Hot Money and Quantitative Easing: The Spillover Effects of U.S. Monetary Policy on the Chinese Economy

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Abstract

We develop a factor-augmented vector autoregression (FA-VAR) model to estimate the effects that unanticipated changes in U.S. monetary policy and economic policy uncertainty have on the Chinese housing, equity, and loan markets. We find the decline in the U.S. policy rate since the Great Recession has led to a significant increase in Chinese housing investment. One possible reason for this effect is the substantial increase in the inflow of "hot money" into China. The responses of Chinese variables to U.S. shocks at the zero lower bound are different from those responses in normal times.

JEL codes: F3, C3, E4

Keyword: International policy spillover, Chinese real estate market, U.S. monetary policy, policy uncertainty

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1. Introduction

Since the Great Recession, the federal funds rate, the primary tool of U.S. monetary policy, has hit the zero lower bound (ZLB) for extended periods, and researchers have been keenly interested in investigating how this unconventional U.S. monetary policy and its tapering affect emerging markets, particularly the Chinese market. Although China is the world's largest emerging economy, questions have arisen about the existence and magnitude of the spillover effects, because the Chinese capital account is not fully open and Chinese exchange rates are not fully flexible. Nevertheless, earlier studies by Miniane and Rogers (2007) found that capital controls cannot insulate developing countries from U.S. monetary shocks. Is it true, then, that U.S. monetary policy has had little spillover effect on the Chinese economy?

We investigate this question in this paper, and we also study the manner in which the central bank of China, the People's Bank of China (PBoC), reacts to U.S. monetary policy shocks. We use the shadow rate measure as constructed by Wu and Xia (2016) as an extension of the effective federal funds rate during the times when the ZLB is binding, and this measure is designed to capture the U.S. monetary policy stance when unconventional monetary policy is implemented. Moreover, since the outbreak of the most recent financial crisis in the United States, economists have wondered whether uncertainty regarding U.S. economic policy has detrimental effects on the U.S. economy. Thus, we will also study whether any spillover effect on the Chinese economy occurs due to U.S. economic policy uncertainty, as measured by the EPU index recently proposed by Baker, Bloom and Davis (2016).

Our estimation results suggest that there are significant cross-country spillover effects. We find that an expansionary U.S. monetary policy shock boosts Chinese real estate investment and stock market during the ZLB period. However, the market interest rate, trade balance, and exchange rate do not change significantly in response to the same shock. This result suggests that U.S. monetary policy shocks do not affect the Chinese economy through the market interest rate or trade channels. This finding is consistent with the earlier finding of Canova (2005) that trade channels played an insignificant role in the effect of U.S. monetary shocks on Latin American countries during the 1980-2002 period. Our results suggest that so-called ''hot money'' may play an important role in the transmission mechanism, which resonates with the finding of Prasad and Wei (2007) that ''hot money,'' rather than trade surplus, is the most important component of reserve accumulation in China. We also find that the responses of the Chinese economy to U.S. monetary policy shocks and policy uncertainty shocks exhibit different dynamics in periods before and after the federal funds target rate hit the ZLB in the United States. This result suggests the existence of structural changes both in the Chinese economy and in the transmission mechanism of U.S. monetary policy.

In terms of the methodology, we use a broad set of Chinese economic indicators and run a factor-augmented vector autoregression (FA-VAR) model to estimate the effects that shocks in both the U.S. policy rate and U.S. policy uncertainty have on the Chinese economy. Fernald, Spiegel and Swanson (2014) and He, Leung and Chong (2013) have used a similar methodology to study the Chinese economy, although those studies focus on the effects of Chinese monetary policy shocks without addressing the impact of U.S. monetary policy and policy uncertainty shocks on China's economy.

Employing the FA-VAR approach benefits this study in four ways. First, and most importantly, we are able to include a large number of data series—161 Chinese data series in our FA-VAR model—to make full use of information without being constrained by concerns about preserving the degrees of freedom, as is the case with a standard VAR approach. Moreover, measuring policy shocks correctly is known to be difficult, and so a second advantage of the FA-VAR approach is to help us address the potential endogeneity issues that arise from the notion that the Federal Reserve may adjust monetary policy in response to economic conditions in China.[1] The third benefit is that this approach also minimizes our dependence on arbitrary choices regarding which variables to include in a VAR (Evans and Marshall, 2009). Given that China is an important consideration in U.S. monetary policy decisions, it is not immediately clear which Chinese variables one should include in the VAR model.[2] This problem is addressed by using the FA-VAR model, in which we are able to extract factors from a large number of Chinese variables. The fourth advantage is that the FA-VAR methodology allows us to study the impacts of U.S. monetary policy on the general Chinese economy. U.S. monetary policies may have either direct or indirect impacts on any of the 161 Chinese variables, and we can plot the impulse responses of these Chinese variables due to unpredicted innovation in U.S. monetary policy, after controlling for a rich information set.

Related Literature Maćkowiak (2007) uses the structural VAR approach to study the effects of an external shock on eight emerging economies (Hong Kong, Korea, Malaysia, the Philippines, Singapore, Thailand, Chile and Mexico) which are assumed to be small open economies that have no influence on U.S interest rates, although U.S. interest rates may substantially affect them. However, this assumption does not apply to China. China is a large trading partner with the United States, and according to a report by World Bank (2014), China will soon become the largest economy in the world based on purchasing power parity; thus, the state of the Chinese economy

[1]The recent minutes of the Federal Open Market Committee (FOMC) meetings explicitly cite the slowing growth in China as part of the staff review of the economic situation (Madigan, 2016*a*). In addition, Federal Reserve Chair Janet Yellen has singled out China as a central risk factor in current global growth prospects (Fleming, 2016). Endogeneity concerns are also supported by historical precedents, such as when the Fed lowered short-term U.S. interest rates in light of the Russian default and Asian financial crises in the late 1990s (Neely, 2004).

[2]For example, the January 2016 FOMC minutes mentioned "a modest pickup in growth of Chinese manufacturing output," and the April 2016 FOMC minutes mentioned "China's management of its exchange rate," whereas the December 2015 FOMC minutes referred to "favorable economic indicators in China" without specifying the identities of the indicators.

is certainly on the mind of central bankers around the world, which may pose endogeneity challenges for this type of analysis. Maćkowiak (2007) finds that U.S. monetary shocks affect the real output and price levels in emerging economies even more strongly than the real output and price levels in the United States. Furthermore, a U.S. monetary shock can quickly affect the short-term interest rates and exchange rates in emerging markets. In our FA-VAR approach, we find that the impact of U.S. monetary shocks on Chinese industrial production to be rarely statistically significant[3], nor do they affect the RMB/USD exchange rate due to the managed floating system of the PBoC.

Chang, Liu and Spiegel (2015) use a DSGE framework to investigate the optimal monetary policy of China, which currently implements capital control and nominal exchange rate targets as well as sterilization of foreign capital by swapping exporters' foreign-currency revenues with domestic-currency bonds. Under the current set of policies, which mandates both capital control and an exchange rate peg, the authors have found that this combination prevents effective monetary policy adjustments that would maintain stable macroeconomic conditions and shield China from the impact of fluctuations in foreign capital. We indeed find in our paper that a significant inflow of hot money and an increase in Chinese real estate investments occur as a result of quantitative easing policies in the United States, and the current monetary policies of China are not effective in preventing booms and swings in housing investments as a result of fluctuations of foreign capital inflows. Chang et al. (2015) also argue that liberalizing either the capital account or the exchange rate or both would be welfare increasing.

Mumtaz and Surico (2009) applied the FA-VAR approach in order to study the international transmission of structural shocks on the U.K.'s economy. Moreover, Aastveit, Bjørnland and Thorsrud (2014) have built a structural FA-VAR model to analyze the contribution of developed and emerging

[3]We therefore omit plotting the impulse response of Chinese industrial production in our results.

countries to oil market variables.

Dedola, Karadi and Lombardo (2013) have studied the global implications of unconventional monetary policy. Their key finding is that, in general, a lack of cooperation between countries will result in suboptimal credit policies. In our results, we find that the PBoC takes contractionary credit measures by raising required reserve ratio in response to expansionary monetary policy shocks in the United States. These measures are plausibly aimed at restricting the credit available to the Chinese economy when hot money flows into China. Failing to respond in this manner might lead to higher than optimal credit availability in the Chinese economy.

The remainder of this paper is structured as follows. Section 2 illustrates the model and data we use. Section 3 contains the results and analysis. Section 4 concludes.

2. FA-VAR Model and Data

2.1. Model

We use the FA-VAR model developed by Bernanke, Boivin and Eliasz (2005) to investigate the effects of shocks to both U.S. monetary policy and U.S. policy uncertainty on the Chinese economy. Let X_t ($N \times 1$ vector) denote a large number of observed macroeconomic time series that contain rich information on economic conditions. We also have observed variables Y_t ($M \times 1$ vector), and we aim to investigate how the shock to Y_t affects X_t. In this paper, we study the impacts of shocks to two particular variables: the U.S. monetary policy rate and policy uncertainty.

However, using all the series in X_t in a structural VAR analysis is challenging because, although hundreds of series exist, the number of observations in each series is small. Fortunately, many studies have confirmed that a few factors can explain a large fraction of the variations in many macroeconomic series. Therefore, instead of directly using all the macroeconomic series, the informational contents are summarized succinctly using a small number of unobserved factors F_t ($K \times 1$ vector). We also include three U.S. aggregate variables—industrial production, unemployment, and CPI —represented by Z_t ($J \times 1$ vector) in the VAR system to accommodate the expected changes in U.S. monetary policy. This is because U.S. monetary policy mainly depends on the price and output gaps, following a Taylor (1993) rule. The dynamics of Z_t, F_t, and Y_t are assumed to follow this transition equation:

$$\begin{pmatrix} Z_t \\ F_t \\ Y_t \end{pmatrix} = \Phi(L) \begin{pmatrix} Z_{t-1} \\ F_{t-1} \\ Y_{t-1} \end{pmatrix} + \epsilon_t, \tag{1}$$

where $\Phi(L)$ is a polynomial of the lag operator and ϵ_t is the error term with zero mean and covariance matrix Σ. We assume that the error term can be represented as linear combinations of structural shocks: $\epsilon_t = P \times U_t$. The matrix P is the Cholesky decomposition of the variance-covariance matrix. The structural shocks (U_t) we consider here include U.S. monetary policy shocks, u_t^{USmp}; U.S. policy uncertainty shocks, u_t^{USpu}; and other structural shocks that are not our focus and will not be identified in this paper.

However, equation (1) cannot be estimated directly, because the factors F_t are unobserved. We further assume that our macro series, X_t, are related to the latent factors F_t and observed U.S. policy measures Y_t, by the observation equation:

$$X_t = \Lambda^f F_t + \Lambda^y Y_t + e_t. \tag{2}$$

Because the factors F_t are unobserved, they are substituted by $\widehat{F}_t$, estimated from 161 Chinese macro series and U.S. policy measures in two steps. First, we extract principal components $\widehat{C}_t$ from X_t. All principal components are normalized to have unit variances. Second, to ensure the identification of the VAR system used later, we remove any direct dependence of the factors $\widehat{C}_t$ on Y_t and identify the policy shocks recursively. To do so, we separate all the Chinese variables into two categories: fast-moving variables and slow-moving variables. A variable is classified as slow moving if it is largely predetermined at present, for instance, industrial production, unemployment, and so on. A variable is classified as fast moving if it is highly sensitive to contemporaneous economic news or shocks, such as asset prices. The classification of variables between these two categories is provided in Appendix C.1. The slow-moving factors $\widehat{F}_t^s$ are estimated as principal components of all slow-moving variables, and they are not affected by contemporaneous shocks to the policy measures by assumption. Then, as shown in regression equation (3), we regress the common principal components of all macro series on the policy measures and the slow-moving components to obtain the estimators of coefficients b_{F^s} and b_Y:

$$\widehat{C}_t = b_{F^s}\widehat{F}_t^s + b_Y Y_t + e_t. \tag{3}$$

The latent factors $\widehat{F}_t$, which we use in the following VAR analysis, are then constructed from $\widehat{C}_t - \widehat{b}_Y Y_t$.

2.2. VAR Specification and Shock Identification

Our VAR system contains eight variables, five of which are U.S. variables—including unemployment rate, industrial production index, CPI, monetary policy rate, and policy uncertainty index—and three of which are the Chinese factors extracted from 161 Chinese macro series. We include the U.S. unemployment rate, U.S. industrial production, and U.S. CPI to tease out some of the anticipated components of the U.S. monetary policy attributed to domestic economic conditions in the United States. The FA-VAR methodology is particularly suitable for us because we merely want to know how U.S. monetary policy affects the Chinese economy in general. Since all 161 series contain information on the Chinese macro economy, we prefer to use all series instead of only selecting a few series we judge as important.

We use monthly data from January 2000 to April 2017. Due to the short sample, we use a VAR system with one lag, according to the AIC, BIC and

HQ statistics criteria.

We order the variables in the VAR system from the most exogenous to the least exogenous, thus the ordering of variables is: U.S. unemployment rate, U.S. industrial production index, U.S. CPI, three Chinese latent factors $\widehat{F}_t$, U.S. monetary policy shock, and U.S. policy uncertainty shock. The identification of structural shocks is achieved by putting short-term constraints on the responses of variables. More precisely, we identify the two shocks that we are interested in, namely, U.S. monetary policy shock and U.S. policy uncertainty shock, by assuming that U.S. unemployment, industrial production, and CPI, along with the three Chinese factors do not have a contemporaneous response to U.S. monetary policy shock, and that the first seven variables in the VAR system do not have a contemporaneous response to U.S. policy uncertainty shock.

In the absence of the factors, the ordering of variables is similar to that of Bekaert et al. (2013) and Colombo (2013), that is, policy uncertainty is placed last, and the effective federal funds rate representing U.S. monetary policy is ordered after U.S. CPI but before policy uncertainty. Indeed, this ordering captures the assumption that policy uncertainty responds instantly to monetary policy shocks, but not vice versa, whereas the business cycle variable is relatively slow moving. The position of the Chinese factors in the ordering allows the possibility that the Chinese economy can have contemporaneous impacts on the U.S. monetary policy and policy uncertainty.[4] This assumption is reasonable in light of Federal Reserve Chair Janet Yellen's frequent mentioning of the Chinese economy in conjunction with discussions of the monetary policies of the Federal Reserve as reported in Fleming (2016). In addition, the recent minutes of the FOMC have mentioned the slowdown in China's industrial sector as part of the Federal Reserve staff review of the economic situation (Madigan, 2016*b*). Moreover, the construction of factors also ensures that the two shocks we are interested in, namely the U.S.

[4] We have also tried alternative orderings of the VAR system, by placing the Chinese factors first, or last. They yield qualitatively the same results regarding hot money and real estate investments. The results are not presented here in the interest of brevity.

monetary policy shock and policy uncertainty shock, do not affect Chinese factors contemporaneously, because the ‘‘fast-moving’’ part of the factors has already been removed according to equation (3). In addition, the assumption that U.S. monetary policy shocks and policy uncertainty shocks do not induce any contemporaneous responses from U.S. unemployment, U.S. industrial production, and U.S. CPI is standard in the literature. The ordering of Chinese factors after the U.S. unemployment rate, U.S. industrial production index, and U.S. CPI reflects the assumption that we allow, though do not require, the possibility that the Chinese factors could be influenced by contemporaneous changes in the U.S. aggregate variables given the fact that the United States is China's largest trading partner, and a significant part of the Chinese economy is geared toward exporting to the United States. In summary, we impose the contemporaneous restrictions as follows:

$$\epsilon_t = P \times U_t = \begin{bmatrix} \times & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \times & \times & 0 & 0 & 0 & 0 & 0 & 0 \\ \times & \times & \times & 0 & 0 & 0 & 0 & 0 \\ \times & \times & \times & \times & 0 & 0 & 0 & 0 \\ \times & \times & \times & \times & \times & 0 & 0 & 0 \\ \times & \times & \times & \times & \times & \times & 0 & 0 \\ \times & \times & \times & \times & \times & \times & \times & 0 \\ \times & \times & \times & \times & \times & \times & \times & \times \end{bmatrix} \times \begin{bmatrix} u_t^{USunemp} \\ u_t^{USip} \\ u_t^{UScpi} \\ u_t^{CNf1} \\ u_t^{CNf2} \\ u_t^{CNf3} \\ u_t^{USmp} \\ u_t^{USpu} \end{bmatrix}$$

The VAR system is estimated by OLS regression. We can obtain the coefficients of impulse responses of all variables in the VAR system to the U.S. monetary policy and policy uncertainty shocks. With these coefficients and the transition equation (1), we can back out the impulse responses of all Chinese macro variables in X_t to U.S. policy shocks. The 90% confidence intervals on the impulse responses shown in Appendix A.3 and Appendix A.4 are obtained from a bootstrap procedure based on Kilian (1998).

2.3. Data and Estimation

We have included 161 monthly Chinese macroeconomic series in our analysis, and they are listed in Appendix C.1. All series except for the policy variables are adjusted for the Chinese New Year effect as described by Fernald, Spiegel and Swanson (2014) and then adjusted for seasonality by using the U.S. Census Bureau X-13 program. We address missing values through the EM algorithm as in Stock and Watson (2002). The sample period runs from January 2000 to April 2017. We choose to begin with the year 2000 based on data availability.

The estimation method follows Bernanke, Boivin and Eliasz (2005) as described in Section 2.1. We separate the full sample period into two subsamples. The first period runs from January 2000 to December 2008, and the second runs from January 2009 to April 2017. From December 16, 2008, to December 15, 2015, the effective federal funds rate is below 1/4 percent, and the Federal Reserve has implemented several unconventional monetary policies. We obtain our main results through estimating the second subsample, while the estimation of first subsample is used for comparison.

To incorporate unconventional monetary policies during the ZLB period, the U.S. policy-rate measure we use in the second subsample is the shadow rate proposed by Wu and Xia (2016), as constructed in Appendix D. This series is obtained from the authors and is plotted in Figure 1.

For U.S. policy uncertainty, we use the news-based measure proposed by Baker, Bloom and Davis (2016), as shown in Figure 2.

3. Results

We choose representative variables of the Chinese economy to investigate their dynamics in response to U.S. monetary policy shocks and U.S. policy uncertainty shocks in Section 3.1. Note that we display responses of only 11 Chinese variables out of the 161 that, in principle, could be investigated. We set the U.S. monetary policy shock to be an unanticipated 25 basis points decrease in the U.S. policy rate. The size of this U.S. monetary policy shock is around 10% of the standard deviation of the policy rate. The U.S. policy rate is represented by the effective federal funds rate during normal times, and by the Wu-Xia shadow rate at the ZLB. We set the U.S. policy uncertainty shock to be an unanticipated increase in the uncertainty measure, and this shock size is 10% of the standard deviation of the uncertainty measure. The top, bottom, and middle lines correspond to the 90% bootstrap confidence intervals and the bootstrap median, respectively. The unit of the horizontal axis is time measured in months, and the figures report impulse responses in units of standard deviation.

For each of the two shocks we are interested in, we present results from two subsamples[5]: first from January 2009 to April 2017, which corresponds to the ZLB period[6], and then from January 2000 to December 2008, which corresponds to the pre-ZLB period. For each subsample, we first show what would happen to Chinese variables if the economy were hit by an expansionary U.S. monetary policy shock, and then show what would happen to Chinese variables when there is a positive U.S. policy uncertainty shock.

One thing to note here is that the impulse responses of the Chinese variables are not the ones directly derived from the VAR system, because no specific Chinese variable is in the VAR. We first obtain the impulse responses of Chinese factors from the VAR system, and then back out the responses of each Chinese variable by combining the standard impulse responses of the factor variables in the VAR system and the observation equation (2). The R^2 represents the goodness of fit for equation (2). The average R^2 for each Chinese variables is 43% at the ZLB period. We note that the factors explain

[5]Since we focus on the ZLB period, from which we draw our main conclusions, the subsamples are presented in the following sections in reverse chronological order.

[6]The effective federal funds rate falls below 1/4 percent only from December 16th, 2008 to December 15th, 2015. However, as indicated in Figure 1, from January 2016 to April 2017, the effective federal funds rate is still much lower than pre-ZLB levels. Furthermore, from the Fed announcements, existing QE is contemplated to start in late 2017 or early 2018 (Fleming and Leatherby, 2017). Besides, the sample period from January 2016 to April 2017 is too short to warrant its own separate analysis. We therefore call the period from January 2009 to April 2017 the ZLB period.

a sizable fraction of these Chinese variables, especially for some of the most prominent macroeconomic indicators: industrial sales (58%), SHIBOR (92%), and real estate investment (83%).

Besides the impulse responses, we also compare the contributions of U.S. monetary policy shocks to the forecast errors of representative Chinese variables before and at the ZLB in Section 3.3. This part helps us evaluate the relative importance of U.S. monetary policy shocks to Chinese economy at two different periods.

3.1. Impulse Responses at the Zero Lower Bound

Figure 3 to Figure 6 report the impulse responses to U.S. monetary policy shocks and policy uncertainty shocks at the ZLB.

3.1.1. Impulse Responses to a U.S. Monetary Policy Shock at the Zero Lower Bound

Figure 3 demonstrates the effects of an expansionary U.S. monetary policy shock on the Chinese economy during the ZLB period with 90% bootstrap confidence intervals as well as the bootstrap median. Incidentally, the U.S. monetary policy-rate shock that we have identified does significantly raise the U.S. industrial production. The required reserve ratio of Chinese banks, which is an important policy instrument of the PBoC, has a persistent increase in response to an expansionary U.S. monetary policy shock, and the magnitude of the response is very large, with its bootstrap median reaching above 1 standard deviation in the long run. The Shanghai Stock Exchange index (SSE Composite) reacts positively in response to expansionary U.S. monetary policy shocks. Likewise, the Price/Earnings (P/E) ratio for the manufacturing sector also increases significantly, indicating that on average, an investor needs to pay for an higher price now to hold a share with the same level of earnings.[7]

The same figure also displays the responses of the real estate market. Investment in real estate increases significantly starting from the first month after the arrival of the expansionary U.S. monetary policy shock, and this rise is still significantly positive on the 20th month. The Chinese real estate market is an attractive investment option when interest rates in the United States are low. The sticky demand for housing and the local government's revenue incentives provide security for the boom of the Chinese real estate market when the United States enters into quantitative easing. For foreign investors, instead of investing in the United States with a low rate of return, investing in the Chinese real estate market might be a more attractive option. For Chinese investors, on the other hand, investing in real estate might be an effective hedge against concerns about imported inflation.

Figure 4 shows that the RMB exchange rate with respect to the U.S. dollar and foreign direct investment (FDI) do not respond significantly to U.S. monetary policy shocks, nor is there any significant impact on the Chinese trade balance or Chinese exports to the United States. However, the same figure shows a significant increase in foreign hot money flowing into China in response to expansionary U.S. monetary policy shocks. Although the significant increase in hot money only lasts for several months, it is consistent with the notion that hot money flows across borders quickly. ''Hot money'' is approximated by subtracting the trade surplus (or deficit) and net flow of foreign direct investment from the change in foreign reserves, as in Martin and Morrison (2008). Thus, we can infer from the impulse responses that the channel through which U.S. monetary policy spills over into China is mainly due to the hot money channel rather than the trade or exchange rate

[7]Common practice in financial research dictates that we need to exclude financial firms, as in Fama and French (1992), since a number of firm characteristics that are commonly found in financial firms, such as high levels of leverage, means financial ratios such as P/E ratio are not directly comparable between financial and non-financial firms. We investigate the P/E ratio for the manufacturing sector since it is the most representative sector of the Chinese economy that is non-financial, and we forgo investigating aggregate P/E ratio because we wish to exclude financial firms.

channels. The fact that we observe increases in the SSE Composite Index and in real estate investment is consistent with the notion that the flow of hot money into these two markets can create booms. The hot money story is also consistent with the increase in the required reserve ratio in Figure 3: a substantial inflow of foreign currency largely increases foreign reserves, and hence money base, because of the presence of a compulsory foreign currency settlement system mandated by Chinese laws and regulations.[8] In order to counter the increase in money supply, the PBoC has to raise the required reserve ratio, in order to tame potential run-away inflation.

Based on the figures discussed above, we cannot reject the hypothesis that U.S. monetary policy has spillover effects on China's real economy, but that these effects are not transmitted to China through the market interest rate, trade, or exchange rate channels.

3.1.2. Impulse Responses to a U.S. Policy Uncertainty Shock at the Zero Lower Bound

Figure 5 shows that, at the ZLB, a positive U.S. policy uncertainty shock does increase the required reserve ratio in China. The changes in the required reserve ratio can be viewed as a policy response of the PBoC to the U.S. policy uncertainty shock. Because we are using the FA-VAR approach, after controlling for a rich set of Chinese and U.S. variables, we find that the PBoC may raise the required reserve ratio to caution against potential domestic over-investments when there is an unanticipated increase in U.S. policy uncertainty at the zero lower bound.

Figure 6 shows that, at the ZLB, a positive U.S. policy uncertainty shock has no significant effect on Chinese importing and exporting, trade balance, or FDI, although there is a marginal increase in hot money.

[8]The Regulations of the People's Republic of China on Foreign Exchange Control, promulgated by the State Council, requires most foreign currencies entering the country to be converted into RMB, and thus the inflow of hot money would cause increase in China's money supply.

3.2. Impulse Responses before the Zero Lower Bound

Figures 7 to 10 illustrate the impulse responses of variables to U.S. monetary policy shocks and U.S. policy uncertainty shocks before the federal funds rate hit the ZLB.

3.2.1. Impulse Responses to a U.S. Monetary Policy Shock before the Zero Lower Bound

The responses of certain Chinese variables before the ZLB are different from those at the ZLB. For example, in Figure 7 we see that, with an expansionary U.S. monetary policy shock, there is no longer any significant increase in real estate investment or in the SSE Composite index, nor is there any significant increase in hot money.

3.2.2. Impulse Responses to a U.S. Policy Uncertainty Shock before the Zero Lower Bound

The reaction to an unanticipated increase in U.S. policy uncertainty differs significantly between these two periods. A significant increase occurs in the required reserve ratio at the ZLB, but not for the pre-ZLB period. This result can be interpreted as an indication that, during the period when the ZLB is binding in the United States, the PBoC may be concerned that increases in U.S. policy uncertainty could lead to an inflow of cheap credit from overseas, resulting an overheated Chinese economy. Thus the PBoC may be attempting to curb over-investment in China by increasing the required reserve ratio during the ZLB period, but during the pre-ZLB period the PBoC may be attempting to install confidence in the market and in fact the required reserve ratio actually decreased significantly. Furthermore, there is also significant decrease in Chinese real estate investment and significant outflow of hot money, possibly as a result of heightened investor caution against emerging market in general. In addition, U.S. monetary policy implementation also experienced a regime change at the ZLB, so that even the responses of U.S.

variables are not exactly the same as those at the ZLB.

The differing responses of the Chinese variables can be explained from two perspectives. The first is that the Chinese economy has undergone substantial changes in recent years. Both the interest rate and the exchange rate systems changed significantly during the 2000s. Beginning in 2005, a managed floating exchange rate system was implemented, based on market supply and demand with a basket of currencies. The bond market has also grown and the liberalization of the interest rate was slowly and gradually taking place. All these changes affect the responses of macroeconomic variables to U.S. shocks.

However, we acknowledge that the difference in the results of the pre-ZLB versus the ZLB periods could be due to the fact that the Wu-Xia shadow rate and the effective federal funds rate are different objects. One cannot know for sure which has changed, the global propagation mechanism, or the U.S. monetary policy regime.

3.3. Variance Decomposition

The variance decomposition represents the fraction of the forecasting error of a variable, at a given horizon, that is attributable to a particular shock. Following the same logic of obtaining the impulse response of each Chinese variable, we first get the variance decomposition of factors in the VAR system and then use the observation equation (2) to back out the variance decomposition of each Chinese variable. Following Bernanke, Boivin and Eliasz (2005), we define the fraction of kth-month ahead variance of $X_{i,t+k} - \hat{X}_{i,t+k|t}$ due to the U.S. monetary policy shock as

$$VD(u_t^{USmp}, k) = \frac{var(X_{i,t+k} - \hat{X}_{i,t+k|t} | u_t^{USmp})}{var(X_{i,t+k} - \hat{X}_{i,t+k})}$$

where $X_{i,t}$ represents the ith variable in X_t, and $\hat{X}_{i,t}$ is the estimated value of $X_{i,t}$.

A standard result of the VAR literature is that U.S. monetary policy shock accounts for a small fraction of the forecast errors for U.S. real economic activity. Intuitively, U.S. monetary policy shocks should not play a very important role in accounting for the forecast errors of Chinese macro variables. Therefore, instead of looking at the absolute value of the variance decomposition, we are more interested in the relative importance of U.S. monetary policy shocks to the Chinese economy during pre-ZLB and ZLB periods. We use the ratio of the fraction of the forecast errors caused by U.S. monetary policy shocks at the ZLB to those forecast errors caused by U.S. monetary policy shocks before the ZLB to represent the relative importance:

$$VD_{ratio}(k) = \frac{VD(u_t^{USmp}, k|ZLB)}{VD(u_t^{USmp}, k|preZLB)}.$$

The second to fourth columns of Table 1 represent $VD_{ratio}(k)$ for $k =$ 3rd, 6th, and 12th months. We find that, during the ZLB period, the relative importance of U.S. monetary policy shock has increased substantially for six out of the ten variables under investigation, and the mean of $VD_{ratio}(3)$ for all ten Chinese variables is around 1.9, which means during the ZLB, monetary policy shock can explain more fluctuations of Chinese variables on average. In addition to the reasons discussed in Section 3.2.2 regarding the differences of pre-ZLB versus ZLB period, an additional explanation of the change in the relative importance, of U.S. monetary policy shocks during the pre-ZLB period versus during the ZLB period, would involve the closer integration of Chinese economy into global markets in recent years, or due to the fact that market participants pay more attention to the policy directives of the Fed at the ZLB compared to the pre-ZLB period. However, since we are using the Wu-Xia shadow rate to substitute the effective federal funds rate during the ZLB period, we acknowledge again here that one cannot know for sure which has changed, the global propagation mechanism or the U.S. monetary policy regime.

3.4. Further Discussions

In terms of the role of the PBoC, the March 18th, 1995 Law of the People's Republic of China on the People's Bank of China, states that the PBoC shall "under the leadership of the State Council, formulate and implement monetary policies, guard against and eliminate financial risks, and maintain financial stability," and also "maintain the stability of the value of the currency and thereby promote economic growth." According to the trilemma argument, the PBoC has to abandon capital mobility in order to maintain the stated objective of currency stability and monetary policy autonomy that are aligned with the needs of Chinese economic growth. However, as Miniane and Rogers (2007) have indicated, capital controls have little or no effect, because they can be avoided or evaded at little cost. Hence, even if the PBoC wishes to take the option of exercising monetary autonomy with a managed exchange rate, but because of the policy trilemma, those capital controls cannot be perfectly enforced. Prasad and Wei (2007) and Prasad and Ye (2012) have extensively documented the time line of the capital control policies put in place in China. In fact, China's capital controls are noted to be "leaky" by Glick and Hutchison (2013). Klein and Shambaugh (2013) found that narrowly targeted capital controls do not endow the monetary authority with policy autonomy, and "gates" only work if they function more like "walls;" that is, limited capital controls would not be effective, but pervasive capital controls would be effective in limiting asset price booms and swings. We therefore agree with the literature's implications that, even by having a closely monitored exchange rate and imperfectly enforced capital control regime, the PBoC does not in fact have full autonomy in monetary policy. Therefore the Chinese economy is more susceptible to swings in capital flow and asset prices than under a fully floating exchange rate regime. On the other hand, the fact that China has tightened its capital control in light of the recent economic slowdown is consistent with the view that capital control policy should be tightened during recessions but not pre-emptively during booms (Schmitt-Grohé and Uribe, 2016).

4. Conclusion

Contrary to the notion that U.S. monetary policy shocks have no significant impact on China, we find that such shocks do have significant spillover effects on the Chinese economy. Since the Great Recession, a decline in U.S. policy rates has resulted in a persistent and significant increase in Chinese housing investments, and also an increase in the SSE composite index, possibly as a result of the substantial inflow of hot money into China. The responses of variables to U.S. shocks during the period at the zero lower bound differ from those in normal times, which suggests structural changes in both the Chinese economy and the U.S. monetary policy transmission mechanism. In addition, increases in U.S. policy uncertainty have negative effects on Chinese real estate investment during normal times, but not at the zero lower bound.

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Appendix

A. Figures

A.1. U.S. Monetary Policy Measure

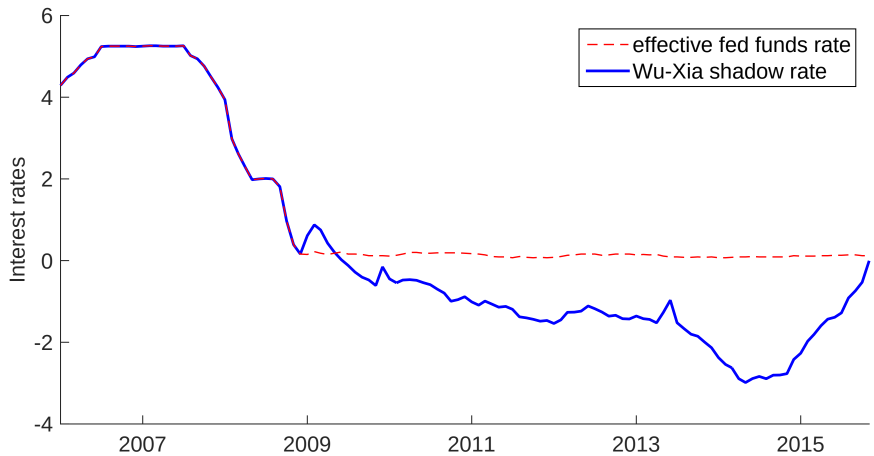

Figure 1: The Wu-Xia shadow rate compared with the effective federal funds rate.
Source: Board of Governors of the Federal Reserve System and Wu and Xia (2016)

A.2. U.S. Policy Uncertainty Measure

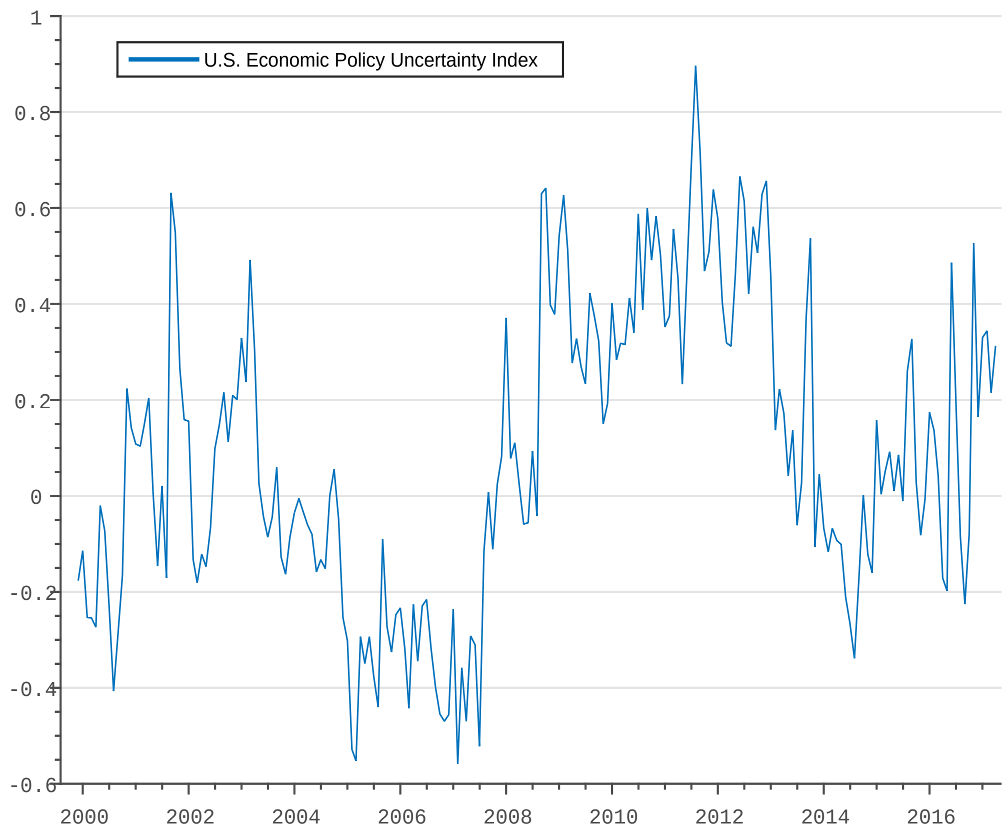

Figure 2: Monthly U.S. economic policy uncertainty index.
Source: Baker, Bloom and Davis (2016)

A.3. Impulse Responses at the Zero Lower Bound

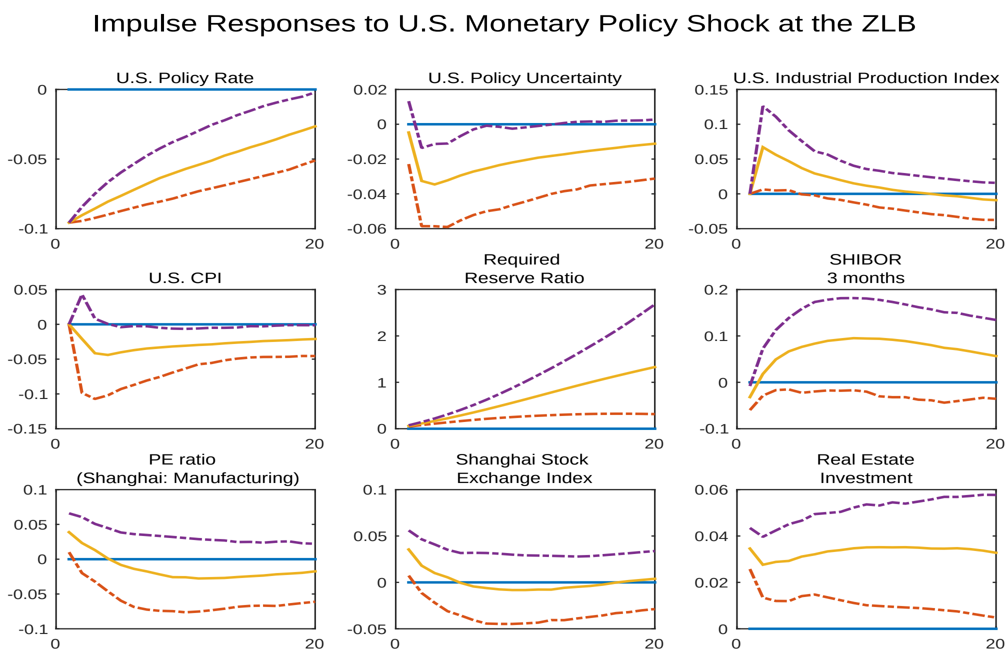

Figure 3: Impulse Responses to U.S. Monetary Policy Shock at the ZLB
Note: Impulse responses to a monetary policy shock from 1 to 20 months at the zero lower bound, estimated using data from January 2009 to April 2017. The solid lines are the bootstrap medians, and the dashed lines are 90% bootstrap confidence intervals. The monetary policy shock corresponds to a decrease in the Wu-Xia shadow rate of 25 basis points.

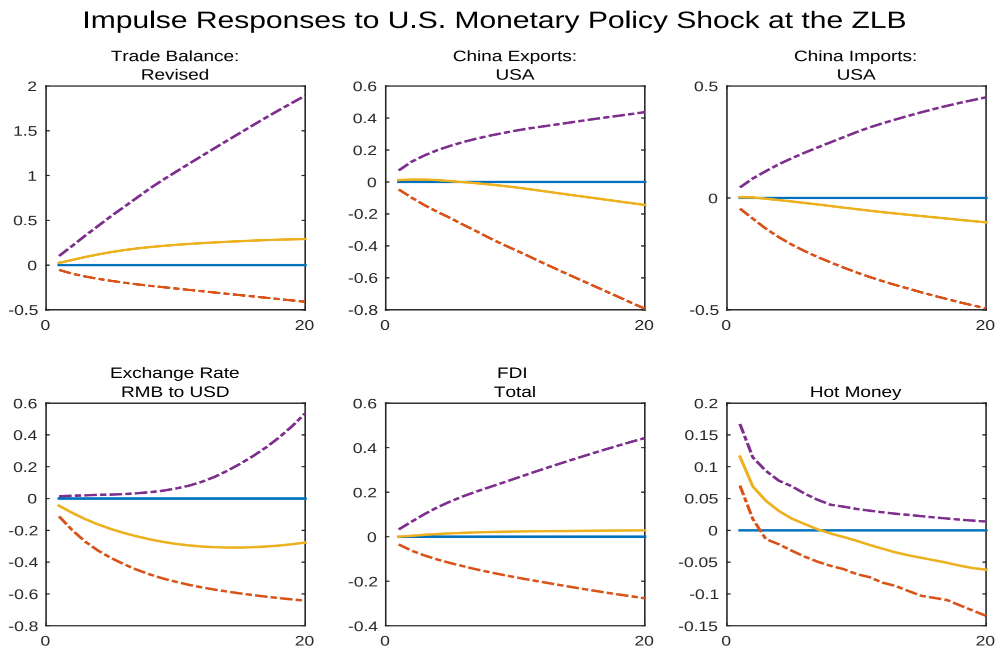

Figure 4: Impulse Responses to U.S. Monetary Policy Shock at the ZLB
Note: Impulse responses to a monetary policy shock from 1 to 20 months at the zero lower bound, estimated using data from January 2009 to April 2017. The solid lines are the bootstrap medians, and the dashed lines are 90% bootstrap confidence intervals. The monetary policy shock corresponds to a decrease in the Wu-Xia shadow rate of 25 basis points.

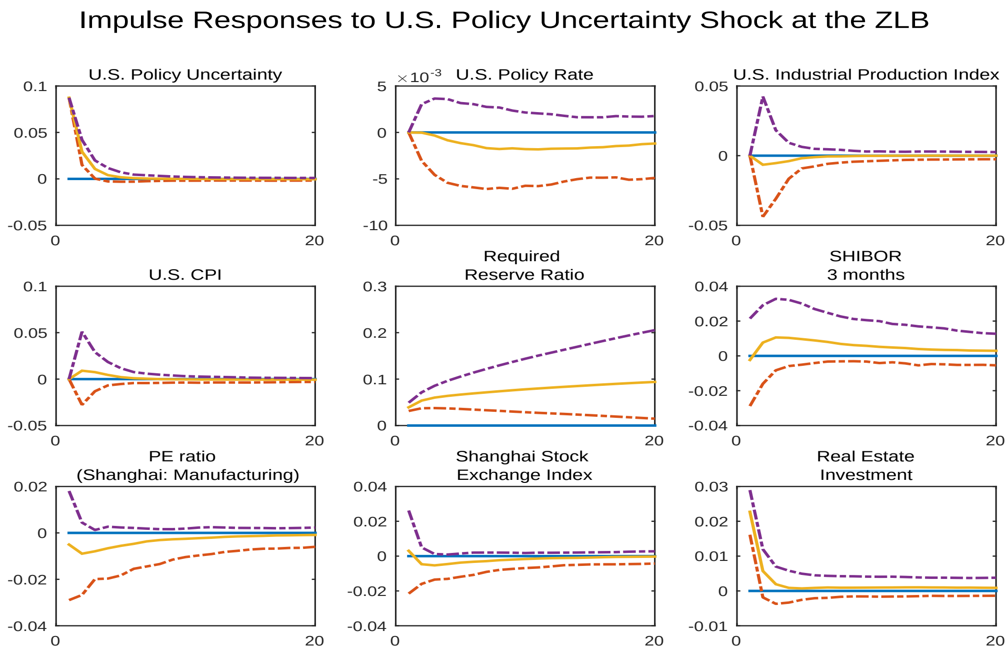

Figure 5: Impulse Responses to U.S. Policy Uncertainty Shock at the ZLB
Note: Impulse responses to a policy uncertainty shock from 1 to 20 months at the zero lower bound, estimated using data from January 2009 to April 2017. The solid lines are the bootstrap medians, and the dashed lines are 90% bootstrap confidence intervals. The policy uncertainty shock corresponds to an increase in the U.S. policy uncertainty Index of 10% of the standard deviation.

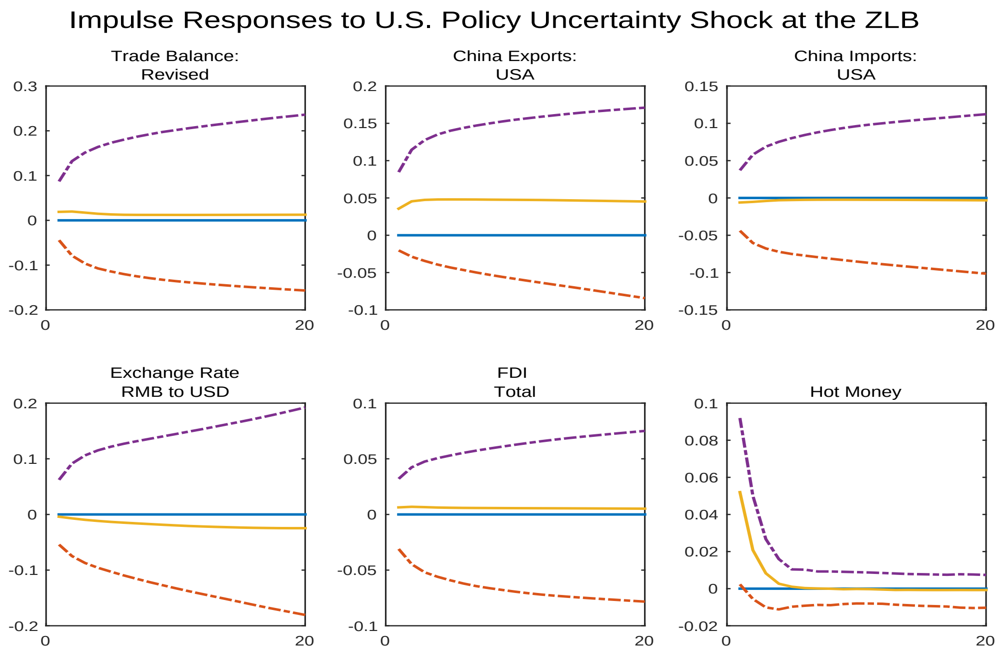

Figure 6: Impulse Responses to U.S. Policy Uncertainty Shock at the ZLB
Note: Impulse responses to a policy uncertainty shock from 1 to 20 months at the zero lower bound, estimated using data from January 2009 to April 2017. The solid lines are the bootstrap medians, and the dashed lines are 90% bootstrap confidence intervals. The policy uncertainty shock corresponds to an increase in the U.S. policy uncertainty index of 10% of the standard deviation.

A.4. Impulse Responses before the Zero Lower Bound

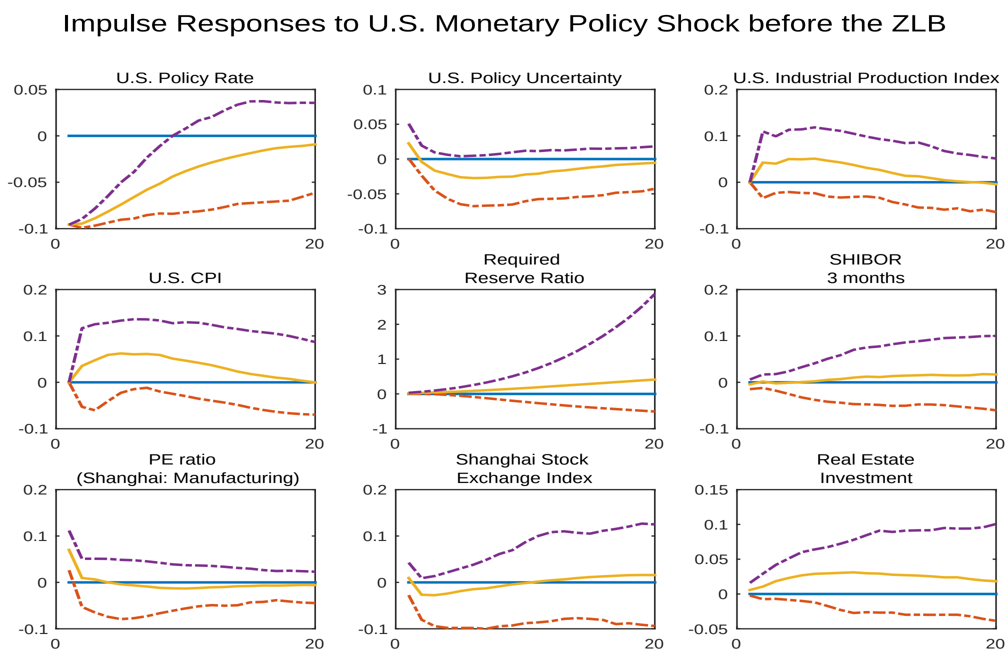

Figure 7: Impulse Responses to U.S. Monetary Policy Shock before the ZLB
Note: Impulse responses to a monetary policy shock from 1 to 20 months before the zero lower bound is binding, estimated using data from January 2000 to December 2008. The solid lines are the bootstrap medians, and the dashed lines are 90% bootstrap confidence intervals. The monetary policy shock corresponds to a decrease in the effective federal funds rate of 25 basis points.

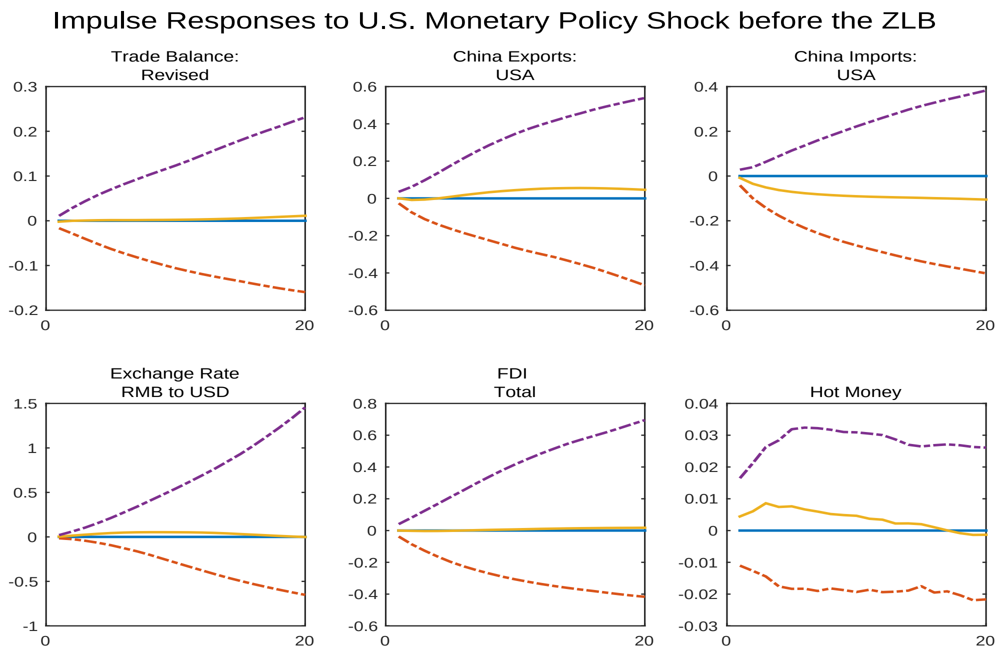

Figure 8: Impulse Responses to U.S. Monetary Policy Shock before the ZLB
Note: Impulse responses to a monetary policy shock from 1 to 20 months before the zero lower bound is binding, estimated using data from January 2000 to December 2008. The solid lines are the bootstrap medians, and the dashed lines are 90% bootstrap confidence intervals. The monetary policy shock corresponds to a decrease in the effective federal funds rate of 25 basis points.

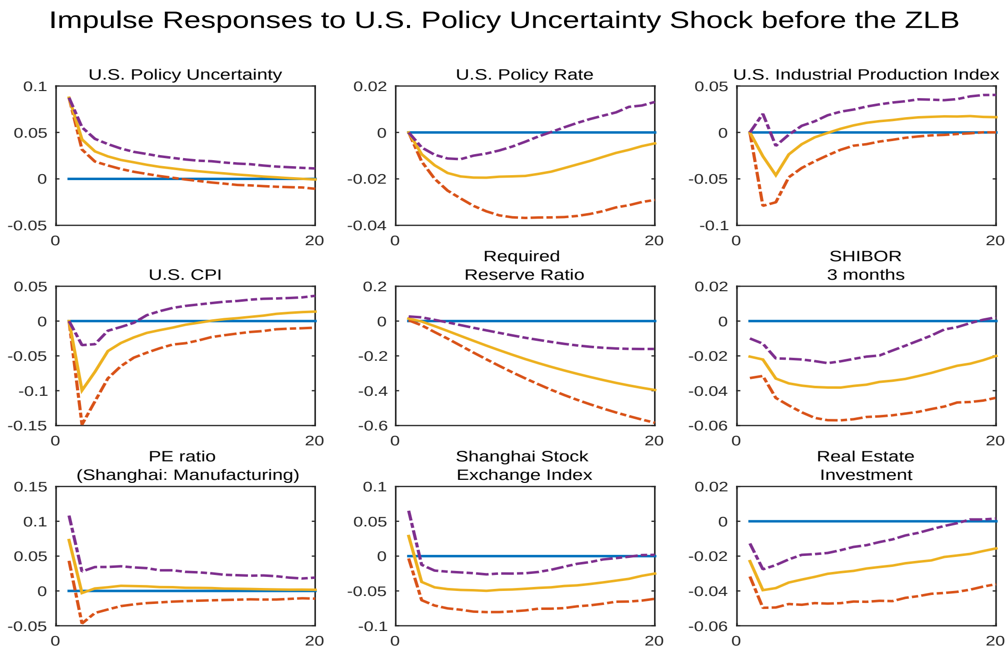

Figure 9: Impulse Responses to U.S. Policy Uncertainty Shock before the ZLB

Note: Impulse responses to a policy uncertainty shock from 1 to 20 months before the zero lower bound is binding, estimated using data from January 2000 to December 2008. The solid lines are the bootstrap medians, and the dashed lines are 90% bootstrap confidence intervals. The policy uncertainty shock corresponds to an increase in the U.S. policy uncertainty index of 10% of the standard deviation.

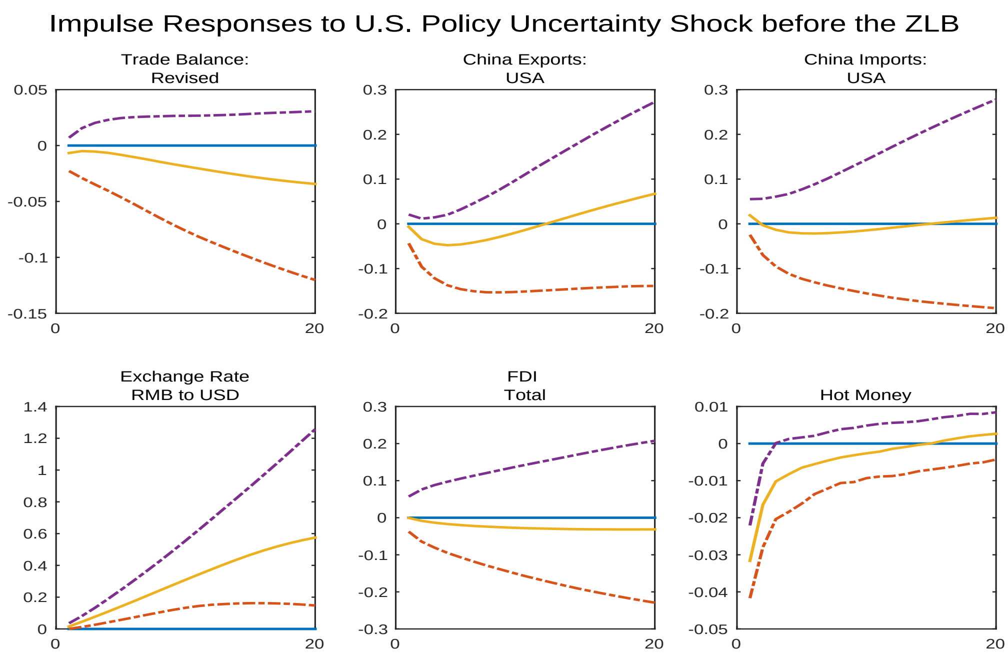

Figure 10: Impulse Responses to U.S. Policy Uncertainty Shock before the ZLB

Note: Impulse responses to a policy uncertainty shock from 1 to 20 months before the zero lower bound is binding, estimated using data from January 2000 to December 2008. The solid lines are the bootstrap medians, and the dashed lines are 90% bootstrap confidence intervals. The policy uncertainty shock corresponds to an increase in the U.S. policy uncertainty index of 10% of the standard deviation.

B. Tables

Table 1: Relative Variance Decomposition of Selected Chinese Variables

Variables	3m	6m	12m
SHIBOR 1 year	0.40	0.34	0.33
PE ratio Shanghai: Class A Shares	1.43	1.80	1.99
Shanghai Stock Exchange Index	1.55	1.76	2.06
Real Estate Investment	8.41	8.16	7.52
Trade Balance: Revised	0.29	0.48	0.59
China Exports: USA	4.95	6.19	5.17
China Imports: USA	0.46	0.61	0.64
Exchange Rate RMB to USD	3.19	2.66	2.59
FDI Total	0.29	0.34	0.35
Hot Money	4.64	6.01	5.93

Note: The table reports the "Variance Decomposition Ratio", representing the ratio between the percentage of k-month-ahead forecast errors that monetary policy shocks account for at the ZLB and the counterpart percentage before the ZLB. The forecast horizon k we report takes the values 3, 6, and 12.

C. Data Description

C.1. Data Description: Chinese Variables

All series are taken from CEIC China Premium Database. All series are in monthly frequencies and data spans are shown. Missing data are imputed by utilizing the EM algorithm as in Stock and Watson (2002). Each variable is assumed to be either fast moving or slow moving for the purpose of FA-VAR estimation. Seasonality adjustment is performed using the U.S. Census Bureau's X-13 program: SA=seasonally adjusted, NS=no seasonal adjustment. The transformations are Δ-first difference; ln-logarithm; Δln-first difference of logarithm; $none$-no transformation.

Real Activities

1.	Retail Sales of Consumer Goods: Total	1999/12-2017/04	Slow	NS	Δln
2.	Gross Industrial Output	2003/01-2012/05	Slow	SA	Δln
3.	Industrial Sales	1999/12-2017/04	Slow	SA	Δln
4.	Industrial Sales: Delivery Value for Export	2000/01-2017/04	Slow	SA	Δln
5.	Industrial Sales: Light Industry	1999/12-2017/04	Slow	SA	Δln
6.	Industrial Sales: Heavy Industry	1999/12-2017/04	Slow	SA	Δln
7.	Industrial Sales Nominal Growth: Light Industry	1999/12-2017/04	Slow	NS	$none$
8.	Industrial Sales Nominal Growth: Heavy Industry	1999/12-2017/04	Slow	NS	$none$
9.	Industrial Sales Nominal Growth: Delivery Value for Export	2000/01-2017/04	Slow	NS	$none$
10.	Industrial Sales Nominal Growth: Same Period Last Year	1999/12-2017/04	Slow	NS	$none$
11.	Macro Index	1999/12-2017/04	Fast	SA	Δln
12.	Production of Primary Energy: Electricity	1999/12-2017/04	Slow	SA	Δln
13.	Transport: Passenger Traffic	1999/12-2017/04	Slow	SA	Δln
14.	Automobile Sales	2000/01-2017/04	Slow	SA	Δln
15.	Automobile Sales: Domestic Made	2000/01-2017/04	Slow	SA	Δln
16.	Automobile Production	2000/01-2017/04	Slow	SA	Δln
17.	Automobile Production: Domestic Made	2000/01-2017/04	Slow	SA	Δln
18.	Steel Production: Iron Ore	2000/01-2017/04	Slow	SA	Δln
19.	Steel Production: Pig Iron	2000/01-2017/04	Slow	SA	Δln
20.	Steel Production: Coke	2000/01-2017/04	Slow	SA	Δln
21.	Steel Production: Ferroalloy	2000/01-2017/04	Slow	SA	Δln
22.	Steel Production: Crude Steel	2000/01-2017/04	Slow	SA	Δln
23.	Steel Production: Steel Product	2000/01-2017/04	Slow	SA	Δln
24.	Petro Production: Natural Gas	2000/01-2017/04	Slow	SA	Δln
25.	Petro Production: Crude Oil	2000/01-2017/04	Slow	SA	Δln
26.	Petro Production: Crude Oil Processed	2000/01-2017/04	Slow	SA	Δln
27.	Petro Production: Oil Product: Coal Oil	2000/01-2017/04	Slow	SA	Δln
28.	Petro Production: Oil Product: Gasoline	2000/01-2017/04	Slow	SA	Δln
29.	Petro Production: Oil Product: Diesel Oil	2000/01-2017/04	Slow	SA	Δln
30.	Petro Production: Fuel Oil	2000/01-2017/04	Slow	SA	Δln
31.	Product Inventory	1999/12-2017/04	Slow	SA	Δln
32.	Purchasing Managers' Index: Manufacturing	2005/01-2017/04	Slow	SA	$none$
33.	Purchasing Managers' Index: New Export Orders	2005/01-2017/04	Slow	SA	$none$

Investments

34.	Fixed Assets Investment	2000/01-2017/04	Slow	SA	Δln
35.	FDI Utilized: Joint Ventures	1999/12-2017/04	Slow	SA	Δln
36.	FDI Utilized: Total	1999/12-2017/04	Slow	SA	Δln
37.	FDI Utilized: Cooperative Ventures	1999/12-2017/04	Slow	SA	$none$
38.	FDI Utilized: Foreign Enterprises	1999/12-2017/04	Slow	SA	Δln

International Accounts

39.	Foreign Reserve	1999/12-2017/04	Fast	SA	Δln
40.	Financial Institutions CF: Position for Forex Purchase	1999/12-2017/04	Fast	SA	Δln
41.	Exports (fob)	1999/12-2017/04	Slow	SA	Δln
42.	Imports (cif)	1999/12-2017/04	Slow	SA	Δln
43.	Trade Balance	1999/12-2017/04	Slow	SA	Δ
44.	Export FOB: Revised	2000/01-2017/04	Slow	SA	Δln
45.	Import CIF: Revised	2000/01-2017/04	Slow	SA	Δln
46.	Trade Balance: Revised	2000/01-2017/04	Slow	SA	Δ
47.	China Exports: USA	1999/12-2017/04	Slow	SA	Δln
48.	China Imports: USA	1999/12-2017/04	Slow	SA	Δln
49.	Monetary Authority: Asset: Total	2002/01-2017/04	Fast	SA	Δln
50.	Monetary Authority: Asset: Foreign Asset: Foreign Exchange	1999/12-2017/04	Fast	NS	Δln
51.	Monetary Authority: Asset: Foreign Asset: Gold	1999/12-2017/04	Fast	NS	Δln
52.	Monetary Authority: Asset: Foreign Asset: Foreign Exchange	1999/12-2017/04	Fast	NS	Δln
53.	Monetary Authority: Liab: Reserve Money	1999/12-2017/04	Fast	NS	Δln
54.	Monetary Authority: Liab: Reserve Money: Currency Issue	1999/12-2017/04	Fast	NS	Δln
55.	Hot Money	1999/12-2017/04	Fast	NS	$none$

Exchange Rates and Swaps

56.	Foreign Exchange Rate: PBOC: Month End: RMB to USD	1999/12-2017/04	Fast	NS	Δln
57.	Currency Swap: USD: 1 Week: Bid	2006/09-2017/04	Fast	NS	$none$
58.	Currency Swap: USD: 1 Week: Offer	2006/09-2017/04	Fast	NS	$none$
59.	Currency Swap: USD: 1 Month: Bid	2006/09-2017/04	Fast	NS	$none$
60.	Currency Swap: USD: 1 Month: Offer	2006/09-2017/04	Fast	NS	$none$
61.	Currency Swap: USD: 3 Month: Bid	2006/09-2017/04	Fast	NS	$none$
62.	Currency Swap: USD: 3 Month: Offer	2006/09-2017/04	Fast	NS	$none$
63.	Currency Swap: USD: 6 Month: Bid	2006/09-2017/04	Fast	NS	$none$
64.	Currency Swap: USD: 6 Month: Offer	2006/09-2017/04	Fast	NS	$none$
65.	Currency Swap: USD: 1 Year: Offer	2006/09-2017/04	Fast	NS	$none$
66.	Currency Swap: USD: 1 Year: Bid	2006/09-2017/04	Fast	NS	$none$

Government

67.	Government Expenditure	1999/12-2017/04	Slow	NS	Δln
68.	Govt Revenue	1999/12-2017/04	Slow	SA	Δln
69.	Govt Revenue: Tax	1999/12-2017/04	Slow	SA	Δln
70.	Govt Revenue: Tax: Tariffs	1999/12-2017/04	Slow	SA	Δln
71.	Govt Revenue: Tax: Value Added	1999/12-2017/04	Slow	SA	Δln
72.	Govt Revenue: Tax: Operation	1999/12-2017/04	Slow	SA	$none$
73.	Govt Revenue: Tax: Security Stamp	1999/12-2017/04	Slow	SA	Δln

Money Supply and Credits

74.	Money Supply M0	1999/12-2017/04	Fast	SA	Δln
75.	Money Supply M1	1999/12-2017/04	Fast	SA	Δln
76.	Money Supply M1: Demand Deposit	1999/12-2017/04	Fast	SA	Δln
77.	Money Supply M2	1999/12-2017/04	Fast	SA	Δln
78.	Money Supply M2: Quasi Money: Saving Deposit	1999/12-2017/04	Fast	SA	Δln
79.	Money Supply M2: Quasi Money: Time Deposit	1999/12-2017/04	Fast	SA	Δln
80.	Money Supply M2: Quasi Money: Other Deposit	1999/12-2017/04	Fast	SA	Δln

81.	Loan	1999/12-2017/04	Slow	SA	Δln
82.	Required Reserve Ratio	1999/12-2017/04	Slow	SA	*none*

Interest Rates

83.	Loan Rate (1yr)	1999/12-2014/10	Slow	NS	*none*
84.	Nominal Lending Rate: Medium and Long Term: 3 Year or Less	1999/12-2014/10	Slow	NS	*none*
85.	Nominal Lending Rate: Medium and Long Term: 5 Year or Less	1999/12-2014/10	Slow	NS	*none*
86.	Nominal Lending Rate: Medium and Long Term: Over 5 Year	1999/12-2017/04	Slow	NS	*none*
87.	Nominal Lending Rate: Housing Loan (Reserve Fund A/C): 5 Yr or Less	1999/12-2017/04	Slow	NS	*none*
88.	Nominal Lending Rate: Housing Loan (Reserve Fund A/C): Over 5 Year	1999/12-2017/04	Slow	NS	*none*
89.	Central Bank Benchmark Interest Rate: Loans to FI: 1 Year	1999/12-2017/04	Slow	NS	*none*
90.	Central Bank Benchmark Interest Rate: Loans to FI: 6 Month or Less	1999/12-2017/04	Slow	NS	*none*
91.	Central Bank Benchmark Interest Rate: Loans to FI: 3 Month or Less	1999/12-2017/04	Slow	NS	*none*
92.	Household Savings Deposits Rate: Time: 3 Month	1999/12-2017/04	Slow	NS	*none*
93.	Household Savings Deposits Rate: Time: 6 Month	1999/12-2017/04	Slow	NS	*none*
94.	Household Savings Deposits Rate: Time: 1 Year	1999/12-2017/04	Slow	NS	*none*
95.	Household Savings Deposits Rate: Time: 2 Year	1999/12-2017/04	Slow	NS	*none*
96.	Household Savings Deposits Rate: Time: 3 Year	1999/12-2017/04	Slow	NS	*none*
97.	Household Savings Deposits Rate: Time: 5 Year	1999/12-2014/10	Slow	NS	*none*
98.	Household Savings Deposits Rate: Demand	1999/12-2017/04	Slow	NS	*none*
99.	Reloan Interest Rates: within 20 days	1999/12-2017/04	Slow	NS	*none*
100.	Reloan Interest rates: within 3 months	1999/12-2017/04	Slow	NS	*none*
101.	Reloan Interest rates: within 6 months	1999/12-2017/04	Slow	NS	*none*
102.	Reloan InterestRrates: 1 year	1999/12-2017/04	Slow	NS	*none*
103.	Shanghai Interbank Offered Rate(SHIBOR): 1 day	2006/10-2017/04	Fast	NS	*none*
104.	Shanghai Interbank Offered Rate(SHIBOR): 1 month	2006/10-2017/04	Fast	NS	*none*
105.	Shanghai Interbank Offered Rate(SHIBOR): 3 months	2006/10-2017/04	Fast	NS	*none*
106.	Shanghai Interbank Offered Rate(SHIBOR): 6 months	2006/10-2017/04	Fast	NS	*none*
107.	Shanghai Interbank Offered Rate(SHIBOR): 1 year	2006/10-2017/04	Fast	NS	*none*
108.	Private Lending Rate: Wenzhou: Monthly Average	2012/06-2017/04	Fast	NS	*none*
109.	Bond index: Inter-bank: Treasury bonds: short-term	2002/06-2017/04	Fast	NS	*none*
110.	Bond Index: Interbank: Treasury Bond: Medium Term	2002/06-2017/04	Fast	NS	*none*
111.	Bond Index: Interbank: Treasury Bond: Long Term	2002/06-2017/04	Fast	NS	*none*
112.	Bond Index: Interbank: Policy Financial Bond	2002/06-2017/04	Fast	NS	*none*

Stock Markets

113.	Shanghai Stock Exchange Index	1999/12-2017/04	Fast	NS	*none*
114.	Index: Shenzhen Stock Exchange: Composite	1999/12-2017/04	Fast	NS	*none*
115.	Price to Earnings Ratio-Shanghai Stock Exchange: All shares	1999/12-2017/04	Fast	NS	*none*
116.	Price to Earnings Ratio-Shanghai Stock Exchange: Class-A shares	1999/12-2017/04	Fast	NS	*none*
117.	Price to Earnings Ratio-Shanghai Stock Exchange: Financial industry	2001/04-2017/04	Fast	NS	*none*
118.	Price to Earnings Ratio-Shanghai Stock Exchange: the Real estate industry	2001/04-2017/04	Fast	NS	*none*
119.	Price to Earnings Ratio-Shanghai Stock Exchange: the Construction industry	2001/04-2017/04	Fast	NS	*none*
120.	Price to Earnings Ratio-Shanghai Stock Exchange: Manufacturing industry	2001/04-2017/04	Fast	NS	*none*
121.	Price to Earnings Ratio-Shenzhen Stock Exchange: All Share	1999/12-2017/04	Fast	NS	*none*
122.	Price to EarningsRatio-Shenzhen Stock Exchange: Class-A Share	1999/12-2016/03	Fast	NS	*none*

Price Indices

123.	Consumer Confidence Index	1999/12-2017/03	Fast	NS	$none$
124.	Consumer Expectation Index	1999/12-2017/03	Fast	NS	$none$
125.	Consumer Price Index	1999/12-2017/04	Slow	NS	Δln
126.	CPI: Food	1999/12-2017/04	Slow	SA	Δln
127.	CPI: Core (excl. Food & Energy)	2005/01-2017/04	Slow	SA	Δln
128.	CPI: non Food	2005/01-2017/04	Slow	SA	Δln
129.	Coking Coal Price: Monthly average, 36 cities	2000/01-2017/04	Slow	SA	Δln
130.	Shanghai Futures Exchange: Fuel Price	2000/01-2017/04	Slow	SA	Δln
131.	Diesel Price: Monthly average	2004/06-2017/04	Slow	SA	Δln
132.	Pork Price: Lean Meat: 36 city average	2004/06-2017/04	Slow	SA	Δln
133.	Nanhua Composite Index Monthly	2004/06-2017/04	Slow	SA	Δln
134.	Nanhua Industrial Index Monthly	2004/06-2017/04	Slow	SA	Δln
135.	Nanhua Agricultural Index Monthly	2004/08-2017/04	Slow	SA	Δln
136.	Nanhua Metal Index Monthly	2004/08-2017/04	Slow	SA	Δln

Employment

137.	No of Employee: Coal Mining & Dressing	1999/12-2017/04	Slow	SA	Δln
138.	No of Employee: Ferrous Metal Mining & Dressing	1999/12-2017/04	Slow	SA	Δln
139.	No of Employee: Food Manufacturing	1999/12-2017/04	Slow	SA	Δln
140.	No of Employee: Wine, Beverage & Refined Tea Manufacturing	1999/12-2017/04	Slow	SA	Δln
141.	No of Employee: Textile	1999/12-2017/04	Slow	SA	Δln
142.	No of Employee: Paper Making & Paper Product	1999/12-2017/04	Slow	SA	Δln
143.	No of Employee: Chemical Material & Product	1999/12-2017/04	Slow	SA	Δln
144.	No of Employee: Medical & Pharmaceutical Product	1999/12-2017/04	Slow	SA	Δln
145.	No of Employee: Electrical Machinery & Equipment	1999/12-2017/04	Slow	SA	Δln
146.	No of Employee: Computer, Communication & Other Electronic Equipment	1999/12-2017/04	Slow	SA	Δln

Real Estate

147.	Commodity Bldg Selling Price	1999/12-2017/04	Fast	SA	Δln
148.	Commodity Bldg Selling Price: Residential	1999/12-2017/04	Fast	SA	Δln
149.	Floor Space Started: Commodity Bldg	2000/01-2017/04	Slow	SA	ln
150.	Real Estate Investment	2000/01-2017/04	Slow	SA	ln
151.	Real Estate Inv: Source of Fund: Domestic Loans	2000/01-2017/04	Slow	SA	ln
152.	Real Estate Inv: Source of Fund: Foreign Inv	2000/01-2017/04	Slow	SA	ln
153.	Real Estate Inv: Source of Fund: Self Raised	2000/01-2017/04	Slow	SA	ln
154.	Real Estate Inv: Source of Fund: Other	2000/01-2017/04	Slow	SA	ln
155.	Building Sold	2000/01-2017/04	Slow	SA	ln
156.	Building Sold: Residential	2000/01-2017/04	Slow	SA	ln
157.	Building Sold: Residential: House in Advance	2005/01-2017/04	Slow	SA	ln
158.	Building Sold: Residential: Existing House	2005/01-2017/04	Slow	SA	ln
159.	Building Sold: Commercial: House in Advance	2005/01-2017/04	Slow	SA	ln
160.	Building Sold: Commercial: Existing House	2005/01-2017/04	Slow	SA	ln
161.	Real Estate Climate Index	2016/02-2017/04	Slow	NS	$none$

C.2. Data Description: U.S. Variables

The series for the shadow rate is from Wu and Xia (2016) and the series for U.S. policy uncertainty is the EPU index from Baker, Bloom and Davis (2016). Whenever the Wu-Xia shadow rate is above 1/4 percent, it is exactly equal to the effective federal funds rate by construction per Wu and Xia. All other series are taken from CEIC Global Database. Seasonality adjustment is performed using the U.S. Census Bureau's X-13 program: SA=seasonally adjusted, NS=no seasonal adjustment. The transformations are Δ-first difference; ln-logarithm; Δln-first difference of logarithm; $none$-no transformation.

163.	Effective Federal Runds Rate/Shadow Rate	1999/12-2017/03	NS	$none$
164.	US Policy Uncertainty Index	1999/12-2017/04	NS	$none$
165.	US Industrial Production Index	1999/12-2017/03	NS	Δln
166.	US Unemployment Rate	1999/12-2017/03	NS	Δln
167.	US Consumer Price Index	1999/12-2017/03	NS	$none$

D. Construction of the Wu-Xia Shadow Rate

We use the Wu-Xia shadow rate as the measure of U.S. monetary policy (Wu and Xia, 2016). Unlike the observed short-term interest rate, the Wu-Xia shadow rate allows the policy to drop below zero. Whenever the Wu-Xia shadow rate is above 1/4 percent, it is exactly equal to the effective federal funds rate by construction.

Following Black (1995), the short-term interest rate is the maximum of the shadow rate s_t and a lower bound $\underline{r}$:

$$r_t = \max(\underline{r}, s_t).$$

If the shadow rate is greater than the lower bound, s_t is the short rate.

Furthermore, we assume the shadow rate s_t is an affine function of state variables X_t:

$$s_t = \delta_0 + \delta_1' X_t. \tag{4}$$

The state variables follow a VAR(1) process under the physical measure ($\mathbb{P}$):

$$X_{t+1} = \mu + \rho X_t + \Sigma\epsilon_{t+1}, \epsilon_{t+1} \sim N(0, I). \tag{5}$$

Then, the stochastic discount factor is

$$M_{t+1} = exp(-r_t - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t'\epsilon_{t+1}). \tag{6}$$

The price of risk λ_t is linear in the factors

$$\lambda_t = \lambda_0 + \lambda_1 X_t. \tag{7}$$

It follows that the risk-neutral measure ($\mathbb{Q}$) dynamics for the factors are also VAR(1):

$$X_{t+1} = \mu^{\mathbb{Q}} + \rho^{\mathbb{Q}} X_t + \Sigma\epsilon_{t+1}^{\mathbb{Q}}, \epsilon_{t+1} \overset{\mathbb{Q}}{\sim} N(0, I). \tag{8}$$

The parameters under $\mathbb{P}$ and $\mathbb{Q}$ measures are related as follows:

$$\mu - \mu^{\mathbb{Q}} = \Sigma\lambda_0, \tag{9}$$

$$\rho - \rho^{\mathbb{Q}} = \Sigma\lambda_1. \tag{10}$$

The shadow rate term structure model (SRTSM) is described by equations (4) - (8).

Define $f_{n,n+1,t}$ as the forward rate at time t for a loan starting at $t+n$ and maturing at $t+n+1$. The forward rate in the SRTSM described before can be approximated as

$$f^{SRTSM}_{n,n+1,t} = \underline{r} + \sigma^{\mathbb{Q}}_n g(\frac{a_n + b'_n X_t - \underline{r}}{\sigma^{\mathbb{Q}}_n}), \tag{11}$$

where $(\sigma^{\mathbb{Q}}_n)^2 \equiv \mathbb{V}ar^{\mathbb{Q}}_t(s_{t+n})$. The function $g(z) = z\Phi(z) + \phi(z)$ consists of a normal cumulative distribution function $\Phi(\cdot)$ and a normal probability density function $\phi(\cdot)$. The exact expressions for a_n, b_n, and $\sigma^{\mathbb{Q}}_n$ in terms of deep parameters can be found in the appendix of Wu and Xia (2016).

The measurement equation related the observed forward rate $f^o_{n,n+1,t}$ to the factors as follows:

$$f^o_{n,n+1,t} = \underline{r} + \sigma^{\mathbb{Q}}_n g(\frac{a_n + b'_n X_t - \underline{r}}{\sigma^{\mathbb{Q}}_n}) + \eta_{nt}, \tag{12}$$

where the measurement error η_{nt} is i.i.d. normal, $\eta_{nt} \sim N(0, \omega)$.

The input data for the model are one-month forward rates beginning n (n =1/4, 1/2, 1, 2, 5, 7, and 10) years hence. These forward rates are constructed with end-of-month Nelson-Siegel-Svensson yield curve parameters from the gurkaynak2007us dataset. The latent factors and the shadow rate are estimated with the extended Kalman filter.[9]

[9] The full details of the Wu-Xia shadow rate model are described in their paper published in the *Journal of Money, Credit and Banking* (Wu and Xia, 2016).