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The U.S Monetary Policy Spillover Effect in China and Its Transmission Mechanism

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Abstract

With the rapid development and continuous advancement of economic globalization, the links between countries around the world have become increasingly tight. Among them, the United States, as the world's largest economy, its monetary policy is bound to cause significant spillover effects on other economies around the world. By constructing a Threshold SVAR model with monthly data from 1996 to 2019, this paper empirically investigates the spillover effects of US monetary policy on China's economy during different U.S policy regimes. The transmission mechanism of such effects has been examed through different channels including policy channel, trade channel, asset value channel and information channel. The estimated threshold values of the Fed Fund rates/Shadow rates are between 0.905-0.990, which coincides with the unconventional policy period of U.S monetary policy. Also, the responses of different channels to U.S. monetary shocks in the lower regime(unconventional time) are different from those responses in the upper regime(conventional time).

Keywords: International policy spillover, U.S. monetary policy, Chinese economy, policy uncertainty, Threshold SVAR, GIRFs, ARDL
JEL codes: F3, C3, E3

I. Introduction

The traditional study of the monetary policy transmission mechanism focuses on how a country's monetary policy affects its target economic variables through various channels. However, in the open economy, in addition to the impact of a country's monetary policy on its economy, policy effects often spill over into other countries. The spillover effects of the monetary policy from one country to the other has also been studied by scholars through history. As far back as the 18th century, philosopher David Hume conducted an in-depth study on the issue of international economic fluctuations and proposed the theory of price-specie-flow mechanism which showed that the increase in domestic prices due to the gold inflow would discourage exports and encourage imports, thus automatically limiting the amount by which exports would exceed imports. During the period of the Bretton Woods system where it was called for a fixed exchange rate against the U.S dollar, the theoretical community had a heated discussion about the impact of US fiscal and monetary policy on other countries. A common view is that expansionary policy in the U.S increased inflation. To maintain fixed exchange rates, other countries had to accommodate U.S. expansionary policies by intervening in the foreign exchange market and increase their money supply by importing U.S. inflation. For instance, some of the G7 countries experienced an increase in aggregate demand due to US expansionary policies. After the collapse of the Bretton Woods system, U.S continuously played a dominate role around the world economy and its impact only got stronger. In recent decades, with the continuous strengthening of trade, finance, and cultural ties among countries, economic and financial communications between different countries have become more frequent and intertwined, shocks in macroeconomic policies including both fiscal and monetary aspects of a relatively big country will immediately form an impact on the state of the global economy. Therefore, as the world's largest economy, U.S monetary policy will inevitably affect the global economy at deep levels.

After the outbreak of the 2008 financial crisis, the Fed implemented a series of unconventional monetary policies to stimulate the economy. Although these policies have achieved the recovery of the domestic economy and eased the pressure on unemployment, their effects on the emerging economies cannot be overlooked. As the world's second-largest economy, the U.S's main trading partner and an important bondholder, China are certainly on the receiving side of the impact from the Fed's monetary policy. The spillover effects of US monetary policy on China's economy have been studied mainly by Chinese scholars. However, the results are controversial. On the one hand, the conclusion of spillover effects derived by major economic theories is ambiguous. For example, the traditional

Mundell–Flemming–Dornbusch (MFD) model believes that the expansion of foreign monetary policy has the potential to increase domestic output or reduce domestic output, depending on tradeoff between the expenditure-switching effect and the income-absorption effect. On the other hand, the current empirical research mainly focuses on the period before the financial crisis due to the difficulty to catch the U.S monetary stance when the Zero Lower Bound is binding.

Based on the above considerations, this paper focuses on the spillover effect of US monetary policy on China's economy pre and post-crisis period. First, based on various theoretical models, the author uses Threshold Structural Vector Autoregressive Regression (ThSVAR) to investigate the existence of spillover effect among different U.S policy regimes. Then the transmission channels of such spillover effects are examed and analyzed again through different restrictions of the ThSVAR.

The transmission mechanism of the monetary spillover effects is influenced by many factors. An in-depth analysis of this issue will help to reveal the dynamics of the foreign monetary policy spillover effects on the macroeconomic fluctuations of the domestic country. This paper summarizes the transmission channels of US monetary policy spillover effects on China's economy into four aspects. The first is the policy channel. In such a channel, China's monetary policy may directly respond to changes in US monetary policy by changing the interest rate or money supply. Analysis of such channels will also inspect the independence of China's monetary policy. The second is the trade channel. The US monetary policy adjustment may affect China's trade income through the expenditure-switching effect and the income-absorption effect. The net effect depends on the relative strength of the two effects, which in turn affects China's output. The third channel to inspect is the asset value channel. The changes in international capital flows and investor expectations caused by changes in US monetary policy may affect China's asset prices, while the change of asset price will act on China's output through wealth effect and Tobin's q. The final channel is the information channel. In the increasingly integrated global environment, U.S monetary policy shock may have a strong effect on the news-based policy uncertainty of China (Baker, Bloom and Davis 2016) and such policy uncertainty may as well imposes effects on the stance of U.S monetary policy. For instance, Janet Yellen frequently mentioned China's economic uncertainty when she was at the duty of the Federal Reserve Chair. Besides, to address the difficulty of catching the U.S monetary stance during the unconventional policy period, in this paper, the Federal Fund rate around the Zero Lower Bound is replaced by the Shadow rate developed by Wu and Xia (2016).

The structure of the paper organizes as follows: Section 2 reviews the literature on the studies of spillover effects between the U.S and other countries, Section 3 describes data and methodology, Section 4 explains the empirical results, and Section 5 concludes.

II. Literature review

The spillover effects of the monetary policy have been widely studied both theoretically and empirically. The theoretical researches on this issue are mainly based on two foundational frameworks: The Mundell-Fleming-Dornbusch (MFD) model and "The New Open Economy Macroeconomics" (NOEM) model. Mundell (1963) and Fleming (1962) first proposed a Keynesian analytical framework to study monetary policy issues in an open economy. Dornbusch (1976) expanded the theory by adding perfect foresight. The resulting Mundell-Fleming-Dornbusch (MFD) (see appendix) framework remains one of the theoretical foundations for the study of international monetary policy problems. Obstfeld and Rogoff (1995) proposed to add the monopolistic competition and price stickiness into the dynamic general equilibrium model, and established a micro-foundation for analyzing the dynamics of exchange rates, trade balances, and other macroeconomic variables. The related studies based on this framework are collectively called "The New Open Economy Macroeconomics" (NOEM).

On the empirical side, many works of literature attempt to study the international transmission mechanism of foreign monetary policy shocks on domestic economy, and representative studies include Stam et al. (1991), Shin(2000), Kim(2001), Holman and Neumann (2002), Miniane and Rogers (2003), Mackowiak(2006,2007) and so on.

Stam et al. (1991) examed the impact of the US money supply on Japan and the European monetary system. They found that the increase of the US money supply has a greater impact on the output of Belgium, Canada, and the United Kingdom, while the impact on Germany, Japan, and Italy was limited.

Kim (2001) examed the spillover effect of U.S monetary policy on other developed countries. He used the SVAR model and employed the ''marginal'' method by adding each international variable one by one to the benchmark model. The author found that the expansion of US monetary policy had a positive spillover effect on the actual output of other G7 countries. Its transmission path was mainly through the world capital market. The expansion of US monetary policy reduced the world's real interest rate and stimulated the world's total demand. Although the US expansionary monetary policy could improve the US mid-term and long-term trade balance and worsen foreign trade balances, this effect was small. The author concluded that the basic Mundell–Flemming–Dornbusch (MFD) model did not seem to be consistent with the evidence about the transmission mechanism. In this paper, we will adopt a similar "marginal" strategy in the SVAR framework since, In this way, we can study the

effects on a wide variety of variables without confronting the complexity of modeling variable interdependence.

Holman and Neumann (2002) studied the impact of currency shocks between the United States and Canada on various real economic variables. Through the cointegration test of monetary and consumption, investment, bilateral trade, and other real economic variables, it shows that money plays an important role in the economic balance between the two countries. The variance decomposition and impulse response show that the US and Canadian monetary policy does have a significant impact on the US and Canada's domestic economy and the Canadian and American economic variables, and the degree of influence on each other is almost equal in quantitative estimation.

In addition to research on developed country issues, there are also studies focusing on emerging markets. Shin (2000) found that during the period of the fixed exchange rate system, the Korean monetary policy was greatly affected by US monetary policy, but was less affected by Japanese monetary policy. This is because, under the Bretton Woods system, South Korea needs to maintain a fixed exchange rate against the US dollar. During the floating exchange rate system, the Korean monetary policy was minimally affected by the US monetary policy and was greatly affected by the Japanese monetary policy. It was considered to be the result of the Korean monetary authorities adopting a monetary policy to prevent the Korean won from appreciating the yen. Mackowiak (2006, 2007) found that the monetary policy shocks of developed countries have a negative spillover effect on the output of emerging market economies. The impact of US monetary policy can quickly affect the interest rates and exchange rates of emerging markets. The price level and actual output of emerging market countries are more responsive to the impact of US monetary policy than the US itself, confirming that "the United States is sneezing and emerging markets are catching a cold" It is vividly stated that the impact of US monetary policy can explain 3% to 6% of macroeconomic fluctuations in emerging market countries.

The studies of the U.S monetary spillover effects on China have been mainly conducted by Chinese scholars. Wu (2003) expanded the Mundell-Fleming model and analyzed how the US economic policy is transmitted to China. The model shows that the US expansionary fiscal and monetary policy will promote the growth of China's economy, but due to the asymmetry of China's capital account regulation, the impact on the Chinese economy in the case of US interest rates above and below China's interest rate is different.

Zhuang (2009) was the first scholar who incorporated the Structural Vector Autoregressive (SVAR) method to conduct quantitative empirical research on the analysis of the U.S monetary spillover effect over China. He used a similar structure as Kim (2001) to exam the direction of the spillover effect and various transmission channels with monthly data from 1995 to 2008. Later, a large number of related empirical researches have emerged in China. Scholars have had some different results regarding such an issue. Zhuang (2009) found that US monetary policy had a positive spillover effect on Chinese output, and this mid- and long-term spillover effect has been increasing since 1995. Zhang (2014) shows that the spillover effect of the US monetary policy shock on China's output is first negative than positive. That is, if the US lowers the federal funds rate, it will cause Chinese output to decline in the short term but will help China's output rise afterward. Bg contrast, He (2017) uses the Vector Autoregressive (VAR) model to show that under the positive shock of US interest rates, Chinese interest rates continue to rise, but have lasted for just a short period. The federal funds rate shock has a strong positive spillover effect on China's output in the short term, and it has a certain negative spillover effect in the medium term and a weak effect in the long run. It worth noticing that most analyses have used Fed Fund rates as policy rates to conduct research even during the period when the U.S conducted unconventional monetary policy. This paper addresses such issues by using the shadow rate proposed by Wu and Xia (2016).

Recently, Ho, S. W., J. Zhang, and H. Zhou (2018) have developed a factor-augmented vector autoregression (FA-VAR) model to study the spillover effect of U.S monetary policy on the Chinese economy during the quantitative easing period. They include 161 Chinese data series in their FA-VAR model which allows them to exam the impacts of U.S policy on the general Chinese economy with richer information sets than previous studies. They also adopted the shadow rates during the period of Zero Lower Bound. In this paper, we use SVAR instead of FA-VAR specifically because we are more interested in the different spillover transmission channels and the "marginal" strategy proposed by Kim (2001) lets us isolate different channels independently.

One thing worth noticing is that all the above studies either skip the unconventional policy period or using the specific date as a breakpoint to study the spillover effects with U.S policy rates within and out of Zero lower Bond, which makes it difficult to capture the nonlinear effects among the variables under the regime change. To improve such an issue, this paper proposes the Threshold Structure Vector Autoregression (ThSVAR). In terms of this methodology, according to the author's knowledge, no previous studies have used the Threshold SVAR model to analysis the monetary spillover effects from one country to the other. One reason is that there's no significant interest rate regime change before 2007-2008 in the U.S. and during the period of unconventional policy period the interest rates stay around ZLB. Such a scenario makes the threshold study meaningless. Incorporating Wu Xia shadow rates into Fed fund rates provides us the ideal circumstances to apply the Threshold SVAR model by using the combined rates as the threshold variable.

Besides spillover effects, various studies are using the Threshold SVAR model to address the nonlinear response effects under different regimes. Balke (2000) is the first to employ the Threshold SVAR model in the literature of macroeconomics. He tests and estimates a threshold vector autoregression that changes the structure if credit conditions cross a critical threshold. Then he uses nonlinear impulse-response analysis to isolate the relative effects of shocks. The author finds that monetary shocks represented by Fed fund rates are more potent in the tight-credit regime. The following studies mainly adopt and extend the methodology proposed by Balke (2000). For instance, Afonso, Baxa, and Slavik (2011) from European Central Bank use a threshold VAR to study the fiscal policy effects under different financial market conditions and they find the responses of macroeconomics variable to a fiscal shock are mostly positive in both financial stress regimes but with different magnitude. Then Fazzari, Morley, and Panovska (2014) investigate the effects of government spending on U.S. economics using the Threshold SVAR model. Their findings use Capacity Utilization as a threshold variable and the results support state-dependent effects of fiscal policy. Guo (2013) applies threshold structural vector autoregression analysis to explore the asymmetric effects of macro-variables on inflation in low and high inflation regimes, and he finds that the reactions of inflation to shocks are regime-dependent and asymmetric. Likewise, Mallick and Sethi (2018) conduct the Threshold SVAR model to study the nonlinear interactions between macroeconomic variables in India under different inflation regimes. In this paper, the author will adopt the Threshold SVAR methodology of Balke (2000) to investigate the U.S monetary policy spillover effect on China under different U.S interest rate regimes.

III. Methodology and Data

Structural Vector Autoregressions (SVAR)

Structural Vector Autoregressions (SVAR) introduced by Sims (1980) is a multivariate, linear representation of a vector of observables on its lags and other variables as a trend or a constant. According to certain economic theories, the researcher can establish an SVAR model by applying some contemporaneous constraint relationship to each equation in the model system, and identify the relevant parameters under the premise of satisfying certain order conditions.

A structural form of VAR

$$A(L)Y_t = e_t$$

Where A(L) is a matrix polynomial in the lag operator L; Yt is an n by 1 data vector, and $e_t$is an n by 1 structural disturbance. Var(e_t)=Λ whereΛ is a diagonal matrix so that structural disturbances are mutually uncorrelated.

A reduced form can be estimated as

$$Y_t = B(L)Y_{t-1} + u_t$$

where B(L) is a matrix polynomial in lag operator L and $Var(u_t) = \Omega$

To recover the parameters in the structural-form equation from the estimated parameters in the reduced-form equation. We need to impose restrictions on contemporaneous structural parameters only. Let denote A(0) the contemporaneous matrix of the structural form, and That the coefficient matrix in A(L) without A0.

$$A(L) = A_0 + \widetilde{A}(L)$$

Then

$$e_t = A_0 u_t$$

$$B(L) = -A_0^{-1}\widetilde{A}(L).$$

Which implies

$$\Omega = A_0^{-1}\Delta A_0^{-1}$$

Identification is achieved by imposing constraints on contemporaneous short-run effects of the shocks since Ωit contains n(n + 1)/2 parameters, by normalizing n elements of A0 to 1's, n(n -1)/2 additional restrictions are necessary to achieve identification. Generally, A0 can be any structure. In this paper, the recursive modeling is used.

Threshold Structural Vector Autoregressions (ThSVAR)

According to Balke (2000), the threshold SVAR may be considered as the nonlinear version of SVAR with two regimes and can be rewritten as (with different notations):

$$Y_t = A^1 Y_t + B^1(L)Y_{t-1} + (A^2 Y_t + B^2(L)Y_{t-1})I[s_{t-d} > \gamma] + U_t$$

Where Yt is a vector containing endogenous variables. B1(L) and B2(L) are lag polynomial matrices, A1 and A2 represent the structural contemporaneous relationships across the two regimes. Ut is structural disturbances. And is the threshold variable and it determines which regime the system is in. Generally, the threshold variable is a member of the endogenous variable in the VAR system. I am an indicator function that equals 1 when St-d > γ, and 0 otherwise. The γ is the threshold value and the integer d is the delay lag for the threshold switch; that is if the threshold variable St−d crosses γ at time t − d, the dynamics change at time t.

Identification and Ordering

A1 and A2 are assumed to have a recursive structure with the causal ordering of all the variables. While this recursive structure is not without controversy, much of the macroeconomics VAR literature uses a similar recursive ordering. Specifically, in the studies on the international transmission spillover effect of US monetary policy, scholars such as Kim (2001) and Zhuang (2009) used the "marginal" method by adding each international variable one by one into the recursive structure to observe the effects of newly added variables independently. Referring to similar structure like Kim (2001), Zhuang (2009) and Zhang (2014), this paper first constructs the baseline ThSVAR model with Chinese output as the only response variable, and then further studies the impact of shock on different transmission channels by replacing the response variables one at a time to the baseline model. It's important to note that we may impose different recursive identifications on different channels. For instance, we consider the information channel as a two-way channel.

In terms of the causal ordering of the variables for the ThSVAR model, following Christiano et al. (1998), all the variables are divided into three parts. The first part of the variable appears in the information set of the monetary authority period, that is, included in the monetary rule. The second part of the variable is the monetary policy tool such as the US federal funds rate. The third part of the variables does not appear in the information set of the monetary authority period. Under this assumption, although we can not identify all the structural impacts, Christiano et al. (1998) prove that it is only necessary to correctly select the variables of the three parts and the corresponding structural impact can be identified by using Chelosky decomposition. Notice that we can either place the Chinese variable in the third part or second part depending on the specific economic reasoning of that channel.

Testing and estimation Threshold models

If the threshold value is exogenous, the nonlinear behavior of the SVAR system can be examed by a conventional test on the null hypothesis that A2 = B2(L) = 0. However, in terms of regime change of the monetary spillover effects, it's hard to give a priori for the policy rates, the threshold value γ need to be estimated. In this case, testing involves nonstandard inference because the threshold value is not identified under the null hypothesis of no nonlinear effect. Therefore, based on Balke (2000), in order to test for thresholds when γ is not known, the ThSVAR model is estimated for all possible values of γ (to avoid over-fitting, the possible values were set so that at least 15% of the observations plus the number of coefficients is included in each regime) by least squares, and for each γ the values of the Wald statistics testing the hypothesis of no difference between regimes are calculated. Then three Wald statistics have been constructed: the maximum value of the Wald statistics (sup-Wald), the average (avg-Wald) and the sum of exponential Wald statistics (exp-Wald):

$$\mathrm{SupW}=\mathrm{SupWald}(\omega) \quad (\omega_p \leqslant \omega \leqslant \omega_d)$$

$$\mathrm{AveW}=\frac{1}{p_i-p_j+1}\sum_{\omega=p_i}^{p_j}\mathrm{Wald}(\omega)$$

$$\mathrm{ExpW}=\ln\{\frac{1}{p_i-p_j+1}\sum_{\omega=p_i}^{p_j}\exp[\mathrm{Wald}(\omega)]\}$$

To conduct inference, the empirical distributions of these Wals statistics are stimulated by the method of Hansen (1996). Now the Wald statistics calculated from the model can be compared with the critical values from the empirical distributions. Finally, the estimated thresholds can be found by maximizing the log determinant of the structural residuals Ut.

Nonlinear Impulse Response Function

After the Threshold SVAR estimation, the impulse response needs to be employed to further analyze the dynamic relationship between variables. However, in the nonlinear ThSVAR model, the traditional impulse response analysis is no longer valid since when we allow the system to evolve and switch between regimes, the impulse response function depends on the entire history and possibly on the size and the sign of the shock. This also results in asymmetric responses to the positive and negative shock and such asymmetry is specifically informational in our

monetary policy spillover effects analysis. To solve this issue, Koop, Pesaran and Potter (1996), generalized impulse response functions (GIRFs):

$$GIRF_y(k, shock_t, \Psi_{t-1}) = E[Y_{t+k}|shock_t, \Psi_{t-1}] - E[Y_{t+k}|\Psi_{t-1}]$$

A GIRF is defined as the difference in conditional expectation of Yt+k as a result of an added shock at time t, where Ψ_{t-1} is the information set at time t-1 and it provides initial values of the variable in the model. Calculating the GIRFs requires specifying the nature of the shock and the initial conditions t−1, and then the conditional expectations are computed by simulating the model. Finally, the GIRFs are constructed by averaging all the possible initial conditions. Similar to Fazzari, Morley, and Panovska (2014), we consider an orthogonal exogenous shock identified from the SVAR model.

Detailed steps to construct the GIRF in one regime:

1. Pick a history with specific initial condition (date) under one regime
2. Draw shocks from 0 to k period from the bootstrapped residuals of the estimated Threshold SVAR model.
3. Given the history, the estimated coefficients of ThSVAR and the bootstrapped residuals, stimulate the evolution of Yt over k period.
4. Repeat step 3 with the initial shock into one variable equal to +/- 1 or 2 SD
5. Calculate the difference between step 3 and step 4 forecasts, then repeat this B times to construct an impulse response given a particular history
6. Repeat the above steps for each initial conditions and report the average impulse response overall histories

Data

Kim (2001) suggests that the following three basic principles should be paid attention to when constructing the SVAR model: First, the impulse response of the US economic variables to the impact of US monetary policy is in line with theoretical expectations. Second, when there are multiple SVAR systems with similar impulse response results, choose the one with the least variable as the reference model. Third, the benchmark SVAR system is easy to expand. Based on the above criteria, as well as related empirical research on domestic transmission and international transmission of US monetary policy, the following economic variables are selected to construct the Threshold SVAR model.

1. **Federal Funds Rate and Shadow Rate proposed by Wu and Xia (2016)**. Since Greenspan adjusted the real interest rate as the main tool for macroeconomic regulation and control in 1993, the federal funds rate has continued to be the main instrument of U.S monetary policy. However, during the period after 2007-2008 Global Financial Crisis, specifically from December 16, 2008, to December 15, 2015, the effective federal funds rate is below 25 basis points, and the Fed has implemented several unconventional monetary policies. To catch such effect, We use the shadow rate constructed by Wu and Xia (2016) as a replacement of the effective federal funds rate during the times when the unconventional monetary policy is implemented. Importantly, the Wu-Xia shadow rate allows the policy to drop below zero and whenever it is above 1/4 percent, it is exactly equal to the effective federal funds rate by construction. The combination of the effective Fed fund rates and shadow rates would serve as a suitable threshold variable in the ThSVAR setting that allows us to explore the nonlinear structure of the U.S monetary policy spillover effects on the Chinese economy.

2. **US industrial production index and US consumer price index**. Output and price are good representatives of the overall macroeconomic situation, and also reflect the Taylor Rule of monetary policy. Due to the lack of monthly data in the United States, this article is replaced U.S GDP by the US industrial production index.

3. **The US producer price index(PPI)**. When studying monetary policy, it is generally necessary to add a price index of sensitive commodities to control the impact of oil prices and other supply shocks on output and prices (Bernanke and Gertler, 1995). At the same time, the price index of sensitive commodities is an appropriate indicator that can better reflect the response of the central bank policy. This paper takes the producer price index (PPI) as the proxy of the sensitive commodity price index.

4. Money supply (M1/M2). Money supply can appear in the system as a lagged variable that doe not appear in the information set of the monetary authority. For example, Christiano (1998) has included M1 in his study. At the same time, since the article uses monthly data with a greater degree of freedom, the M1/M2 variable can act as a role to stabilize the VAR system.

All the U.S data except shadow rates are from the Fred website. As mentioned above, this paper will adopt the “marginal” method proposed by Kim (2001) to exam the overall U.S monetary spillover effect on China output as

well as various transmission channels. All the Chinese data (except China Economy Policy Uncertainty)is from Fred and the Chinese National Bureau of Statistics. Below are the Chinese macroeconomic variables using in this paper.

5. Industrial value-added (growth). Considering the lack of monthly statistics for Chinese GDP, this paper uses the industrial value added (IVA) as the proxy of China's output. Since the correlation coefficient between the GDP and IVA is more than 90% according to the annual data, this substitution is feasible. The data is seasonally adjusted.

6. 1-year deposit rate/required reserve ratio for Chinese bank. These are the main policy instruments to be examed in this paper. Some previous studies about Chinese monetary policy were using the Shanghai Interbank Offered Rate (SHIBOR) as the policy rate for the Chinese central bank, in which they found there were no significant spillover effects on SHIBOR. However, China's interbank offered rate does not represent monetary policy very well. Some researchers (Xie and Luo 2002) pointed out that when the Chinese central bank adjusts interest rates, it does not do it by adjusting certain benchmark interest rates. Instead, PBoC firstly sets the 1-year rates for deposits, then extends the deposit rates for different periods, and finally determines according to loan rates. Therefore the 1-year deposit rate may be considered as one of the most effective monetary policy tools. Besides interest rate policy, the Chinese central bank also adjusts the required reserve ratio rapidly to control the money supply of the entire economy.

Therefore, this paper selects the 1-year deposit rate and required reserve ratio for analysis to better reflect the intention of the central bank's monetary policy.

7. Chinese imports/exports/net exports. These variables are seasonally adjusted. They are used to exam the trade channel of the U.S monetary policy spillover effect mechanism. Trade channel is one of the most studied transmission mechanism when analyizing the spillover effect.

8. The Shanghai Stock Exchange Composite Index (SSE). SSE is the benchmark stock market index in China. With the increasing interconnectedness of the global financial markets, the monetary policy in U.S may have interwinded effect on Chinese market. For instance, In 2015, the Chinese stock market experienced one of the greatest bubble bursts in its history, where the SSE gained 100% within half year then lost over 40% in less than two months. Some scholars have argued that the unconventional monetary policies (such as QEs) from U.S and other major countries may have contributed the bubble. Therefore, this paper examines the assets value channel by analyzing the U.S monetary spillover effect on the Chinese stock market.

9. China's economic policy uncertainty indices. The newspaper-based indices of policy uncertainty in China are developed by Steven J. Davis, Dingqian Liu and Xuguang S. Sheng (2019) and the data can be found on their website. (https://www.policyuncertainty.com/china monthly.html). To construct the economic policy uncertainty index for China, the researchers adopt the keywords capturing method proposed by Baker, Bloom, and Davis (2016) to quantify uncertainty-related concepts from October 1949 onwards using two mainland Chinese newspapers: the Renmin Daily and the Guangming Daily. Such indices provide us a reasonable way to exam the two-way information channel of the monetary spillover effect since the government based media such as Renmin Daily not only plays an important role in Chinese people's overall economic decisions but also reflects the Chinese government's attitude to the overseas.

All the data are transformed into logarithms except for the rates. We do not first difference the variables to eliminate the non-stationarities mainly because our primary focus is on the short-run reactions of different Chinese macroeconomics variables respected to U.S monetary policy shocks and the first differenced data will have a different economic meaning. For instance, the impulse response function of the first differenced policy rate is no longer a monetary policy shock. A lot of studies in the subject of monetary policy use VAR or SVAR with level data. In fact, many authors argue that variables with unit roots in SVARs shouldn't be first differenced at all. (eg, Sims, C. A., Stock, J. H., & Watson, M. W. (1990), Bernanke & Gertler (1995), Christiano et al. (1998) and Lütkepohl, H. (2011)). Phillips and Durlauf (1986), as well as Ashley and Verbrugge (2009), have argued that, under certain conditions, one should use SVAR in levels instead of VECM even if cointegration is presented. Besides, most literature studying U.S monetary policy spillover effect on China uses SVAR with level data, such as Zhuang (2009), Zhuang (2014) and Ho, et al. (2018). Adopting a similar structure allows us to compare the empirical results conveniently.

IV. Empirical Results

U.S monetary spillover effect on Chinese output

As discussed above, to inspect the general effect of U.S monetary policy shock on the Chinese overall economy. A baseline ThSVAR is estimated with the ordering (us output, uscpi, usppi, ffr/shadow, usm1, china output). The first five U.S variables are in line with Kim (2001), Zhuang (2009) and Zhang (2014), which constitute the conventional

SVAR structure for U.S domestic economy. Then the last Chinese variable is the response variable we are interested in. Note that later studies of the different spillover effect transmission mechanisms are conducted in a similar manner by switching only the Chinese response variable in the structure. However, the different ordering is considered in the informational channel.

The lag length of 2 is selected based on combining the results of different selection criterions (AIC, Schwarz SIC, and HQ). we assume the number of lags stay the same across different regimes.

In terms of the nonlinear test and estimation of the model, the combined rates of the effective fed fund rates and shadow rates are used as the threshold variables, represented by ffr/shadow. The delay lag of the threshold variable d is set at 1. The number of bootstraps is set as 500 and the percent of buffer period is set as 15%. Table-1 shows the result of the threshold test. The test shows strong evidence of threshold effect for ffr/shadow since all kinds of Wald statistics are extremely significant. It also shows that the estimated threshold value is 0.905 by optimizing the log determinate of sigma.

Test for Threshold SVAR
Threshold Value** = 0.905000

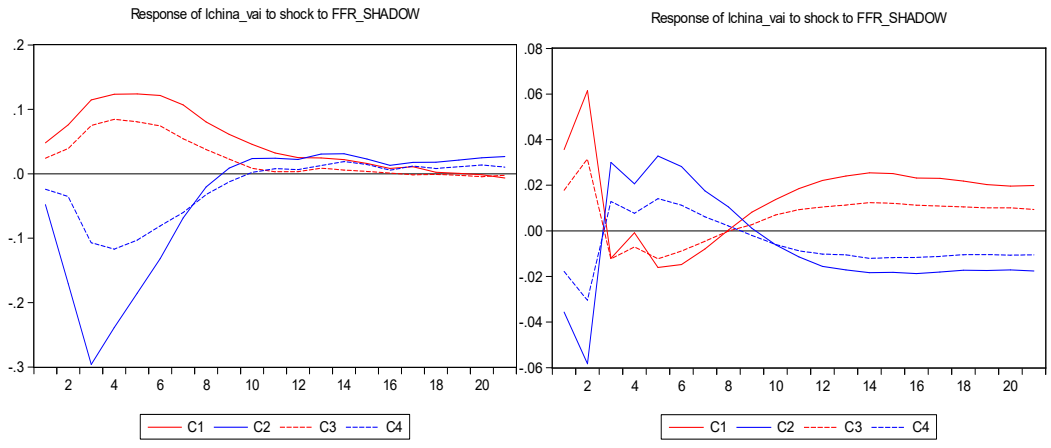
Test statistics	Value	P-Value
sup-Wald	314.63	0.000
avg-Wald	242.13	0.000
exp-Wald	152.97	0.000

** specification that minimizes logdet(sigma): -50.78470

(table 1)

The threshold value of 0.905 tells us that the SVAR model exhibits nonlinear dynamics when the ffr/shadow rates are above and below the 0.905 percent. This number itself is of great importance because it provides us nontrivial information according to the U.S monetary spillover effect on China. Also if we locate the regime period that the rates are below 0.905 percent, the resulting period between November 2008 and April 2017 suggests that the spillover effects for low rates regime largely coincides with the Fed's unconventional monetary policy period after the 2007-2008 financial crisis. Note that the effective federal funds rate falls below 0.25 percent only from late 2008 to December 2015. However, from January 2016 to April 2017, the rate is still much lower than pre-ZLB levels. In fact, from the Fed announcements, existing QE is contemplated to start in 2017 (Fleming and Leatherby, 2017). Our estimated value reflects such dates without imposing any outside information. In the rest of the paper, the regime above the threshold value is noted as a conventional regime and the regime below the threshold value is referred to as the unconventional regime.

After estimating the threshold value of the model, The GIRFs are constructed under conventional and unconventional regimes. (regime with ffr/shadow above 0.905 and the regime with ffr/shadow below 0.905) Both positive and negative monetary policy shocks are shown on the graphs (see figure-1 below). It worth mention that the effects of the shocks are not guaranteed to be symmetric. For the comparason purpose, the impulse responses without nonlinear structure is also shown in the Appendix.



Conventional regime Unconventional regime

Figure-1 GIRFs of U.S monetary shock on Chinese output

C1 and C3 (red) are the +2 and +1 standard deviation shocks. C2 and C4 (blue) are -2 and -1 standard deviation shocks. The graphs represent the response of the Chinese output (industrial value-added) to the ffr/shadow rate shocks.

There are some interesting observations according to our results. First, the response dynamics and sizes are vastly different under different regimes, this implies the significance of the estimated threshold value. Second, the spillover effects of the U.S monetary policy on Chinese output are generally positive at the very beginning but exhibit different dynamics later on depending on regimes. Third, Figure-1 also suggests the existence of asymmetric responses: the expansionary U.S rates shock (negative shocks) impose a larger effect on Chinese output than the contractionary shocks (positive shocks).

In more detail, under the conventional regime, the contractionary U.S rates shocks have positive effects on output in the short term and the effects die out in the median long term. The expansionary shocks have a stronger negative impact in the short term but the effects become positive after about 10 periods. By contrast, the impulse responses under unconventional regime are more volatile: the contractionary shocks exhibit positive effect in the very short term, negative effect on the medium-term and positive effect in the long term; the expansionary shocks have the negative effect at the very beginning but relatively strong positive effect in the medium term, and small but persistent negative effect in the long term. Our results under the conventional regime are consistent with the findings of Zhang (2009) and Zhang (2014). It is considered that the expansionary U.S monetary policy imposes delayed positive effects on the Chinese economy. However, under the unconventional monetary policy regime, the response of Chinese output to expansionary monetary policy shocks has a relatively smaller size and switches to positive rather quickly but goes back to negative in the long run. This may imply that unconventional U.S monetary policy such as QE may shortly help the Chinese economy but the long term effect remains negative.

Transmission mechanisms of the U.S monetary policy spillover effect

In this section, the author applies Threshold SVAR to exam four channels of the spillover effect transmission mechanism: policy channel, trade channel, asset value channel and information channel.

1. <u>Policy channel</u>

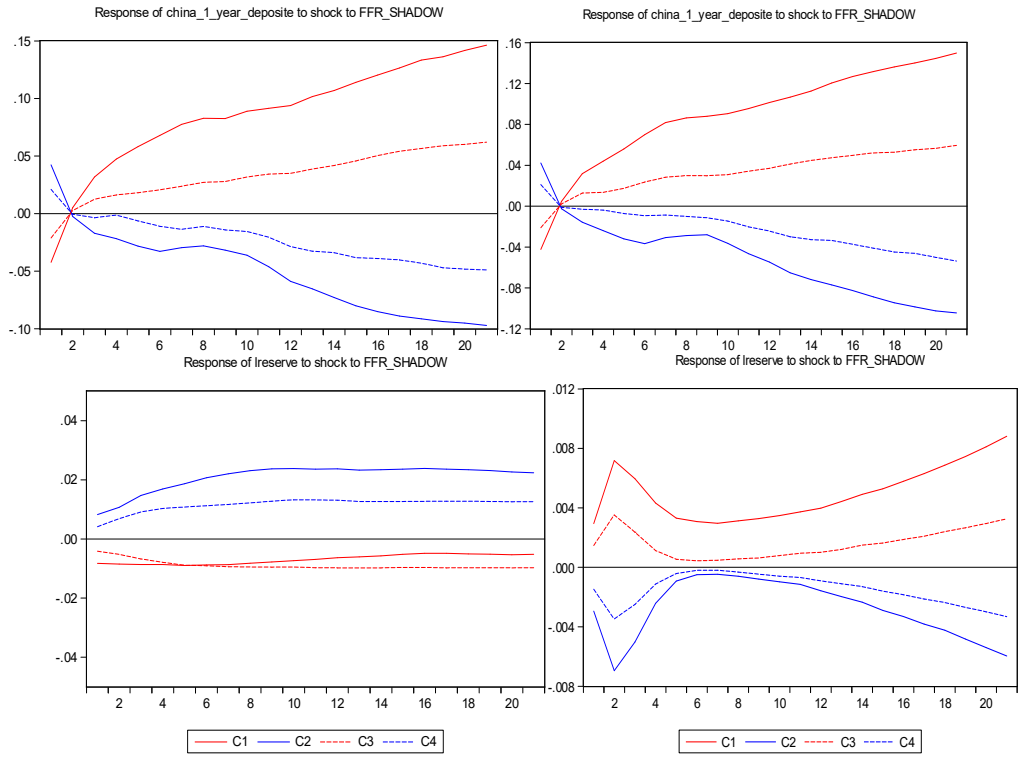
Both Kim (2001) and Zhuang (2009) find that the expansionary monetary policy in the U.S will directly affect the interest rates of other countries and the spillover effect is positive, which means that the positive (negative) shock will have a positive (negative) impact on the country's policy rates. To exam such a mechanism, the policy rate variables will be included in the Threshold SVAR model using the marginal method proposed by Kim (2001). Specifically, 1-year deposit rate and required reserve ratio will be separately tested in different Threshold SVAR structures: (us the output, uscpi, usppi, ffr/shadow, usm1, 1-year deposit rate) and (us the output, uscpi, usppi, ffr/shadow, usm1, required reserve ratio)

Table-2 shows the test results and estimated threshold values for both SVAR structures. The nonlinear test reveals that all the statistics are significant, which implies the existence of the threshold structures. The estimated threshold values are 0.990 percent for both the Chinese policy rates channel. This value is slightly different from the estimated threshold value in the previous section, but its corresponding periods are roughly the same. (eg, the unconventional period ranges from Octorber 2008 to May 2017)

Test for Threshold SVAR Threshold Value** = 0.990000			Test for Threshold SVAR Threshold Value** = 0.990000		
Test statistics	Value	P-Value	Test statistics	Value	P-Value
sup-Wald	332.05	0.000	sup-Wald	346.73	0.000
avg-Wald	256.87	0.000	avg-Wald	259.56	0.000
exp-Wald	162.00	0.000	exp-Wald	168.91	0.000
** specification that minimizes logdet(sigma):		-51.46604	** specification that minimizes logdet(sigma):		-54.99209

Tabel-2

The GIRFs of the policy channel is plotted under conventional and unconventional regimes. (see figure-2) Both positive and negative monetary policy shocks are shown on the graphs and the effects of the shocks are not guaranteed to be symmetric.



Conventional unconventional

Figure-2

C1 and C3 (red) are the +2 and +1 standard deviation shocks. C2 and C4 (blue) are -2 and -1 standard deviation shocks. The graphs represent the response of the Chinese policy rates (1-year deposit and required reserve ratio) to the ffr/shadow rates shocks.

1-year deposit rate

According to Figure-2, the responses of Chines 1-year deposit rate to U.S monetary shocks are similar across conventional and unconventional regimes. Under both regimes, the contractionary U.S monetary policy will have a persistent positive effect on the Chinese deposits rate and U.S monetary expansion will have a persistent negative effect on the Chinese deposit rates. Such a result is consistent with the findings of Kim (2001) and Zhuang (2009). After constructing SVAR models for G-7 countries, Kim (2001) concludes that under a U.S. monetary expansion, the decrease in the U.S. real interest rate leads to the decrease in the world real interest rate (and the non-U.S. real interest rate) given the world capital market is integrated to some extent. Therefore, the decrease in world real interest rate following a U.S. monetary expansion seems to be the major transmission channel for foreign booms under U.S. Zhuang (2009) constructs the similar SVAR using Chinese deposit rate from the sample before 2008 financial crisis, and he finds that the U.S monetary spillover effect has positive impact on Chinese policy rates. Also, to compare and verify the conclusions from previous empirical studies, our results provide more information than those studies due to the characteristics of the Threshold SVAR and GIRFs. First, asymmetry of the positive and negative shock is allowed in the construction of GIRFs. The result shows that the response of the Chinese 1-year deposit rate to U.S monetary shock is stronger under contraction than expansion. One possible explanation is that credit condition is often more tight under monetary contraction than expansion, and the interactions between monetary shocks and credit regimes generate such asymmetry. Second, by incorporating shadow rates into the Fed fund rates, we can isolate the dynamics of impulse responses through Threshold modelling. In terms of Chinese 1-year deposit rates, the spillover effects are very similar across regimes. This may imply that the Chinese central bank, PBOC, regards the Fed's QE under the unconventional regime as rate cut during normal times.

Required Reserve Ratio

The result according to the Chinese Required reserve ratio shows regime dependent dynamics, although the overall spillover effect seems to be smaller. Under the conventional regime, the contractionary U.S monetary policy will have a slightly negative effect on the Chinese required reserve ratio and the expansionary U.S monetary policy will have a strong positive effect on the required reserve ratio. Interestingly, under the unconventional regime, the spillover effect will have the opposite impact: U.S monetary contraction will have a positive effect on the Chinese required reserve ratio and U.S expansion will have a negative effect. Such pattern reversal across regimes may be

explained by two conflicting factors: hot money effect (Ho, Zhang, and Zhou 2018) and precautionary effect. Under normal regime, U.S monetary expansion may cause foreign currency inflow of China, hence money base, due to the presence of a compulsory foreign currency settlement system mandated by Chinese laws and regulations. To counter the increase in money supply, the PBoC has to raise the required reserve ratio, in order to offset potential inflation. By contrast, under the unconventional regime, mainly the period after the global financial crisis, besides considering the hot money effect, PBoC has to take the weak global economy (low inflation) into account and provide redundant liquidity. This logic can be seen clearly from the GIRF of the required reserve ratio under the unconventional period, the response of the required reserve ratio spikes up during the short-median period due to the possible hot money effect but remain negative in the longer term due to the weak global economic environment.

2. Trade Channel

The trade balance is widely considered by many scholars as one of the main transmission mechanisms for the monetary spillover effects. Theoretically, it is supported by the basic Mundell–Fleming–Dornbusch (MFD) model (see appendix). Intuitively, the depreciation of the domestic real exchange rate during the monetary expansion will increase the export, but at the same time, the increase in output caused by the expansion will increase the demand for foreign products, hence increase import. Therefore, various Threshold SVAR models have been conducted to exam this transmission mechanism across both regimes. The three Chinese variables that will be analyzed marginally are imports, exports, and net exports.

As usual, table-3 reflects the threshold test of the SVAR structure as well as the estimated threshold value.

Test for Threshold SVAR
Threshold Value** = 0.905000

Test statistics	Value	P-Value
sup-Wald	289.18	0.000
avg-Wald	208.99	0.000
exp-Wald	140.42	0.000

** specification that minimizes logdet(sigma): -52.32684

Test for Threshold SVAR
Threshold Value** = 0.905000

Test statistics	Value	P-Value
sup-Wald	348.05	0.000
avg-Wald	250.61	0.000
exp-Wald	169.61	0.000

** specification that minimizes logdet(sigma): -53.60732

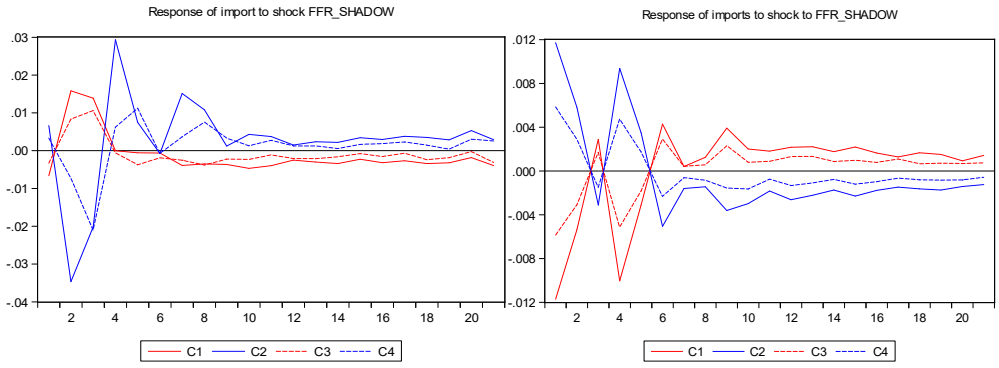
Test for Threshold SVAR
Threshold Value** = 0.905000

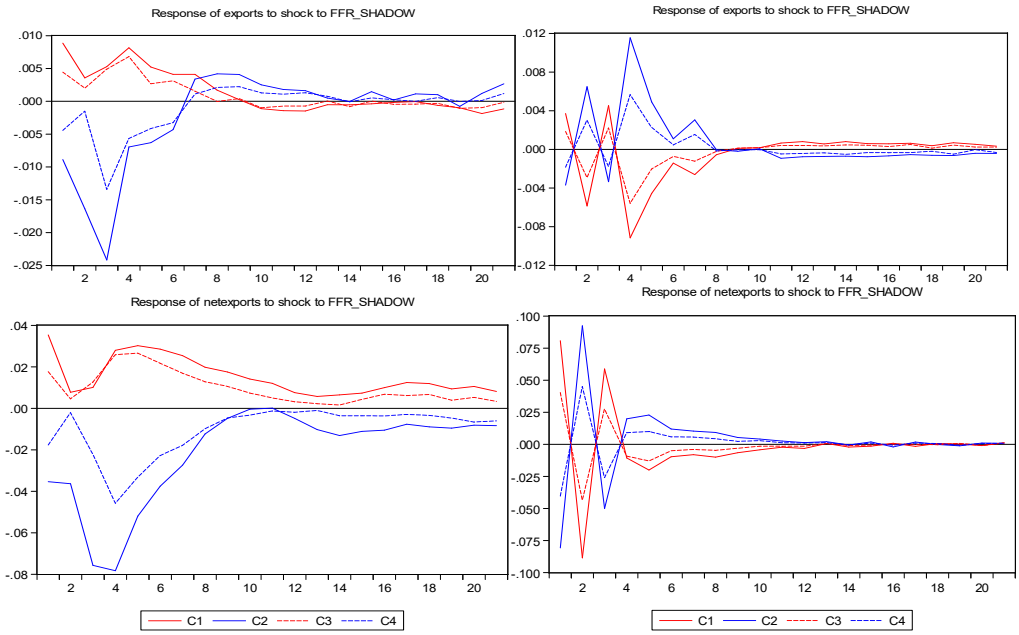
Test statistics	Value	P-Value
sup-Wald	316.61	0.000
avg-Wald	220.72	0.000
exp-Wald	154.21	0.000

** specification that minimizes logdet(sigma): -50.14378

Table-3

The threshold value is estimated to be 0.905 across the models. This value is the same as the estimated threshold value in the output model, which reflects that the threshold structure of the spillover effect on China is stable and robust. The results of the GIRFs are shown below in the figure-3





Conventional unconventional

Figure-3

C1 and C3 (red) are the +2 and +1 standard deviation shocks. C2 and C4 (blue) are -2 and -1 standard deviation shocks. The graphs represent the response of the Chinese trade variables (top to bottom: imports, exports, and net exports) to the ffr/shadow rates shocks.

The results under the conventional regime are consistent with the theoretical prediction of the MFD model as well as the empirical results of Kim (2001) and Zhuang (2009). Both Chinese exports and imports are increasing in the median long term after short term negative spikes under U.S expansionary monetary policy. The eventual increases in Chinese imports reflect the so-called expenditure switching effect where the U.S increases its exports to the rest of the world due to the lower interest rate and dollar depreciation. By contrast, the long term rise of the Chinese exports shows that U.S consumers demand more foreign goods during monetary expansion, hence the existence of the income absorbing effect. Notice that both effects seem to be time-delayed under the conventional regime. The GIRF of the net exports also shows that expenditure switching effect dominates income absorbing effects in the short-median term and such domination decreases gradually over time. Another implication from the GIRFs under the conventional regime is that the transmission mechanisms of the trade channels are not symmetric while facing contractionary and expansionary U.S monetary policies. The responses to expansionary shocks are generally greater.

Under the unconventional regime, the impulse responses of the trade variables exhibit different dynamics. The expansionary U.S monetary shocks have a positive effect on Chinese imports in the short-median term but the effect becomes negative afterward. This suggests that the expenditure switching effect takes more immediate effect but fades away in the long term. This is consistent with the usual criticism of the unconventional monetary policies, which states that although these policies have achieved the recovery of the domestic economy and eased the pressure on unemployment, their effects on the emerging economies can create unintended consequences. In our case, the QE seems to weaken Chinese imports over the long run. In terms of Chinese exports, the unconventional monetary expansion will have an immediate positive effect, consistent with income absorbing effect, which implies that QE does play an important role in recovering the U.S economy. Finally, the unconventional expansionary policy has an overall positive effect on net exports, which is the opposite case under conventional regimes. In other words, the income absorbing effect dominates the expenditure switching effect in the short-median term. The dynamics in trade channels also imply that, in terms of spillover effect on China's trade condition, QE policy may take effect more quickly than conventional monetary policies, but it also fades away more rapidly. All of the observations may have important implications for policy makings in China and the U.S since the trade channel of the U.S monetary spillover effect exhibits different dynamics under conventional or unconventional regimes. However, the overall spillover effect size is smaller in the trade channels compared to the Policy channel.

3. Asset value channel

As the Chinese financial market has become more open to global investors, the spillover effect of the U.S monetary policy on asset value cannot be overlooked. On one hand, the adjustment of the US monetary policy will have a direct impact on global capital flows, which in turn will change China's liquidity status. In the open capital markets,

if a country's stock market has a considerable degree of international investors, then when the liquidity of these investors' countries changes due to monetary policy, international investors will adjust their global portfolio accordingly. This kind of effect seems to get more obvious under the unconventional monetary period. The Chinese stock market crash in 2015 has been considered by many economists as an example of such arguement. On the other hand, the macroeconomics signal reflected by US monetary policy will also change the expectations of the domestic investors on the profitability of listed companies or the cost of capital. Through this kind of anticipatory psychological effect, the stock price of China will change as well. With the deepening of the world economic and financial integration, information is rapidly transmitted between different markets; Chinese investors are increasingly concerned about the macroeconomic fluctuations of the United States and the adjustment of U.S monetary policy. This paper will use the return of the Shanghai Composite Index (SSE) to represent the asset value channel of China. A Threshold SVAR model is applied to study the spillover effects across the conventional and unconventional regimes.

Tabel-4 reflects the threshold test of the SVAR structure as well as the estimated threshold value.

Test for Threshold SVAR
Threshold Value** = 0.905000

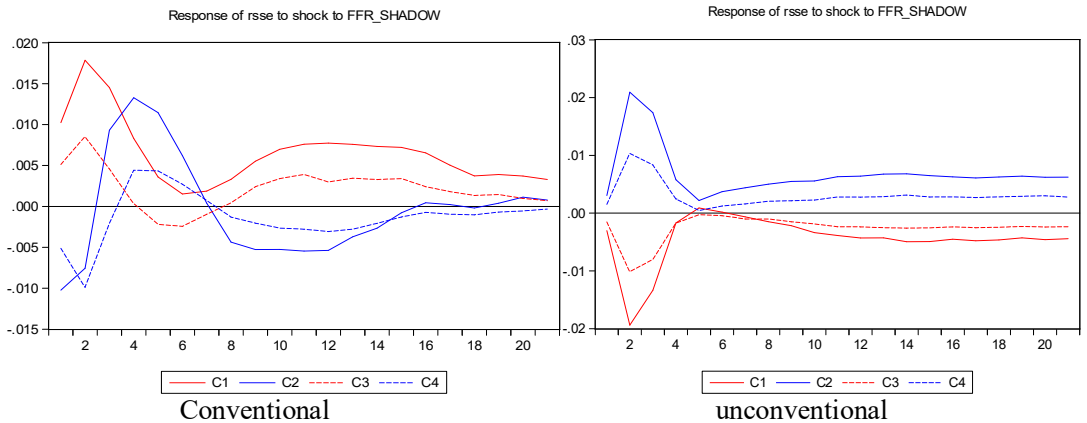
Test statistics	Value	P-Value
sup-Wald	327.38	0.000
avg-Wald	234.41	0.000
exp-Wald	159.77	0.000

** specification that minimizes logdet(sigma): -54.21247

Table-4

The nonlinear test shows that there's a significant threshold effect in the SVAR structure. The estimated threshold value is 0.905 again, which reconfirms the stability of our Threshold SVAR modeling.

After the estimation of the threshold value, GIRFs across regimes are computed and shown below in the figure-4.



Conventional unconventional

Figure-4

C1 and C3 (red) are the +2 and +1 standard deviation shocks. C2 and C4 (blue) are -2 and -1 standard deviation shocks. The graphs represent the response of the Chinese stock market return (SSE) to the ffr/shadow rate shocks.

The result in figure-4 contains much more information than regular VAR analysis. It does not only exhibit different dynamics under different regimes but also shows the obvious asymmetry between positive and negative shocks within one regime (conventional). More importantly, the result is consistent with previous studies that seem to produce conflicting conclusions. Zhuang (2009) finds that contractionary U.S monetary policy (positive shock) has a positive effect on the Chinese stock market, and he goes on to conclude that the monetary expansion will have a negative effect on Chinese asset value due to the symmetry of the shocks. By contrast, Ho, Zhang, and Zhou (2018) conduct an FA-VAR model to find that U.S monetary expansion will generally inflate the stock market price in China, especially under the QE period. Interestingly, all of these conclusions could be explained by our GIRF results of the Threshold SVAR structure. During the normal U.S policy regime, consistent with Zhuang's (2009) finding, monetary contraction does lead to positive response of Chinese stock market return, but the expansion also has positive effect on the stock return in short term, then the effect goes to slightly negative in the medium term and dies out in the long term. This scenario can only happen under the asymmetry of impulse responses. During the unconventional regime, our result is consistent with the finding of Ho, Zhang, and Zhou (2018), where the unconventional monetary expansion in the U.S has a positive effect on the Chinese stock market return while the monetary contraction has a negative effect during the same period. In other words, the shocks are more symmetric. These results also help to expain the Chinese stock market crash in 2015. While the Fed fund rates stayed around

zero, the Wu-Xia shadow rates had beening increasing from 2015, relecting the monetary contraction under the unconventional regime, and such contraction negatively affected Chinese stock market return according to our GIRF results.

4. Information Channel

As mentioned in the previous sections, given the rising global integration among different countries, it's increasingly important to capture the informational effect embedded in the spillover transmission mechanism, so the author proposes the analysis of the information channel. In this article, we adopt the newspaper-based index of Economic Policy Uncertainty (EPU) in China developed by Davis, Liu, and Sheng (2019) to exam the U.S monetary policy spillover effect over information channel. To construct such an index, they quantify uncertainty-related concepts from October 1949 onwards using two mainland Chinese newspapers: the Renmin Daily and the Guangming Daily. (The detailed steps are shown in the Appendix) The Renmin Daily is widely considered as the most important government based newspaper in China, which does not only set the tone for the national policy in China but also expresses China's stance and central ideas to the rest of the world. Therefore, as a news-based information measure, such an index may respond quickly to the U.S monetary shocks, but at the same time, imposes its shock on the U.S monetary policy decision making. To include such a two-way relationship in our Threshold SVAR structure, we exam the alternative order of variables in the recursive identification. In the alternative case, the Economic Policy Uncertainty (EPU) is placed before the FFR/Shadow rates, so that the EPU may have a contemporaneous effect on U.S monetary policy. The results of both the original recursive structure and alternative structure are shown.

Table-5 has shown the threshold tests of both SVAR structure as well as the estimated threshold values.

Test for Threshold SVAR
Threshold Value** = 0.905000

Test statistics	Value	P-Value
sup-Wald	224.57	0.000
avg-Wald	153.54	0.000
exp-Wald	107.91	0.000

** specification that minimizes logdet(sigma): -39.69850

No contemporaneous effect

Test for Threshold SVAR
Threshold Value** = 0.905000

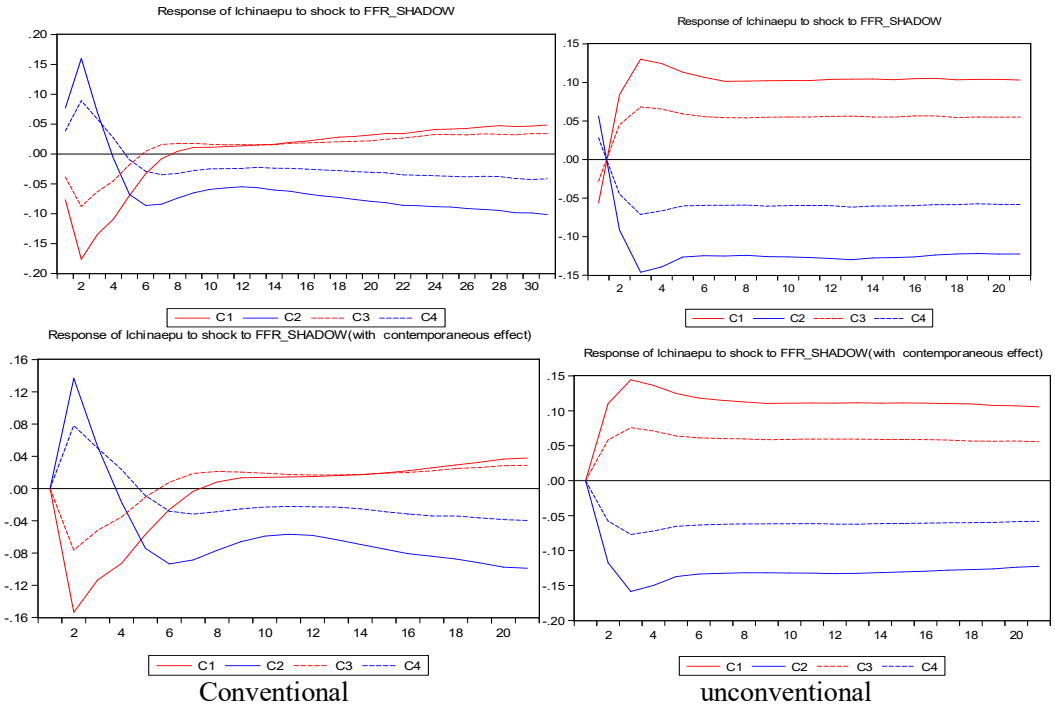
Test statistics	Value	P-Value
sup-Wald	312.36	0.000
avg-Wald	235.46	0.000
exp-Wald	151.83	0.000

** specification that minimizes logdet(sigma): -49.84106

with contemporaneous effect

The test statistics are significant across all the Wald tests for both structures, which implies that the nonlinear structures do exist. The estimated threshold values are 0.905 percent for both structures. The estimated threshold values in all channels are 0.905 percent except for the policy channel where the value is estimated to be slightly different at 0.990 percent. The consistency of the estimated threshold values suggests that our nonlinear SVAR framework is quite stable.

Figure-5 then shows the GIRFs of the China Economic Policy Uncertainty (EPU) that responded to U.S monetary shocks across the conventional and unconventional regimes for both structures.



Conventional unconventional

Figure-5

C1 and C3 (red) are the +2 and +1 standard deviation shocks. C2 and C4 (blue) are -2 and -1 standard deviation shocks. The graphs represent the response of the Chinese Economic Policy Uncertainty (EPU) to the ffr/shadow rate shocks. The top two graphs on the top are the GIRFs without contemporaneous effect and the two graphs on the bottom are the GIRFs with contemporaneous effect.

There are no obvious differences between the structure with the contemporaneous effect and the structure without a contemporaneous effect. According to figure-5, the overall size of the spillover effect in the information channel is quite large, and the dynamics are very different under different regimes. During a normal period, the U.S monetary expansion seems to increase the economic policy uncertainty in China at the beginning (first 4 periods) but the effect becomes negative in the long term. By contrast, under the unconventional policy period, the U.S expansionary monetary policy will decrease the economic policy uncertainty in China persistently. Such difference in dynamics can be explained by the market sentiments towards uncertainty under different regimes: during normal times, monetary expansion in the U.S often suggests that the Federal Reserves see something unpleasant and react to it. This can be perceived by global markets (including China) as a possible increase in future uncertainties. Then, as the monetary expansion takes its effect to calm down or promote the economy, the uncertainties perceived by the markets decreases. However, during the unconventional times, specifically periods after the 2007-2008 global financial crisis, uncertainty seems to be the norm around the world, any policy to recover the economy will decrease the uncertainties.

If we compare the relative effect sizes for all four transmission channels, the policy channel and information channel seem to have larger responses to the U.S monetary shocks. This finding that shows the importance of the policy channel is consistent with the conclusions of Kim (2001) and Zhuang (2009). However, the information channel also plays an essential role in the transmission mechanism, which could considered as one of the main contributions of this paper. To furture inspect the robustness of the informaiton channel, an An autoregressive distributed lag (ARDL) model is appled to study the relationship between Chinese EPU and U.S EPU. (see Appendix for detailed) The results suggest that there is long-term relationship between Chinese economic policy uncertainty and U.S economic policy uncertainty, which then confirm the existence of the information channel.

V. Conclusion

This paper conducts a comprehensive investigation of the spillover effects of US monetary policy on China's economy. Specifically, the transmission mechanism of such spillover effects is analyzed by examing the policy channel, trade channel, asset value channel and information channel. In terms of the methodology, the Threshold SVAR models first proposed by Balke (2000) are employed to capture the nonlinear effects across the U.S monetary policy regimes. The followings are the important findings of this paper.

1. The generall spillover effects of U.S monetary policy exhibit very different dynamics during conventional and unconventional regimes. Our results are consistent with the findings of Kim (2001), Zhuang (2009) and Zhang (2014) for specific shocks under the specific regime, but provide much more information due to the unique structure of the Threshold SVAR and its GIRFs. Our paper is also the first to use such a methodology to study the spillover effects according to the author's knowledge
2. By using the combined rates of Fed Fund rates and the shadow rates constructed by Wu and Xia (2016) as our threshold variables, the nonlinear tests reveal significant threshold structures. The estimated threshold values across all channels (including the general output) are either 0.905 or 0.990 percent, which coincides with the cutoff value for the Fed's conventional and unconventional policy periods proposed by some scholars. The consistent estimations of the threshold values not only reflect the stability of the Threshold SVAR framework but also provide important implications for Policymaking.
3. After analyzing each channel. The results of GIRFs suggest that the policy channel and information channel are more important in terms of spillover effect sizes and persistences. More importantly, our study explores an new way of spreading spillover effects, the information channel, in addition to the traditional monetary policy spillover effects transmission mechanism. This finding may provide potential implications for both U.S and China policy makings.

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Appendix

Mundell–Fleming–Dornbusch (MFD) model based on Borondo, C. (2001)

$$
\begin{aligned}
y_t &= -b_1 r_t - b_2 q_t + b_3 y_t^* && (1)\\
y_t^* &= -b_1 r_t^* + b_2 q_t + b_3 y_t && (2)\\
r_t &= i_t - \left(E_t p_{t+1}^h - p_t^h\right) && (3)\\
r_t^* &= i_t^* - \left(E_t p_{t+1}^{*f} - p_t^{*f}\right) && (4)\\
q_t &= p_t^h - s_t - p_t^{*f} && (5)\\
m_t - p_t^h &= c_1 y_t - c_2 i_t && (6)\\
m_t^* - p_t^{*f} &= c_1 y_t^* - c_2 i_t^* && (7)\\
i_t &= i_t^* + E_t s_{t+1} - s_t && (8)
\end{aligned}
$$

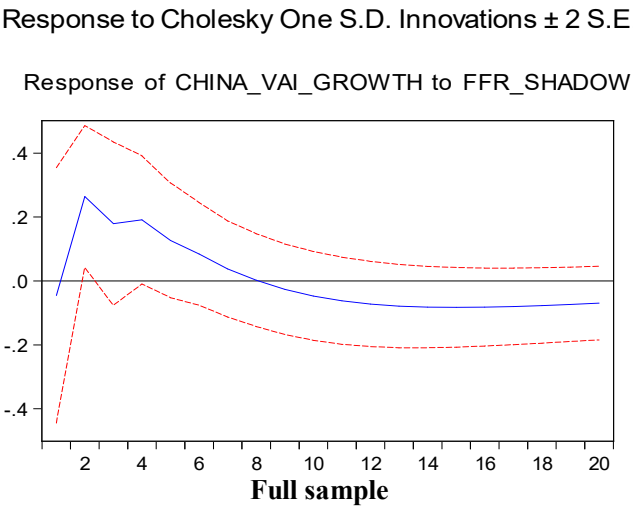
Where the Dornbusch (1976) type of adjustment is to assume that prices increase when output is above the trend:

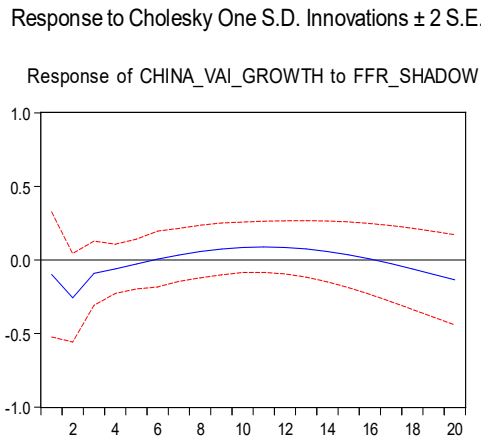
$$\Delta p_{t+1} = \pi y_t$$

y	output (log deviation)
c	consumption (log deviation)
i	nominal interest rate (deviation)
r	real interest rate (deviation)
p^h, p^{*f}	domestic price index (log deviation)
p^{ha}, p^{*fa}	price fixed by firms (log deviation)
p	consumer price index (log deviation)
s	nominal exchange rate (log deviation)
q	terms of trade ($q = p^h - s - p^{*f}$)
e	real exchange rate ($e = s + p^* - p$)
m	monetary aggregate (log deviation)

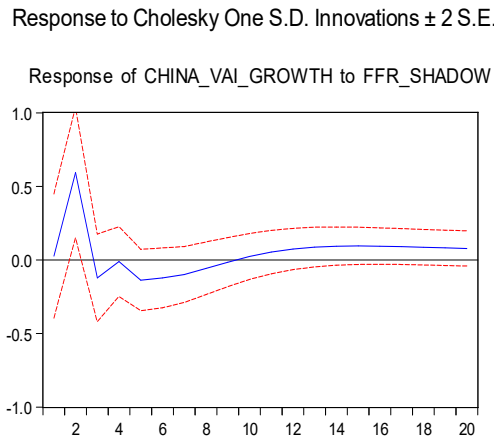
According to Mundell–Fleming–Dornbusch (MFD) model analyzed by Borondo, C. (2001), assuming perfect capital mobility between both countries, there are two main channels through which the Home monetary expansion might have impacts on Foreign output: trade channel and the interest rate channel. The trade channel is related to the expenditure switching effect caused by the depreciation of domestic real exchange rate, and to the income absorbing effect due to the increase of Home output that will increase the demand for Foreign products at the same relative price. The interest channel is related to the UIP that links both nominal interest rates. Without expectations on the exchange rate, the Foreign interest rate would have to fall to match the Home rate, to balance the international movements of capital.

The Impulse Response Function (Chinese Output) without threshold structures





Before crisis



After crisis

Without nonlinear structure, the impulse responses to the negative shocks (expansionary) would be just the exact opposite to the above figures.

The Construction of Economic Policy Uncertainty (EPU) in China

The news-based index is developed by Davis, Liu and Sheng (2019), based on their paper "Economic Policy Uncertainty in China Since 1949: The View from Mainland Newspapers." The Renmin Daily and the Guangming Daily are the two newspapers they use to extract the keywords. Below are the detailed steps:

1. Obtain monthly counts of articles that contain at least one term in each of three-term sets: Economics, Policy, and Uncertainty.
2. Scale the raw monthly EPU counts by the number of total articles for the same newspaper and month.
3. Standardize each newspaper's monthly series of scaled frequency counts to have a unit standardization
4. Compute the simple average of the standardized series over newspapers by the month
they normalize each period's index value to an average of 100

ADRL model for robustness

An autoregressive distributed lag (ARDL) model is appled to Chinese EPU and U.S EPU to exam the long-term relationship between these two. Below are the results
Cointegrating test: bound test

Null Hypothesis: No long-run relationships exist

Test Statistic	Value	k
F-statistic	13.87508	1

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	5.59	6.26
5%	6.56	7.3
2.5%	7.46	8.27
1%	8.74	9.63

Cointegrating form and long run relationship:

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LCHINAEPU(-1))	-0.217254	0.069727	-3.115790	0.0020
D(LCHINAEPU(-2))	-0.109538	0.065070	-1.683392	0.0935
D(LCHINAEPU(-3))	-0.036003	0.056004	-0.642867	0.5209
D(LEPU)	0.665409	0.088772	7.495746	0.0000
D(FFR_SHADOW)	-0.019811	0.014416	-1.374200	0.1705
D(@TREND())	0.000189	0.000624	0.303351	0.7619
CointEq(-1)	-3.934507	0.064491	-61.008641	0.0000

Cointeq = LCHINAEPU - (0.1691*LEPU -0.0050*FFR_SHADOW -0.0174 ... 0.0000*@TREND)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LEPU	0.169121	0.021551	7.847422	0.0000
FFR_SHADOW	-0.005035	0.003682	-1.367638	0.1726
C	-0.017397	0.099008	-0.175709	0.8607
@TREND	0.000048	0.000158	0.304355	0.7611

The results suggest there's significant cointegrating relationship between Chinese EPU and U.S EPU, which confirms the existence of the information channel. In addition, the estimated long run coefficients and the error-correction parameter are shown. The significant error correction parameter implies that there is a relatively quick adjustment in the Chinese EPU when the U.S EPU changes, which in turn confirms the intensity of the information channel.