respectively show the transmission mechanism of the Fed's large-scale asset purchase policy to China's financial market (Equation 6). This paper empirically studies the impact of lag period price index, volatility and macroeconomic fundamentals and the Fed's large-scale asset purchase on China's financial market price index. Model (1) is the baseline model. On the basis of model (1), models (2)-(5) add variables such as *drf_shock*, *ex_shock* and *expect_shock* respectively to analyze the impact of Fed's LSAP on China's financial market price index through interest rate, exchange rate and expected transmission mechanism respectively.

Table 4: Spillover effects of the Federal Reserve's QE on China's bond market price index

Bond(t)	(1)	(2)	(3)	(4)	(5)
C	120.21*** (916.05)	120.20*** (917.08)	120.21*** (915.27)	120.25*** (925.73)	120.24*** (925.23)
Bondhv5(t-1)	-4.69 (-1.03)	-4.67 (-1.03)	-4.78 (-1.05)	-24.26*** (-4.86)	-24.13*** (-4.84)
Shibor1m(t)	-0.63*** (-22.70)	-0.63*** (-22.66)	-0.63*** (-22.63)	-0.59*** (-21.50)	-0.59*** (-21.46)
Drfshock(t)		7.07** (2.23)			6.42* (1.86)
Exshock(t)			-74.02 (-0.80)		6.60 (0.06)
Expectshock(t)				117.51 (1.42)	41.56 (0.45)
R-squared	0.30	0.30	0.30	0.30	0.30
Adj-R-squared	0.30	0.30	0.30	0.29	0.30

Note: The t-test values is in parentheses, ***, **, and * represent significant levels at 5%, 5%, and 10% respectively.

According to equation (6), the bond full price index in China's bond market is studied, as shown in Table 4. Since the historical price of the China Bond Full Price Index is highly correlated with the Shibor interest rate, the lag period price index is excluded from the regression to avoid the multicollinearity problem. *Drf_shock* has a significant impact on the China Bond Full Price Index, while the effects of *ex_shock* and *expect_shock* are not notable. The impact of the Fed's large-scale asset purchase policy on China's bond market is mainly based on the

interest rate transmission mechanism.

The results of the analysis of the transmission mechanism of the Fed's large-scale asset purchase policy on China's stock market are shown in Table 5. The lag period and historical volatility of the Shanghai and Shenzhen 300 Index have a significant impact on the Shanghai and Shenzhen 300 Index, while the shibor interest rate not. Ex_shock has a significant impact on the Shanghai and Shenzhen 300 Index, while drf_shock and expect_shock not. Therefore, the impact of the Fed's large-scale asset purchase policy on China's stock market is mainly based on the exchange rate transmission mechanism.

Table 5: The spillover effect of the Federal Reserve's QE on China's stock market price index

Stock(t)	(1)	(2)	(3)	(4)	(5)
C	21.16** (2.08)	21.07** (2.07)	21.30** (2.10)	22.88** (2.11)	23.66** (2.19)
stock(t-1)	0.99*** (329.22)	0.99*** (329.01)	0.99*** (329.98)	0.99*** (301.80)	0.99*** (302.59)
Stockhv5(t-1)	20.44* (1.87)	20.53* (1.88)	19.38* (1.78)	25.79** (2.14)	25.54** (2.12)
Shibor1day(t)	-1.52 (-1.47)	-1.52 (-1.46)	-1.43 (-1.38)	-1.48 (-1.39)	-1.40 (-1.32)
Drfshock(t)		22.64 (0.27)			-46.90 (-0.50)
Exshock(t)			-6468.50** (-2.65)		-8892.08*** (-3.21)
expect shock(t)				2232.12 (0.98)	2880.70 (1.14)
R-squared	0.99	0.99	0.99	0.99	0.99
Adj-R-squared	0.99	0.99	0.99	0.99	0.99

Note: The t-test values is in parentheses, ***, **, and * represent significant levels at 5%, 5%, and 10% respectively.

The results of the analysis of the transmission mechanism of the Fed's large-scale asset purchase policy on China's futures market are shown in Table 6. The Nan-Hua Futures Commodity Composite Index is significantly affected by its lag period index, and the historical volatility, the Shanghai and Shenzhen 300 Index, while the shibor interest rate not. Ex_shock and expect_shock have significant effects on the Nanhua Futures Commodity Composite Index, while the drf_shock effect not. The impact of the Fed's large-scale asset purchase policy on

China's futures market is mainly based on exchange rates and expected transmission mechanisms.

Table 6: Spillover effects of the Federal Reserve's QE on China's futures market price index

future(t)	(1)	(2)	(3)	(4)	(5)
C	3.88 (1.15)	3.82 (1.13)	4.12 (1.22)	6.40 (1.71)	6.99* (1.88)
future(t-1)	0.99*** (301.39)	0.99*** (301.25)	0.99*** (302.64)	0.99*** (289.95)	0.99*** (291.10)
futurehv5(t-1)	1.10 (0.21)	1.18 (0.23)	-0.13 (-0.02)	5.28 (0.94)	4.42 (0.79)
stock(t-1)	0.002 (1.59)	0.002 (1.59)	0.002 (1.61)	0.001 (1.04)	0.001 (1.02)
Shibor1day(t-1)	0.36 (1.02)	0.37 (1.03)	0.39 (1.10)	0.44 (1.21)	0.47 (1.31)
drfshock(t)		11.70 (0.49)			-25.65 (-0.96)
exshock(t)			-2360.4*** (-3.41)		-2804.3*** (-3.57)
Expect-shock(t)				1657.84** (2.57)	1985.68** (2.78)
R-squared	0.99	0.99	0.99	0.99	0.99
Adj-R- squared	0.99	0.99	0.99	0.99	0.99

Note: The t-test values is in parentheses, ***, **, and * represent significant levels at 5%, 5%, and 10% respectively.

In summary, neither the portfolio balance theory nor the overshooting model is sufficient to explain the short-term spillover effects of the Fed's large-scale asset purchase program on China's financial markets. The portfolio balance theory simply divides the entire economy into domestic currency markets, domestic asset markets, and foreign asset markets without a reasonable distinction between bonds, stocks, and futures markets. At the same time, the portfolio balance theory does not analyze the product market, which limits the application of the theory in practice. Overshooting model ignores the flow analysis such as balance of payments and lacks explanatory power for transnational conduction of unconventional monetary policy.

5 Robustness test

5.1 Estimation method

Bauer & Neely (2014) argues that there is a significant risk in using the VAR as the benchmark estimation equation (Equation 1) to analyze the spillover effects of the Fed's large-scale asset purchases. In the short term, financial market price indices and yields are highly sustainable. In the long run, due to the existence of systemic risk factors, financial market price indices and yields may have some heteroscedasticity. Therefore, the parameters estimated using the VAR model lack certain accuracy. This paper uses OLS, GARCH, TSLS, UR and other methods to verify the robustness of the short-term spillover effect of the Fed's large-scale asset purchase policy on China's financial market (Table 7). The results show that the results obtained in Table 3 are satisfied robustness requirements.

The GARCH model considers variance as a variable that changes over time and is widely used in the analysis of macro financial time series. Lamoureux and Lastrapes (1990) found that the ARCH effect disappears when the trading volume is used as the explanatory variable of the conditional variance estimation equation, which indicates that the GARCH model has a higher interpretation of the stock market yield. This paper uses the GARCH model to simulate the price index of China's bond, stock and futures markets indexes, and examines the short-term spillover effects of the Fed's large-scale asset purchase policy on China's financial market.

If the residual has a high autocorrelation, not only will the estimation of the parameter μ , ϕ be biased, but also the parameter test will be inefficient. In order to solve the problem of endogeneity of variables, this paper uses shibor1day as a tool variable and uses TSLS model to analyze the price indices of stocks, bonds and futures markets in China.

In order to avoid the influence of the unit root, Duffee (2011) sets the first line of the parameter ϕ as the unit vector, and establishes the PC-UR model to distinguish the contribution of each risk factor in the global bond market. As the VAR model estimates show that there may be unit roots in the time series of China's stock, bond and futures market price indices. In this paper, ϕ is set as the unit matrix to investigate the influence of exogenous variables on China's financial market price index, according to Duffee (2011).

Table 7 Spillover Effects of the Fed's QE on China's Financial Market Price Index (Robustness Test)

5.2 Proxy variable

This paper uses drf_surprise, ex_surprise and expect_surprise instead of drf_shock, ex_shock and expect_shock as proxy variables for interest rate,

exchange rate and expected transmission mechanism, and tests the robustness of the transmission mechanism of the Fed's large-scale asset purchase policy. In order to improve the efficiency of the test, only the models (2), (3), (4) and (5) in Table 4-6 are tested.

As shown in Table 8, *Drf_shock* has a significant impact on the China Bond Full Price Index, while *ex_shock* has a significant impact on the Shanghai and Shenzhen 300 Index and the Nan-Hua Futures Composite Index. *Expect_shock* has a significant impact on the Nan-Hua Futures Composite Index, while the impact on the Shanghai and Shenzhen 300 Index and the China Bond Full Price Index is not significant. It can be seen that the interest rate transmission mechanism of Fed's large-scale asset purchase measures have an impact on China's bond market, while the exchange rate transmission mechanism on China's stock market. What's more both the exchange rate transmission mechanism and the expected transmission mechanism have an impact on China's futures market. Therefore, the conclusions drawn from Table 4, Table 5 and Table 6 are robust.

Table 8: The Transmission Mechanism of the Fed's QE on China's Financial Price Index (Robustness Test)

6 Conclusion

Under the framework of the theory of overshooting model and portfolio balance theory, this paper analyzes the short-term spillover effect and transmission mechanism of the Federal Reserve's QE on China's financial market.

The "overall event" of the Federal Reserve's QE has had a significant impact on China's financial market price index. China's China Bond Full Price Index, Shanghai and Shenzhen 300 Index and Nan-Hua Futures Composite Index have risen significantly. The impact of the "single incident" of the Federal Reserve's QE on China's financial market price index is not very significant. For the China Bond Full Price Index, only the release of asset purchase policies that truly change the liquidity of foreign markets will cause fluctuations in the price index of China's bond market. Those policies that only change the public's expectations will not have a notable impact. In terms of the Nan-Hua Futures Price Index and the Shanghai and Shenzhen 300 Index, the Fed may have a significant impact whether it affects market expectations, makes deadline conversion, or real asset purchase.

This paper further analyzes the role of interest rates, exchange rates, and RMB appreciation expectation transmission mechanisms in the transnational transmission of the Fed's large-scale asset purchase. The results show that the interest rate transmission mechanism has a significant impact on the bond market, while the exchange rate transmission mechanism has a significant impact on the

stock and futures markets. What's more, the RMB appreciation expectation transmission mechanism has a significant impact on the futures market. The robustness test shows that the results obtained in this paper are more reliable.

Under the Fed's QE, China's financial market price index has risen significantly. In the context of the prevalence of unconventional monetary policy, China's monetary authorities should pay close attention to the trend of asset prices, and comprehensively use interest rate instruments and expected management tools to avoid the emergence and accumulation of financial market bubbles.

References

- [1] Anaya P, Hachula M, Offermanns C J. Spillovers of U.S. Unconventional Monetary Policy to Emerging Markets: The Role of Capital Flows[J]. *Journal of International Money & Finance*, 2017, 73.
- [2] Bauer M D, Neely C J. International channels of the Fed's unconventional monetary policy[J]. *Journal of International Money & Finance*, 2014, 44(3):24-46.
- [3] Bernanke B. Monetary Policy since the Onset of the Crisis[J]. *Financial Market Research*, 2013.
- [4] Branson W H. Asset Prices and Relative Prices in Exchange Rate Determination[J]. 1977.
- [5] Chen Q, Lombardi M J, Ross A et al. Global Impact of US and Euro Area Unconventional Monetary Policies: A Comparison[J]. *Bis Working Papers*, 2015.
- [6] D'Amico S, King T B. Flow and stock effects of large-scale treasury purchases: Evidence on the importance of local supply ☆[J]. *Journal of Financial Economics*, 2013, 108(2):425-448.
- [7] Dornbusch R. Expectations and Exchange Rate Dynamics[J]. *Journal of Political Economy*, 1976, 84(6):1161-1176.
- [8] Duffee G R. Forecasting with the Term Structure: The Role of No-Arbitrage[J]. Working Paper, 2011, No. 576, The Johns Hopkins University, Department of Economics, Baltimore, MD
- [9] Fratzscher M, Lo Duca M, Straub R. On the International Spillovers of US Quantitative Easing[J]. *Diw Economic Bulletin*, 2013.
- [10] Glick R, Leduc S. Central bank announcements of asset purchases and the impact on global financial and commodity markets[J]. *Journal of International Money & Finance*, 2012, 31(8):2078-2101.

- [11] Krippner L. Measuring the stance of monetary policy in zero lower bound environments[J]. *Economics Letters*, 2013, 118(1):135-138.
- [12] Lamoureux C G, Lastrapes W D. Heteroskedasticity in Stock Return Data: Volume versus GARCH Effects[J]. *Journal of Finance*, 1990, 45(1):221-229.
- [13] Lombardi M J, Zhu F. A Shadow Policy Rate to Calibrate US Monetary Policy at the Zero Lower Bound[J]. *Bis Working Papers*, 2014.
- [14] Neely C J. The large scale asset purchases had large international effects[J]. *Working Papers*, 2011.
- [15] Rajan R. A step in the Dark: Unconventional Monetary Policy after the Crisis[J]. *Bis Working Papers*, 2013.
- [16] Rogers J H, Scotti C, Wright J H. Evaluating asset-market effects of unconventional monetary policy: a multi-country review | *Economic Policy* | Oxford Academic[J]. *Economic Policy*, 2014, 29(80):749-799.
- [17] Wright J H. What does Monetary Policy do to Long-term Interest Rates at the Zero Lower Bound? *[J]. *Economic Journal*, 2012, 122(564):F447–F466.
- [18] Yellen J L. A Challenging Decade and a Question for the Future : a speech at the 2017 Herbert Stein Memorial Lecture, National Economists Club, Washington, D.C. October 20, 2017[J]. *Speech*, 2017.

Table 7: Spillover Effects of the Fed's QE on China's Financial Market Price Index (Robustness Test)

Y(t)	future(t)				Stock(t)				Bond(t)			
	OLS	GARCH	TSLs	UR	OLS	GARCH	TSLs	UR	OLS	GARCH	TSLs	UR
2008.11.26LSAP01	0.60***	0.83**	0.39***	0.37***	2.06	-3.34	3.22	-7.01	3.77	1.64	4.05	3.11
2008.12.2 LSAP02	0.27**	0.18	0.14	0.14	-4.59	-2.37	-3.26	-8.38	-24.18*	-24.88	-22.68*	-24.13**
2008.12.17LSAP03	0.73***	0.62**	0.77***	0.79***	-9.57	-6.12	-8.14	-6.13	2.17	1.88	3.77	2.86
2009.3.19 LSAP05	0.06	0.06	0.05	0.06	44.68	45.74	44.21	44.93	11.78	11.03	13.96	11.82
2010.8.11 LSAP06	0.04	0.07	0.03	0.06	17.02	16.13	15.63	17.83	-7.09	-6.67	-7.80	-5.32
2010.8.27 LSAP07	0.02	0.07*	0.003	0.01	11.68	11.34	11.32	12.77	7.13	6.10	5.63	7.59
2010.10.15LSAP09	0.01	-0.45***	0.01	0.01	110.30**	110.24	109.92**	113.92**	6.92	6.83	4.52	6.36
2010.11.4 LSAP10	-0.10	-0.24	-0.20	-0.21	71.77	69.15	69.84	65.56	26.71**	27.14	24.94**	26.30**
2011.8.26 LSAP11	-0.01	-0.75	-0.03	-0.01	-3.63	-48.92	-1.16	-5.59	2.57	9.53	2.89	2.73
2011.9.22 LSAP12	0.12	-0.08*	0.13	0.10	-85.03*	-85.34	-82.42*	-84.69*	-35.06***	-35.21	-35.30***	-36.31***

Note: The t-test values is in parentheses, ***, **, and * represent significant levels at 5%, 5%, and 10% respectively.

Table 8: The Transmission Mechanism of the Fed's QE China's Financial Price Index (Robustness Test)

Y(t)	future(t)				Stock(t)				Bond(t)			
	(2)	(3)	(4)	(8)	(2)	(3)	(4)	(8)	(2)	(3)	(4)	(8)
C	2.54 (0.75)	2.85 (0.84)	4.55 (1.22)	5.11 (1.37)	21.22** (2.08)	21.45** (2.11)	22.89** (2.11)	23.72*** (2.20)	119.38*** (883.78)	119.38*** (882.70)	119.48*** (893.18)	119.47*** (893.15)
Y(t-1)	0.99*** (303.96)	0.99*** (305.45)	0.99*** (292.26)	0.99*** (293.45)	0.99*** (329.12)	0.99*** (329.98)	0.99*** (301.80)	0.99*** (302.60)				
Yhv5(t-1)	-1.19 (-0.23)	-2.36 (-0.46)	2.30 (0.41)	1.55 (0.28)	20.19* (1.85)	19.48* (1.79)	25.79** (2.14)	25.53*** (2.12)	-2.03 (-0.41)	-2.38 (-0.48)	-24.42*** (-4.47)	-24.36*** (-4.46)
Stock(t)	0.005*** (3.98)	0.005*** (3.95)	0.004*** (3.35)	0.004*** (3.29)								
Shibor1day(t)	0.67* (1.90)	0.68* (1.95)	0.70** (1.99)	0.73** (2.07)	-1.52 (-1.46)	-1.43 (-1.38)	-1.48 (-1.39)	-1.39 (-1.31)	-0.61*** (-15.04)	-0.61*** (-14.95)	-0.56*** (-14.07)	-0.56*** (-14.08)
Drfsurprise (t)	-3.76 (-0.15)			-22.79 (-0.85)	-47.27 (-0.54)			-60.72 (-0.63)	5.97* (1.67)			6.48* (1.69)
Exsurprise (t)		-2437.08*** (-3.44)		-2608.53*** (-3.26)		-6800.85** (-2.71)		-8751.12*** (-3.09)		-97.02 (-0.94)		-63.96 (-0.56)
Expect- surprise(t)			1651.12** (2.56)	1864.03** (2.69)			2222.96 (0.98)	2800.39 (1.14)			153.93* (1.69)	91.16 (0.93)
R-sqr	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.16	0.16	0.16	0.16
Adj-R-sqr	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.16	0.16	0.16	0.16

Note: The t-test values is in parentheses, ***, **, and * represent significant levels at 5%, 5%, and 10% respectively.