MACROECONOMIC CONSEQUENCES OF THE REAL-FINANCIAL NEXUS: IMBALANCES AND SPILLOVERS BETWEEN CHINA AND THE U.S.

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ABSTRACT

Relying on quarterly data since 1998 we estimate, for China and the U.S., small scale econometric models that economize on the number of variables employed and yet are rich enough to provide useful insights about spillover effects between the two countries under different maintained assumptions about the exogeneity of the macroeconomic relationship between them. We conclude that inflation in China responds to credit shocks. Indeed, the monetary transmission mechanism in China resembles that of the U.S. even if the channels through which monetary policy affects their respective economies differ. We also find that the monetary policy stance of the PBOC was helpful in mitigating the impact of the global financial crisis of 2008-9. Finally, spillovers from the U.S. to China are significant and originate from both the real and financial sectors of the U.S. economy.

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1. Introduction

Interest in China's rising economic influence has come at a time when there is recognition that economic interdependence has also increased. Similarly, the global financial crisis and its aftermath made clear that macroeconomic policies in large economies such as the U.S. create both real and financial spillovers. Indeed, even before controversy erupted over whether the extraordinarily loose monetary policy of the U.S. Federal Reserve in recent years generated negative outcomes, particularly in emerging markets, there was an ongoing debate which asked whether China was effectively exporting low inflation to the rest of the world. The impact of globalization more generally is apparent not only in the trading of goods and services but also in finance. Therefore, both real and financial shocks should be considered when one is investigating the aggregate relationship between these two large economies.[1]

It would seem natural then to explore the links between China and the U.S. in a framework that not only recognizes their macroeconomic interdependence but one where real and financial shocks jointly play a role. This is the principal aim of this study. Relying on quarterly data since 1998 we estimate small scale models that economize on the number of variables employed and yet are rich enough to provide useful insights about spillover effects between economies. We are not aware of any extant study that considers the nexus between real and financial conditions, together with an attempt to measure the size of spillover effects, for both China and the U.S.

We investigate the transmission of real and financial conditions between these two large economies and assess whether implications drawn from a modification to a standard macro model stands up to this kind of scrutiny. Juxtaposing China and the U.S. is of particular interest for several reasons. First, the issue of supply side shocks is nowhere more glaring than when addressing the issue of China's growing global economic influence. Second, whereas the U.S. has engaged in unconventional monetary policies over several years while being constrained by the zero lower bound (until December 2015), China has not suffered the same fate. Third, in several respects, China is still an economy that possesses several of the features highlighted by Rey (2013) who supports as seemingly

[1] This result may be generalized leading to the conclusion that all that is left from the trilemma is a dilemma (e.g., see Aizenman, Chinn, and Ito 2015). Hence, the choice is between monetary independence and capital mobility, with no effective role for the exchange rate regime. Consequently, the transmission of financial shocks has come to dominate economic links between countries.

sensible the Chinese authorities' responses to the failure of floating exchange rates to deliver complete monetary policy independence. Hence, an empirical evaluation of spillovers and their macroeconomic consequences seems appropriate.

The rest of the paper is structured as follows. The next section summarizes the relevant literature. The methodology and some stylized facts are described in section three. Empirical results are reported in section four prior to a concluding section that provides some policy implications and suggestions for future research.

Briefly, we conclude that inflation in China responds to credit shocks. Indeed, some elements of the monetary transmission mechanism in China resemble that of the U.S. even if the channels through which monetary policy affects their respective economies differ. Next, we find that the monetary policy stance of the PBOC was helpful in mitigating the impact of the global financial crisis of 2008-9. Finally, spillovers from the U.S. to China are significant and originate from both the real and financial sectors of the U.S. economy.

2. Literature Review

China's macro economy has some unique features which, in principle, can potentially complicate any kind of empirical macroeconomic analysis. Among these, of course, is the level of state involvement in the macroeconomy, the type and management of the exchange rate regime, restrictions on capital mobility, to name but three such characteristics. In addition, there is the unusual structure of China's labour market.[2]

Until recently, some effort was devoted to asking whether and how inflation on a global scale was being influenced by rapid growth in China together with an exchange rate regime that exacerbated pressure on producers around the world to moderate price increases. For example, Bailliu and Blagrave (2010) find that foreign demand shocks impact China's economy more than those in advanced economies. Eickmeier and Kühnlenz (2013) also report that, while Chinese aggregate demand shocks impact oil prices, global shocks play a relatively more important role in global inflation dynamics than do aggregate demand shocks that originate from China. The bottom line is that China's culpability in keeping world inflation rates low since the 1990s is not proven.

Turning to the conduct of monetary policy several authors have considered whether the transmission mechanism of monetary policy in China can be likened to that of other

[2] This is the starting point of Dollar and Jones' (2013) model. The challenge is to explain the country's extraordinary aggregate economic performance at least over the past two decades.

economies with similar levels of development or even compared to the case of an advanced economy. Yet, the People's Bank of China's (PBOC) monetary policy can be understood as being set relying on multiple instruments. This contrasts with the advanced economies where, at least until 2007, central banks relied exclusively on an interest rate instrument. Moreover, these have evolved or changed considerably over time (e.g., see Ma, Xiandong and Xi (2011), Xu and Chen (2012), Köner and Ehmts (2013), He, Leung and Chong (2013), Girardin et.al. (2013)).[3]

A few have tried to evaluate the conduct of monetary policy in China using a policy rule (e.g., a Taylor rule) that is routinely estimated for central banks around the world, while most have argued that a rule based on developments in monetary aggregates (i.e., McCallum's rule) is more suitable for assessing China's experience (e.g., see Burdekin and Siklos (2008), and references therein). Alternatively, a hybrid model that permits a role for both quantity and price variables (viz., interest rates and money growth) is yet another way of characterizing the conduct of monetary policy in China (Liu and Zhang (2010), Li and Wang (2015)). Indeed, Girardin et. al. (2013) propose a new monetary policy index that combines the various monetary policy instruments the PBOC has employed over time. They identify various benchmark interest rates, reserve requirements, PBOC open market operations and window guidance, as the candidate policy instruments.

More recently, some have begun to consider how asset prices (i.e., stock and housing prices) enter into the conduct of monetary policy. Xu and Chen (2012), for example, find that tighter monetary policy does impact housing price growth, as do stock price developments, and point to an additional role played by mortgage down payment policies. Zhang et. al. (2011) use nonlinear models to establish a statistical relationship between monetary variables and housing prices in China. In contrast, Liang and Cao (2007) earlier conclude that there is a weak connection between bank lending and property prices and that a policy rate does not prove to be an effective instrument in controlling them.

Fernald et. al. (2014) argue that interest rates and reserve requirements are the Peoples Bank of China's (PBOC) primary instruments of monetary policy. Nevertheless, the

[3] Körner and Ehmts (2013), for example, define 5 phases in monetary policy in the 2000s (2000-4, inflation control; 2004-6, exchange rate focus; 2006-8, inflation and exchange rate control; 2008-10, exchange rate control; 2010- inflation and exchange rate control). Xu and Chen (2012) subdivide their sample into 3 phases (1998-2003, expansionary monetary policy; 2003-2008, period of monetary policy tightening; 2008-2009, the global financial crisis; and 2010 on which includes a tightening of monetary policy in the face of a perceived real estate bubble).

transmission mechanism in China is found to be not dissimilar from that reported for the U.S. He et.al. (2013) conclude otherwise. Indeed, a pegged exchange rate followed, more recently, by a crawling type pegged regime and administrative controls over certain interest rates (e.g., see He and Wang (2012)), suggests that a higher level of financial repression is practiced in China (e.g., see Lardy (2008)) than in advanced economies. In part for these reasons China's macroeconomic experience is also notable for the spectacular rise over time in the accumulation of foreign exchange reserves, at least until 2015. Of course, macroeconomic developments in some advanced economies, including the Eurozone crisis, together with the determination of certain central banks, including the Fed, to maintain interest rates at the zero lower bound until the economy fully recovers, has arguably narrowed the gap concerning the degree of financial repression being practiced (e.g., see Reinhart and Rogoff (2013)).

Data related considerations also loom large in any macroeconomic study of China's economy. There are two difficulties to contend with here. First, a reliable dataset is often restricted to data since the mid to late 1990s. Hence, researchers must generally work with fairly small samples. Perhaps unsurprisingly several studies, including ours, resort to variants of the factor model approach since this allows for rich yet still parsimonious specifications (e.g., see Fernald et.al (2014), Liu and Zhang (2014), He, Leung, and Chong (2013)).

Second, there is the ongoing debate about the quality of Chinese data. Suffice it to say that there exists a vast literature that casts a negative view on the quality of Chinese macroeconomic data (e.g., see Holz (2013), Sinclair (2012), Burdekin and Siklos (2008), and references therein). However, in spite of continuing doubts, the latest verdict about the usefulness of more recent aggregate data for China seems much improved. Thus, for example, Holz (2013, 2013a) points out that even if the extraordinary growth numbers posted by China appear questionable (for example, see Wu (2011)) there seems to be no evidence that the data have been falsified. Mehrotra and Pääkkönen (2011) also find that the patterns found in real GDP data do not reveal any noticeable statistical discrepancies. Finally, Sinclair (2012) concludes that Chinese macro data appear to be fairly reliable.[4]

Turning to the U.S. case, recent years are dominated by the impact of shocks from the global financial crisis followed by a weak recovery. Monetary policy over the period

[4] The paper also provides an extensive list of researchers who are, or have been, sceptical about the quality and reliability of Chinese macroeconomic data.

examined in this study is characterized by the so-called Great Moderation years when inflation control was the dominant concern of policy makers at the Fed. The crisis of 2008-9 led to the emasculation of the fed funds rate, which reached the zero lower bound by the end of 2008, by a host of other policies since labelled quantitative easing (QE). Paralleling these developments is the switch from robust and stable real GDP growth prior to 2008 to weak economic performance that some herald as signalling an era of stagnation. The Eurozone crisis would further contribute to keep not only policy rates low for the foreseeable future but stunt the emerging global economic recovery.

Prior to the Global Financial Crisis (hereafter GFC), the widely held view was that what is optimal for individual economies translates into the conclusion that international policy cooperation, if not coordination, is unnecessary. This view is associated with the work of Obstfeld and Rogoff (2002). We now know that the conditions required for such a result cannot survive the events of the past five years. Taylor (2013) documents how the NICE (near an internationally cooperative equilibrium) world came into conflict with the phenomenon now referred to as global spillovers. In particular, economic imbalances of the real and financial varieties can, and do, spillover, from one major economy to another and these should actually encourage as opposed to deterring greater cooperation in international macroeconomic policy making.

Taylor (2013) draws his results from model simulations that adhere to a model of the New Keynesian (NK) variety. Friedman (2013), however, explains that this modelling strategy not only omits a role for the financial sector but that many interesting policy related problem cannot be properly answered in this framework. He proposes a simple modification to the NK model that adds a financial sector which gives rise to credit spreads as a means to introduce some frictions into the financial system that provide a vehicle for spillovers into the real economy. The model, however, is tailored to the performance of the U.S. economy and international policy implications are not drawn. Yet, the international dimension, in the form of volatile capital flows, to give one example, represents one such global factor. Research restricted to domestic factors ignores this element at their peril (Rey 2013). As a consequence, her study advocates a macro-prudential response to the failure of floating exchange rates to insulate an economy from external financial shocks.

More recently, Gordon (2013) and Eggertsson and Giannoni (2013) suggest that the omission of aggregate supply side influences, not to mention considerably more inertia than popular models are willing to admit, imply a failure of the NK view of the Phillips curve. One can well imagine that this kind of misspecification is amplified in an open economy environment with international supply side shocks admitted into the model.

A parallel development in empirical models in recent years has been the attempt to ask the data to inform policy makers about the depth of interactions between economies as a way of assessing the importance of the phenomenon of globalization. Various types of factor models (e.g., Global VAR (GVAR), or Factor VAR models (FVAR)) and, more generally, models that are able to handle the over-parameterization that one risks to encounter have been proposed and implemented. Typically, the relevant empirical literature seeks to include as many economies as possible in recognition that even small economies may have effects on the rest of the world that can exceed their relative economic weights due to spillover and contagion type effects.

Nevertheless, as far as we are aware, there have been no attempts to investigate the role of economic interactions between large economies in the context of an ongoing literature that seeks to overcome weaknesses of the NK model while simultaneously capturing the potential spillovers stemming from volatile capital flows. This is the case whether or not the specification allows a financial sector to partially account for the transmission of shocks globally. While the story of global spillovers is plausible it must also confront the view that, conditional on the policy regime in place, pass-through effects have apparently diminished (e.g., see Bailliu and Murray (2010), Takhtamanova (2008), Globerman and Storer (2006), McCarthy (1999)). This phenomenon may reflect the impact of globalization on the real economy and the adoption of inflation control regimes (e.g., inflation targeting) in many parts of the world. It deals with the growth in trade of goods and services but does not consider the globalization of finance.

In the meantime, policy makers in several emerging markets (e.g., Brazil) complain that financial pass-through effects in the form of volatile capital flows resulting in volatile exchange rate movements have been amplified by recent events and policies. This may, in part, stem from the consequence of unconventional monetary policies being pursued especially by the U.S. Federal Reserve. Nevertheless, as Chen et. al. (2015) point out, the policy responses in emerging market economies is equally to blame for the consequences of U.S. based QE policies.

Eggertsson and Giannoni (2013) point out that the zero lower bound has radical implications for policy prescriptions arising from the standard NK model. However, China has limited exchange rate movements while adhering to a monetary rule, as opposed to a rule of the Taylor variety widely adopted in advanced economies. To be sure, China is slowly evolving towards a regime where the most important policy instrument is an interest rate but it will take several years before the transition is completed. Moreover, in light of the macroeconomic events that have transpired since 2008, it is far from clear that the People's Bank of China (PBOC) or, for that matter, central banks elsewhere in the world, will settle back to the consensus that prevailed during the height of the Great Moderation. The asymmetry in economic conditions and structures between these two large economies should provide an interesting test of the relative importance of real versus financial channels in the transmission of global shocks.

3. Methodology and Data

The estimation approach begins by estimating a standard vector autoregressive (VAR) model followed by a dynamic factor-augmented VAR (DFAVAR) model. The various estimated models contain variables that would appear in any standard macro model, including ones of the NK variety. Nevertheless, we extend conventional macro models found in the relevant literature to incorporate a role for financial sector shocks as well as permitting real and financial shocks from abroad to affect China's economy.

Our methodological approach is also motivated by the need to preserve degrees of freedom while utilizing a rich set of macroeconomic indicators from both countries. This type of statistical model has, of course, been widely used recently although, to our knowledge, not to jointly estimate the relationship between the two large economies examined here.[5]

A typical macroeconomic model, expressed in the VAR format, assumes that the chosen variables are temporally related to each other in the following manner

$$\mathbf{y}_t^j = A_0^j + A_1^j \mathbf{y}_{t-i}^j + \boldsymbol{\varepsilon}_t^j \qquad (1)$$

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[5] While the different specifications are partly intended as a test for robustness there are, of course, other ways of estimating the simultaneous relationship between two economies. For example, Dungey and Osborn (2014) propose a VECM-type structural model to investigate the macroeconomic relationship between the U.S. and Eurozone economies. It is feasible, in principle, to adopt such an approach in the present case although the relatively short sample is likely to be problematic when attempting to estimate stable long-run cointegrating relationships.

where **y** is a vector of variables that includes the macroeconomic time series that summarize the key economic relations of interest to policy makers. The index *i* represents the lag length of the VAR. The index *j= US, CN* indicates that the same type of model can be estimated using either data from the U.S. or China (CN). Equation (1) is initially estimated for each economy separately.[6] The vector of a conventional macro model of the form of equation (1) would include real GDP growth or the output gap, inflation (in the GDP deflator or some equivalent), commodity or oil prices, and the central bank's policy rate. Equation (1) explicitly recognizes that all of the variables are endogenous since, potentially, the past history of each one of the variables in the **y** vector may affect all the other variables in the model, with lags.[7]

The drawback with formulations of the kind described above is that, if the financial sector is believed to have macroeconomic consequences, models summarized by equation (1) will produce misleading inferences. The reason is that variables that define financial conditions, such as the volume of loans, and other indicators of tightness or ease in financial conditions are omitted. Incorporating these omitted variables into the previously defined **y** vector then we can modify equation (1) as follows:

$$\mathbf{y}_t^{*j} = A_0^{*j} + A_1^{*j}\mathbf{y}_{t-i}^{*j} + \varepsilon_t^{*j} \qquad (2)$$

where the vector $\mathbf{y}^*$ now includes variables that proxy overall financial conditions. That is, $\mathbf{y}^* = [\mathbf{y},\mathbf{z}]'$, where **z** is a vector of variables that proxies financial conditions. As we shall see below, there exist several proxies for both the U.S. and China. Since we have previously argued that models should incorporate financial conditions, Equation (2) serves as the benchmark model that captures the essence of real-financial links in China's and the U.S. economies.

Next, we consider spillovers effects between the U.S. and China. We estimate the U.S. and China's macroeconomic and financial conditions by creating two variables that proxy, respectively, the real and financial developments in each one of the two economies in question. In particular, two new variables are created and labelled as 'real economic' and

[6] This approach does not prevent us from, say, estimating an open-economy VAR for each economy.

[7] Another possibility not contemplated here is that data for (1) are 'stacked' so that we end up estimating a panel VAR. Data and sample limitations provide no obvious advantage in proceeding in this manner.

'financial' factors for each economy.[8] We then examine the spillover effects between the U.S. and China based on different assumptions about the exogeneity of the economic relationships between them.

We first assume that the U.S. economy impacts China's economy but not vice-versa. In other words, we assume that the U.S. factors are exogenous to China's economy. If we now posit that it takes at least one quarter for U.S. shocks to affect China's macroeconomy, a fairly reasonable assumption under the circumstances, then one way of expressing the sources of spillovers from the U.S. to the Chinese economy is obtained by estimating the following specification:

$$\mathbf{y}_{\mathrm{t}}^{*\mathrm{CN}} = \mathrm{A}_0^{*\mathrm{CN}} + \mathrm{A}_1^{*\mathrm{CN}} \mathbf{y}_{\mathrm{t-i}}^{*\mathrm{CN}} + b_1\, \mathrm{f}_{t-1}^{R,US} + b_2\, \mathrm{f}_{t-1}^{F,US} + \boldsymbol{\varepsilon}_{\mathrm{t}}^{*\mathrm{CN}} \qquad (3)$$

Equation (3) contains the variables from China defined in our benchmark equation (2), all of which are endogenous, with two additional exogenous variables capturing spillovers from the U.S.. The terms $\mathrm{f}_{\mathrm{t-1}}^{\mathrm{R,US}}, \mathrm{f}_{\mathrm{t-1}}^{\mathrm{F,US}}$ are, respectively, lagged U.S. real economic (R) and financial (F) factors. We explain below how these factors are estimated via principal components analysis.

If we relax the restriction that shocks from China cannot influence the U.S. economy, and at the same time try to preserve the degree of freedom by retaining a parsimonious specification, we can estimate the relationship between the factors in a VAR framework by writing

$$\boldsymbol{\Gamma}_{\mathrm{t}}^{*\mathrm{j}} = \mathrm{A(L)}\boldsymbol{\Gamma}_{\mathrm{t-i}}^{*\mathrm{j}} + \boldsymbol{\eta}_{\mathrm{t}}^{*\mathrm{j}} \qquad (4)$$

where $\boldsymbol{\Gamma}^{*j}$, j=CN, US, is the vector of real economic and financial factors extracted from data for each economy (i.e.,$\mathrm{f}^{R,CN}, \mathrm{f}^{F,CN}, \mathrm{f}^{R,US}, \mathrm{f}^{R,US}$).

Of course, the real economic and financial factors are unobservable while some monetary policy variables (e.g., policy rates, money growth) are observable. In yet another variant then, we can estimate the following specification

$$\begin{bmatrix} \boldsymbol{\Gamma}_t^j \\ \mathbf{X}_t^j \end{bmatrix} = \mathrm{B(L)} \begin{bmatrix} \boldsymbol{\Gamma}_{t-i}^j \\ \mathbf{X}_{t-i}^j \end{bmatrix} + \boldsymbol{\zeta}_t^j \qquad (5)$$

[8] We are, of course, implicitly assuming that these two factors are sufficient to explain the US (or China's) macroeconomy. While this is an empirical question imposing this kind of structure is sensible on purely economic grounds. The ability to estimate these factors is also predicated on the assumption that several variables can potentially influence the real and financial sectors of either economy.

where $\boldsymbol{\Gamma}^j$ represents the real economic and financial factors for the U.S. and China, exclusive of monetary policy variables, while $\mathbf{X}^j$ represents the observable policy variables for *j= CN, US*. Equation (5) is a dynamic factor-augmented VAR (DFAVAR) model.[9]

Equation (5) may well be problematic if, *a priori*, one believes that monetary policy in China is passive, unlike the active role played, at least until recently, by the interest rate policy instrument in the U.S. (i.e., the fed funds rate). More importantly, as we have seen, the PBOC potentially relies on a variety of instruments in conducting monetary policy. Hence, it is preferable to rewrite (5) as follows

$$\begin{bmatrix} \boldsymbol{\Gamma}_t^j \\ \phi_t^{MP,CN} \\ \mathbf{X}_t^{US} \end{bmatrix} = \mathrm{B(L)} \begin{bmatrix} \boldsymbol{\Gamma}_{t-i}^j \\ \phi_{t-i}^{MP,CN} \\ \mathbf{X}_{t-i}^{US} \end{bmatrix} + \boldsymbol{\zeta}_t^j \qquad (6)$$

where $\phi^{MP,CN}$ is a monetary indicator for China. The construction of this indicator is explained below.

Real economic and financial factors, and China's monetary policy factor in equation (6), are estimated via the method of principal components. In a first step, the first two principal components are extracted from the data set such that

$$\boldsymbol{\Gamma}_t^j = \mathrm{P}_t^j \mathbf{v}_t^j + \mathbf{e}_t^j \qquad (7)$$

where P is a (linear) transformation of the data series, represented by $\mathbf{v}^j$. As previously defined, **Γ** are the estimated factors while **e** is a zero mean, constant variance error term. The index *j= US, CN* is also unchanged.

The recursive ordering assumes that the Chinese block comes first so that U.S. shocks are relatively more exogenous than are shocks from China. Formulations (5) or (6) pose empirical challenges. In the case of Fed policy substantial changes took place after the fed funds rate is reduced to the effective zero lower bound.[10] Thereafter, the myriad actions undertaken to ease credit and monetary conditions, since called QE, have led to a substantial expansion of the Fed's balance sheet.

A narrative history of recent monetary policy in China, briefly summarized earlier, suggests a multiplicity of policy instruments but their relative importance may have changed over time. Accordingly, we assume that the real effective exchange rate, reserve

[9] In the foregoing expressions we exclude other exogenous influences (e.g., the period of the global financial crisis). These can easily be added without jeopardizing the thrust of the discussion so far.
[10] As a result, there have been suggestions that a shadow fed funds rate better describes the state of policy ease for the US in recent years. Wu and Xia (2014) provide one illustration. We consider their estimates below.

requirements for financial institutions, credit or window guidance (i.e., base money growth) or, either open market operations or the total assets of the PBOC, at one time or other represent the policy instrument for China. We also include an interest rate (the central bank rate).[11]

In view of the above characteristics of China's monetary policy, as well as prompted by a need to economize on degrees of freedom (see below), we also rely on principal components analysis to create a monetary policy factor for China ($\phi_t^{\mathrm{CN},MP}$). For the U.S. we use two observable indicators of policy, namely the fed funds rate and the shadow rate after 2007, or the total assets of the Fed.

The data used are quarterly for the sample 1998.1-2014.1, before any data transformations (e.g., differencing). Sources of data include the International Monetary Fund's *International Financial Statistics,* the Federal Reserve Bank of St. Louis' FRED II data bank, *Global Financial Data*, China's National Bureau of Statistics, and CEIC (www.ceicdata.com). Since it is important that the series are stationary, the raw data were either differenced or log differenced if a unit root is detected (tests not shown).[12]

Nevertheless, even as seems probable, the global financial crisis (GFC) of 2008-9 clearly influences the behavior of key time series. The GFC's most visible impact is likely in the behavior of real GDP. If growth rates are used then the effect is seen as temporary so an exogenous dummy variable may well be adequate under the circumstances.[13] If, instead, an output gap proxies real economic performance then the standard approach of estimating an H-P filter will not be adequate because the end point problem will likely bias the size of the gap both prior and following the GFC. A straightforward alternative is to estimate separate output gaps for the pre and post-GFC periods and splice the data.[14] We adopt both strategies. However, as our overall conclusions are unaffected, we only report the results where we use real GDP growth.

4. Empirical Results

[11] We considered a number of alternative interest rate series including the 3 month and 1 year Shanghai interbank offer rate (SHIBOR), but found that using the "immediate rates: less than 24 hours", also referred to as a central bank rate performed adequately (series IRSTCB01CNM156N from FRED).

[12] An Appendix provides a list of the variables employed in the empirical analysis below.

[13] Dominguez, Hashimoto, and Ito (2012) date the GFC for China as starting 2008Q3 and ending 2009Q1. For the US the dates are: 2008Q4-2009Q2.

[14] Based on previous work (e.g., see Borio and Lowe (2002), and references therein) we impose a large smoothing parameter ($\lambda = 100{,}000$).

Since several models are estimated it is useful to begin by providing additional details about the series included in various specifications. In the case of China the basic VAR model that omits a role for financial shocks (i.e., equation (1)) consists of real GDP growth, inflation (annualized) in consumer prices, an indicator of global commodity prices from the IMF, the real exchange rate, and the growth rate (annualized) in base money. Of course, alternative versions of equation (1) were also considered as part of the robustness exercise (e.g., a measure of the output gap instead of real GDP growth or a policy rate instead of base money growth).

For the U.S., following a long line of studies that estimate a small scale macro model, equation (1) would include real GDP growth, PCE (personal consumption expenditures) inflation, inflation in oil prices (annualized; West Texas Intermediate crude), and the fed funds rate as the monetary policy instrument. Once again, alternative series are considered such as an output gap measure (either based on an HP filter or relying on the Congressional Budget Office's measure of potential output) as well as a shadow fed funds rate after 2008 from Wu and Xia (2014).

As noted above, the benchmark (i.e., see equation (2)) VAR model adds financial variables to equation (1). They include: the required reserve ratio and credits advanced by financial institutions for China while the U.S. equivalent adds the data from the Senior Officer Loan Survey (SLOS) as well as the volume of commercial loans. The variables added to the U.S. model are inspired by relevant work suggesting that financial sector conditions in the U.S. are well proxied by these two variables (e.g., see Siklos and Lavender (2015), and Lown and Morgan (2006)). For China the additional financial variables capture a role for reserve ratios and loans made by financial institutions.

Real economic and financial factors are estimated via principal components analysis. We restrict the analysis to the first two principal components.[15] Details are provided below. The results reported below extract the principal components based on up to 16 series for China and 11 series for the U.S.. Details about the series used in the principal components analysis are highlighted in bold characters in a separate Appendix.

For China, variables considered include: all the variables in the benchmark model (equation (2)), real GDP growth forecasts from Consensus Economics, an indicator of the

[15] Although we limit the number of factors to two, tests (not shown) support the choice.

business climate, a measure of property prices, share prices using Shanghai stock index, an indicator of energy production, the current account to GDP ratio, an indicator of economic policy uncertainty due to Baker, Bloom and Davis (2015) adapted for China[16], the rate of change (annualized) in foreign exchange reserves, and the central bank (PBOC) policy rate.

For the U.S. the following time series are included in addition to those in the benchmark model (equation (2)): real GDP growth forecasts from Consensus Economics, the term spread (10 year yield on U.S. government bonds less the yield on 3 month Treasury bills), an index of financial conditions published by the Chicago Federal Reserve, economic policy uncertainty, and housing prices (National Housing Price index).

Together with the series that make up the benchmark model these series combine to form the basis of the principal components analysis used to extract the real economic and financial factors. Finally, the monetary policy variables for China used in the DFAVAR model consist of the required reserve ratio, the real exchange rate, the central bank (PBOC) policy rate, and base money growth. In the U.S. case, **X** (see equation (6)) is given either by the fed funds rate or the fed funds rate replaced by its shadow rate after 2008.[17] As noted above the sample limits the lag lengths that can be included in the various specifications considered. However, based on the Schwarz and the final prediction error (FPE) criteria it was generally found that all the specifications can be reliably estimated with 2 lags.

We begin our discussion with the performance of the benchmark model. Figure 1 shows a selection of impulse responses (IRFs) from the benchmark model for China.[18] Recall that this model augments traditional macro model with proxies for developments in the financial sector.[19] However, it ignores the potential impact of spillovers from the U.S. economy. Figure 1a reveals a positive relationship between inflation and real GDP growth for at least 3 quarters. Also shown in Figure 1a is real GDP growth responding positively to a credit shock. The impact remains positive but the impact of this shock begins to decline after 3 quarters. After 7 quarters, it becomes insignificant. Clearly then, even the benchmark model highlights an important role for the financial sector in explaining the evolution of economic

[16] The data are available from http://www.policyuncertainty.com/media/BakerBloomDavis.pdf.

[17] We experimented with adding an indicator of changes in the size of the Fed's balance sheet to **X** (including a version deflated by U.S. GDP) but the results were inconclusive. This is not entirely surprising as the time series properties of this series make it a difficult one to deal with. Hence, we did not pursue this line of enquiry.

[18] All confidence intervals are generated via Monte Carlo (1000 replications).

[19] Not shown are IRFs that show real exchange rate appreciations reducing real GDP growth over 3 quarters. Finally, a shock to money base growth has a negligible impact on inflation or real GDP growth and the same is true when a commodity price shock is considered.

activity in China. Figure 1b reveals, however, that inflation initially responds positively to a required reserve ratio shock although the effect becomes insignificant after 3 quarters.[20] Inflation responds positively to a credit shock and the impact seems permanent. However, the (analytic) confidence bands suggest that the effect may not be significant.

Figure 2 plots additional IRFs from the benchmark model where the monetary policy variable for China is the required reserve ratio.[21] The required reserve ratio responses positively to an inflation shock which lasts for about 4 quarters. A positive shock to real GDP growth and a positive shock from the financial sector (i.e., a rise in credit growth) are both seen as prompting a monetary policy response in the form of a rise in the required reserve ratio. However, these results suggest a misspecification as the effects of a real GDP shock and a credit shock on the required reserve ratio continue to rise over time. The bottom line so far is that while there are some elements of the transmission of monetary policy in China that resemble ones reported for the U.S. and other advanced economies, even if the channels through which the effects take place differ from, say, the well-known interest rate channel emphasized in many economies, the benchmark specification is misspecified or incomplete due to the omission of spillovers from the U.S..

We next turn to the analysis of the various factor VAR models (i.e., especially equations (3) and (6)). Figure 3a plots two versions of the estimated real and financial factors for China. In one case the four monetary policy instruments are excluded[22] while in another case all candidate series (a total of 16) are considered for China. A total of 11 series are considered in the principal components analysis for the U.S.. Factor loadings are presented in the Appendix. To save space, we only focus on China's factors here, while the U.S. factors are discussed in the Appendix.

Most of the loadings for the first principal component are heavily weighted on real economic variables such as real GDP growth, consumer price inflation, commodity price

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[20] A rise in inflation following a required reserve ratio shock suggests the presence of the Chinese equivalent of the well-known prize puzzle found in many U.S., and other empirical applications of this kind (e.g., see Castelnuovo and Surico 2009, and references therein). Also, no statistical link is discernible between a shock to required reserves and base money growth.

[21] As noted previously, the conclusions are similar when the PBOC interest rate (the so-called 24 hour rate) is used. We opted to show the case where the reserve ratio is used since this permits easier comparisons with the extant literature.

[22] As a sensitivity test we also tried a version which excluded the interest rate as several authors in the relevant literature are skeptical about the effectiveness of an interest rate instrument for China during much of the period considered. The conclusions are unchanged.

inflation, business climate, economic policy uncertainty, and energy production growth. Therefore, we name it the real economic factor which proxies the real economic performance of China's economy. As shown in Figure 3a, we observe a rise in the real factor, signalling an improvement in China's real activity, over time with a peak around 2007. Thereafter, the global financial crisis leads to a fall in real economic activity followed by a recovery. For the second principal component, the largest loadings are dominated by financial variables such as credit growth, property price growth, stock price growth, and foreign exchange reserve growth. As a result, we name it the financial factor which proxies the overall financial or credit conditions of China much like the financial condition indexes produced by several central banks. Here a rise signifies a loosening in financial conditions. Figure 3a shows that this factor is broadly stable with some tightening in the early 2000s followed by an even more pronounced tightening in financial conditions in 2008 due to the global financial crisis. The rise in this factor since early 2009 indicates that China's financial conditions have improved as its monetary policy loosens in 2008-9 and its real economy recovers after 2009.

While the two sets of proxies for real and financial conditions are comparable there are subtle differences between the two sets of estimates. The real factor exhibits a relatively smaller fall around the time of the global financial crisis (2008-9) than when monetary policy instruments are excluded. Perhaps this is suggestive of the role of monetary policy during this period. Evidence concerning the possible role of monetary policy is provided below in the form of a counterfactual experiment. Similarly, omitting a role for monetary policy instruments would imply financial conditions that are tighter than otherwise would have been the case between the second half of 2009 and the first half of 2010. This confirms that monetary policy was indeed loose, at least for a while, following the global financial crisis.

Figure 3b shows the estimate of the monetary policy factor for China based on a principal component analysis applied to the four selected monetary policy instruments, namely the real effective exchange rate, the required reserve ratio, the base money growth, and the PBOC policy rate. In line with much of the relevant literature, the weights suggest the relative importance of the exchange rate, followed by the required reserve ratio, as the main monetary policy instruments. A rise in the factor here implies a tightening in policy. The tightening of policy by the PBOC leading up to the global financial crisis is clearly evident as well as the large and rapid loosening of policy as the global financial crisis unfolded. The appreciation of the Renminbi thereafter largely accounts for the renewed tightening until early 2014 when policy begins to loosen again. This gives the appearance of a tendency for policy to tighten over time interrupted by episodes of monetary policy loosening. Our estimates are also similar to the ones proposed by Girardin et. al. (2013, Graph 1) who rely on different variables and a different methodology to derive an indicator of monetary policy in China.

Tables 1 and 2 show selected estimates of spillover effects from the U.S. to China's economy. To provide some perspective, Table 1 shows the case for China when the benchmark model is augmented with estimated real and financial U.S. factors (i.e., equation (3)). It is clearly seen that a rise in real economic activity in the U.S. positively impacts China's real GDP growth and inflation. A loosening of the U.S. financial sector is seen as prompting a real appreciation of the Renminbi.

Table 2 presents spillover estimates from the DFAVAR model (i.e., equation (6)). The results here are somewhat similar to the more restricted model above. We find significant and positive spillovers from the U.S. real factor to China's real factor. We also find significant impact of a change in U.S. financial conditions on real activities as well as financial conditions in China. Of course, the coefficients provide estimates of mean responses. The full set of impulse responses is given in Figure 5 which clearly reveals that, other than responses to own shocks (i.e., response along the main diagonal) the responses of China's real and financial factors to US real or financial factors are significant.[23]

We conduct a number of sensitivity tests (not shown). For China and the U.S. we re-estimate all specifications replacing real GDP growth with HP filtered versions or, in the U.S. case, relying on the Congressional Budget Office's estimate of potential real GDP. The overall conclusions are unchanged although the positive impact from a credit shock to China's real GDP becomes insignificant at all lags when output gaps replace real GDP growth (i.e., see Figure 1a). We also replace consumer price inflation in China with a retail price index or the GDP deflator. This change has almost no impact on the conclusions. To deal with the price puzzle we add inflation expectations, using Consensus inflation forecasts. The results shown above are unchanged except that the source of the price puzzle (i.e., top portion of Figure 1b) disappears when inflation forecasts are added to the model.

[23] The response of China real factor to US real factor is marginally significant at quarters 2 and 3.

Although we do not separately discuss the U.S. results due to space limitations there are a couple of findings that are worth mentioning. First, while estimates of real and financial factors for both countries are broadly comparable the tightening of financial factors seen in Figure 3a in China beginning in 2005, and lasting until the onset of the global financial crisis, is not seen in the U.S. data. The subsequent sharp loosening of monetary policy is a feature of the macroeconomic responses in both countries in 2008-9. Similarly, the drop in real economic conditions in 2008-9 and the subsequent recovery is also a feature of China's and the U.S. experience. However, the drop in real economic conditions is more modest in China's case while the recovery phase is steadier and more persistent in the U.S. than in China's case as shown in Figure 3a. Impulse responses are somewhat sensitive to the replacement of the observed fed funds rate with the shadow rate. These reveal that the loosening of U.S. monetary policy has a greater impact when the shadow rate is used. Of course, since the shadow rate is derived and not observed this merely serves to illustrate that policy continued to loosen in the U.S. even after hitting the zero lower bound.[24] As pointed out above we face difficulties when using some proxy based on the rise in total assets of the Fed which are difficult to model in a time series framework. Finally, it is notable that while spillovers are found from the U.S. to China the reverse is not found. Hence, at least in the period investigated, macroeconomic conditions in China do not impact U.S. real or financial conditions.

Previous results point to monetary policy in China as a factor in mitigating the impact of the global financial crisis on China. We further investigate this contention in a counterfactual experiment.[25] Basically, if we take the estimated shocks and coefficients from the estimated DFAVAR (i.e., equation 6), and feed all the shocks back into the estimated system, we would be able to replicate the original data (i.e., observed factors). Then if we set the monetary policy shock to zero and feed the rest of the estimated shocks into the estimated system, we would obtain the real and financial factors in an environment absent a role for monetary policy. By comparing the observed factors with the factors generated through the counterfactual exercise, we are able to estimate the effectiveness of China's monetary policy. Figure 4 shows the observed and the counterfactual real and

[24] It is also worth noting that other shadow fed funds rate estimates have been proposed which differ from the Wu and Xia estimates. See, for example Krippner (2014), and Lombardi and Zhu (2014).

[25] We are grateful to an anonymous referee for suggesting the counterfactual experiment. A Matlab code was used to generate the counterfactual estimates.

financial factors of China based on equation (6). We find that the monetary policy loosening in 2008-9 has a negligible impact on real GDP growth. However, there is a noticeable positive impact seen on financial conditions (i.e., China's financial condition would have been tighter without active monetary policy). Hence, we have a little bit of additional evidence of the impact of monetary policy in China.

5. Conclusions

This paper has considered the interaction of shocks between the U.S. and China with a focus on macroeconomic spillovers from the U.S. to China. Spillover effects in the other direction, when permitted, are not found to be statistically significant. A second objective is to highlight the importance of recognizing not just real economic effects between the two economies but the need to condition models on the role of financial factors. Accordingly, we augment a standard small scale macro model with financial factors such as credit and, in the case of the U.S., lending conditions as reflected in the Fed's loan officer survey. The latter, in particular, have been found by other researchers to be useful in improving our understanding of the impact of monetary policy.

Two main conclusions emerge from our analysis. Real economic conditions in the U.S. spill over into China's real GDP growth rate and inflation. Moreover, U.S. financial factors are seen to impact monetary policy responses in China. Additionally, it is clear that monetary policies in both countries help reduce the severity of the negative shock known as the global financial crisis of 2008-9. The subsequent economic recovery can be observed in both countries though it appears to be smoother and more persistent in the U.S. than in China after 2009.

Other extensions to our model might be desirable. First, instead of relying on each economy's output growth or the output gap, consideration might be given to allowing a global measure of slack to influence both economies (e.g., Zhang et.al. (2015) for China's case). Second, in view of the impact of the global financial crisis, estimates of models which incorporate a richer response to such a large shock are desirable. Finally, it may be worth considering richer proxies for the monetary policy stance in both China and the U.S.. We leave these extensions for future research.

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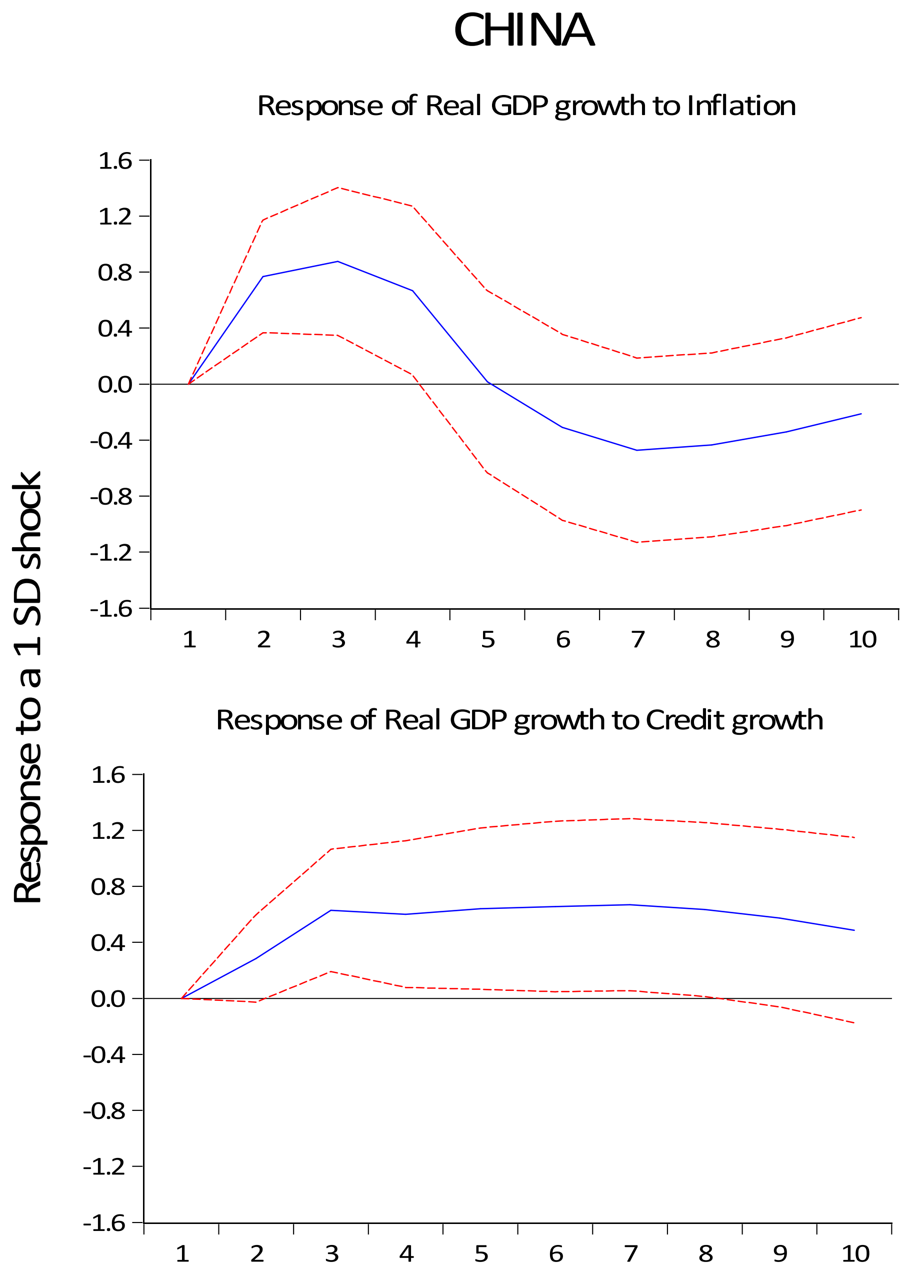
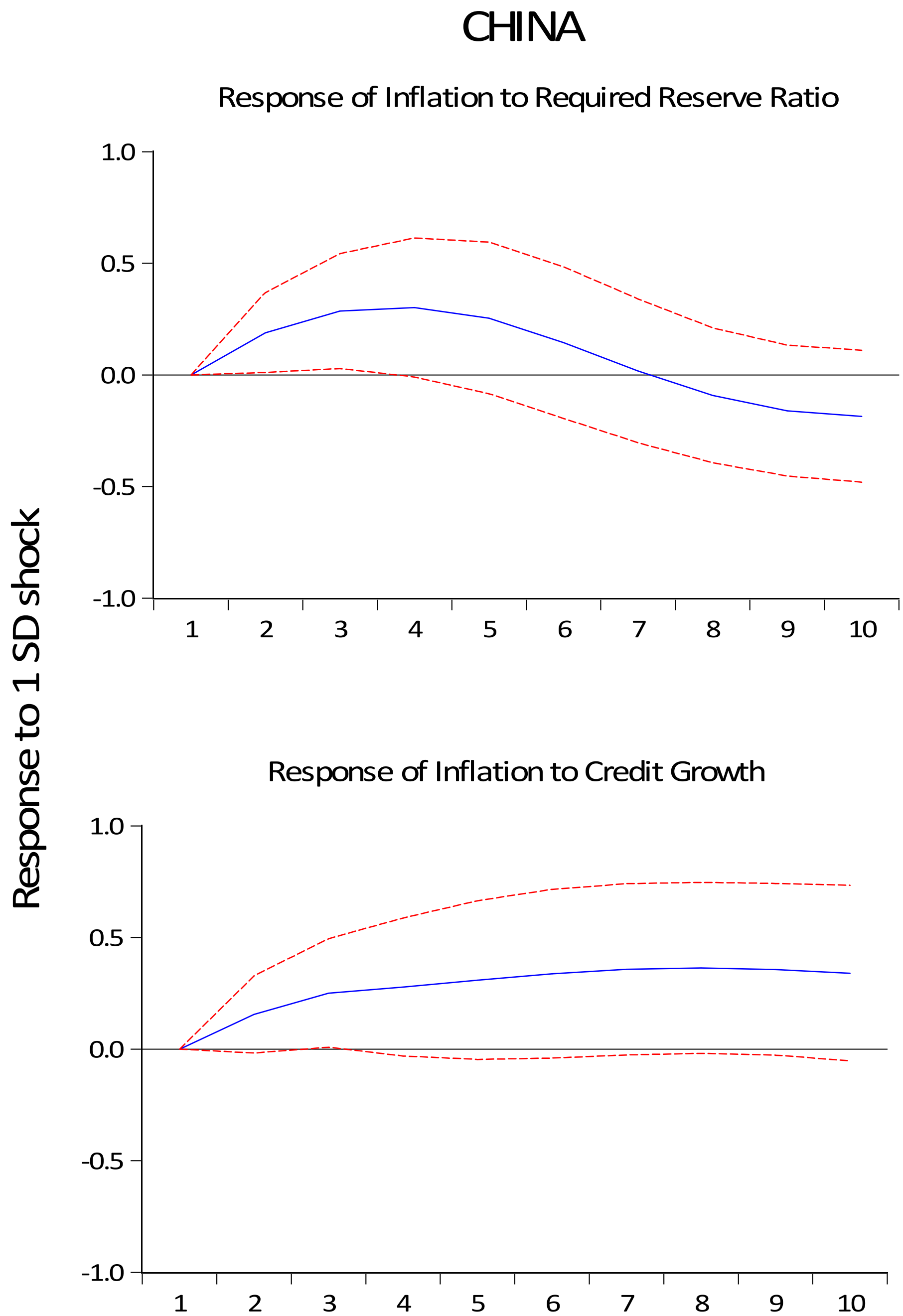
Figure 1a Selected Impulse Response Functions: China, Benchmark Model



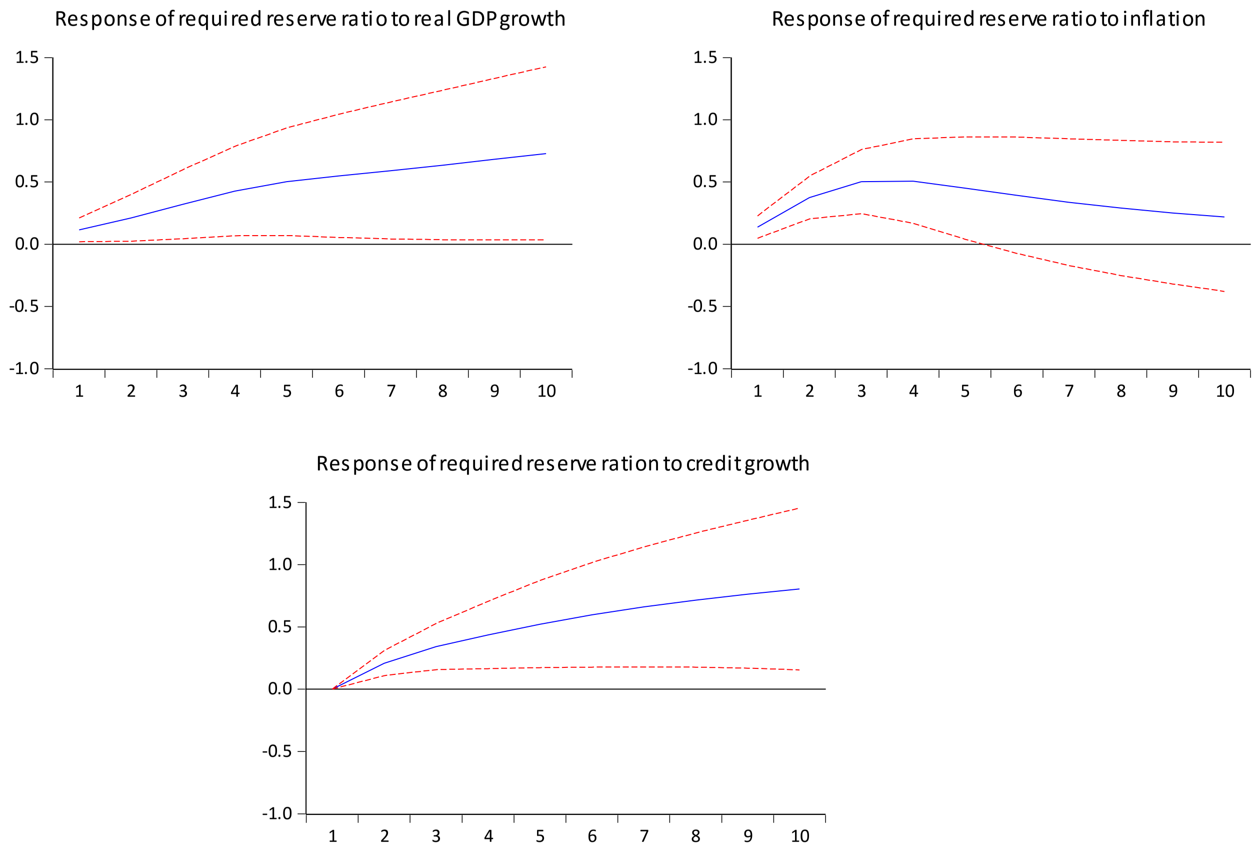
Note: Quarters are labelled on the horizontal axis. The benchmark model is equation (2) estimated with 2 lags. Only selected IRFs are shown. Confidence intervals are based on bootstrapped standard errors (1000 replications).

Figure 1b Selected Impulse Response Functions: China, Benchmark Model (cont'd)



Note: see note to Figure 1a.

Figure 2 Selected Impulse Response Functions: China, Monetary Policy

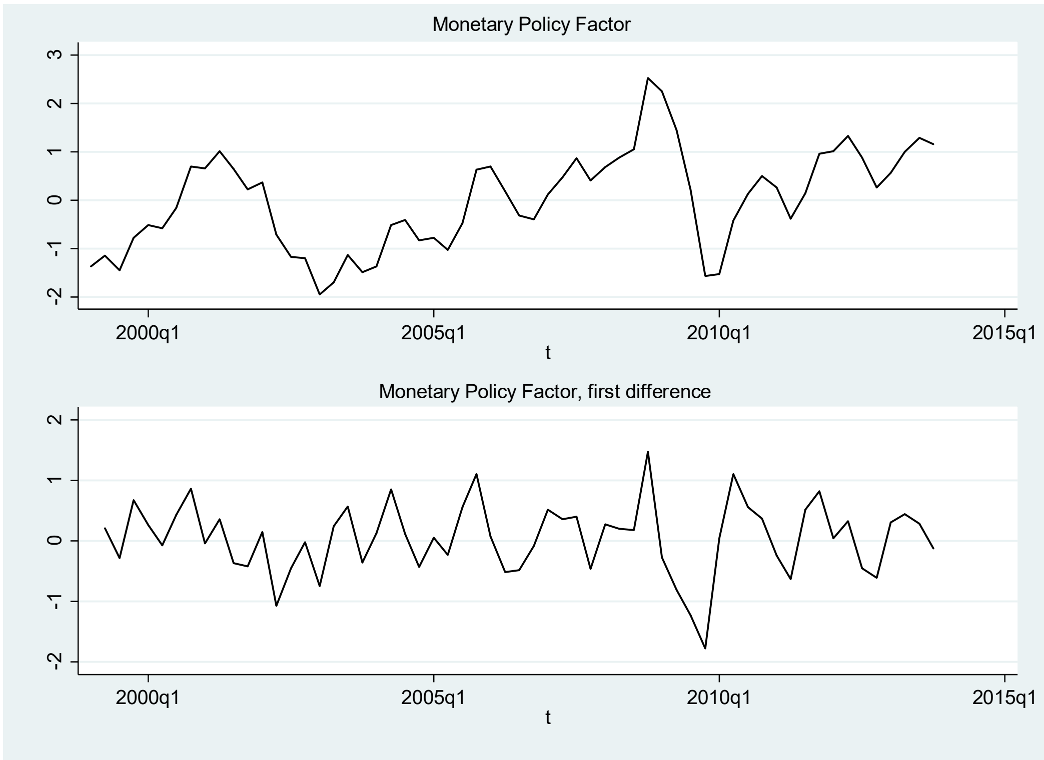


Note: IRFs are for the benchmark model (2). Required reserves are in first differences. Also, see notes to Figure 1a.

Figure 3a Real and Financial Factors, China

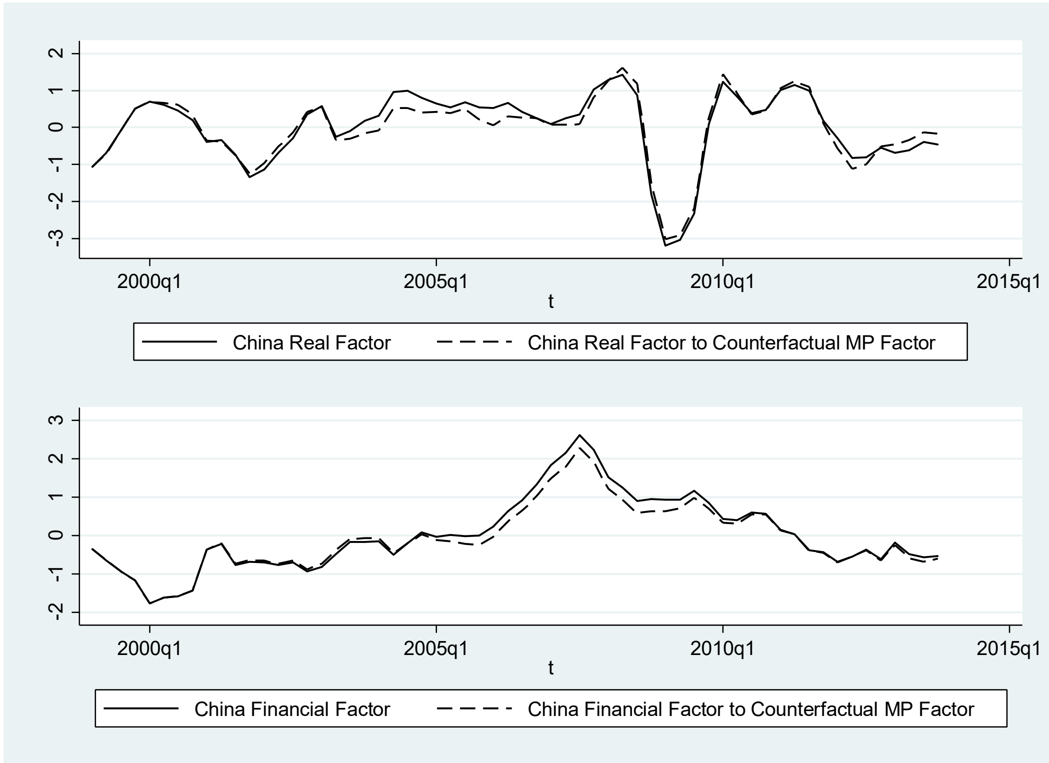
Note: real and financial factors are estimated via principal components. See the text for details. One version excludes monetary policy instruments while the other includes all candidate variables. The series (16 for the full case) in bold characters in the appendix are used to obtain the two factors. Factors are estimated via maximum likelihood and the varimax mehod is used to rotate the factors.

Figure 3b Monetary Policy Factor, China



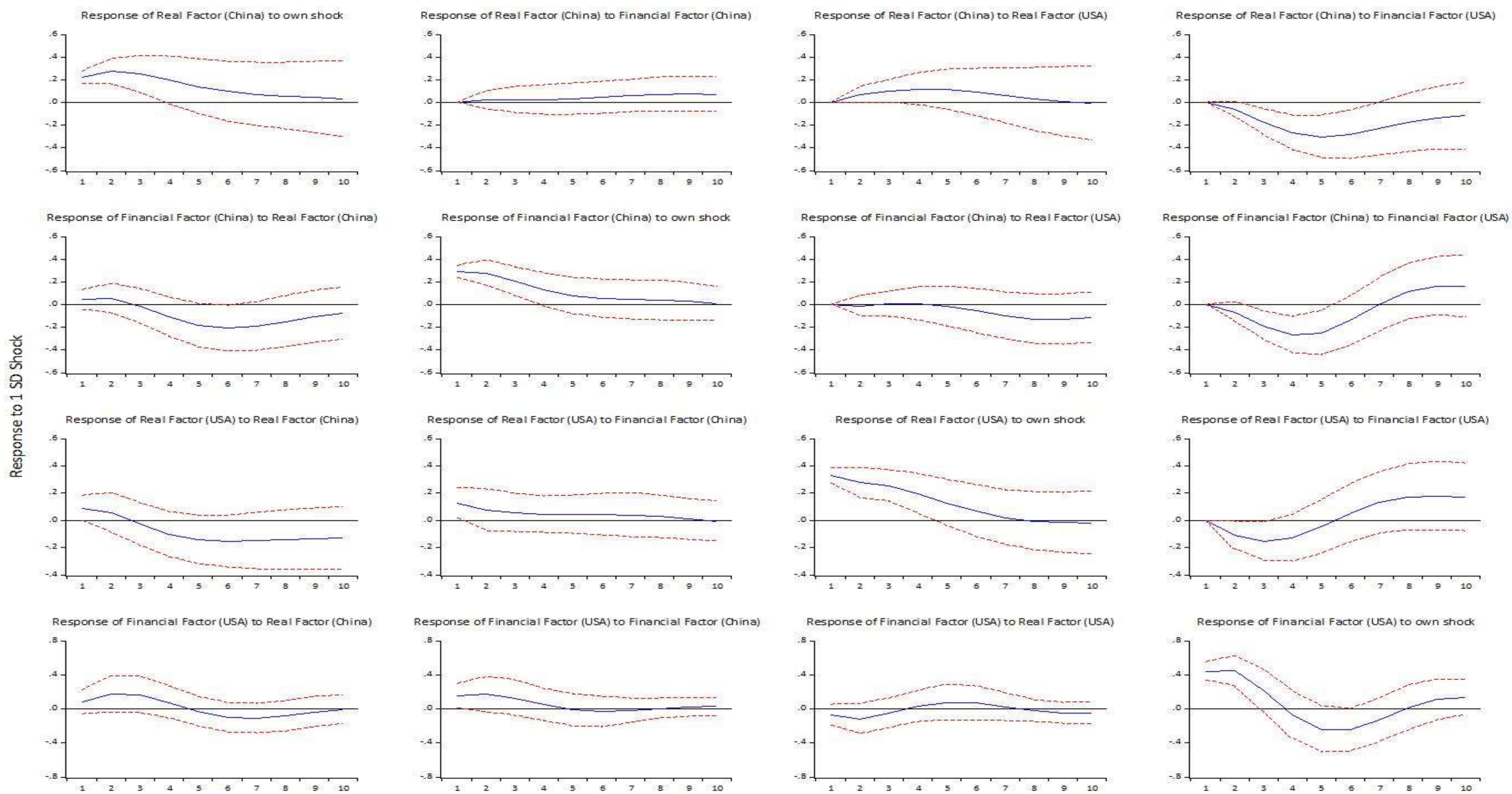
Note: see note to Figure 3a. Monetary policy is the first principal factor from a model containing the 4 instruments of monetary policy: required reserve ratio, PBOC's 24 hour interest rate, the real effective exchange rate, and base money growth.

Figure 4 Real and Financial Factors of China: Observed and Counterfactual



Note: Based on estimates of equation (6).

Figure 5 Impulse Responses Based on Equation (6)



Note: See Table 2 for the description of the VAR and Figure 1a for the derivation of the confidence intervals.

Table 1 Spillovers from the U.S. to China, Selected Estimates from FAVAR

	Real GDP growth	Inflation	Real Exchange Rate
Real USA Factor (-1)	**0.95**	**0.48**	-0.72
	(0.25)	**(0.15)**	(0.54)
	[3.76109]	**[3.26595]**	[-1.31469]
Financial USA factor(-1)	0.34	0.11	**1.67**
	(0.34)	(0.20)	**(0.74)**
	[0.97931]	[0.55187]	**[2.27009]**

Note: Based on equation (3). To emphasize the role of spillovers only the coefficients for b_1 and b_2 are shown. Estimates of the other parameters are available on request. The endogenous variables are: real GDP growth, inflation, real effective exchange rate, base money growth, commodity price inflation, required reserve ratio, and credit growth. The U.S. real and financial factors are exogenous and lagged one period. The VAR has 2 lags.

Table 2 Spillovers from U.S. Real and Financial Factors to China

	Real Factor CHINA	Financial Factor CHINA
Real USA Factor (-1)	**0.15**	-0.06
	(0.09)	(0.13)
	[1.68170]	[-0.48105]
Real USA Factor (-2)	-0.11	0.03
	(0.09)	(0.13)
	[-1.22262]	[0.23146]
Financial USA Factor (-1)	**-0.16**	**-0.16**
	(0.06)	**(0.08)**
	[-2.58980]	**[-1.90981]**
Financial USA Factor (-2)	-0.02	-0.12
	(0.07)	(0.10)
	[-0.25785]	[-1.17070]

Note: Based on estimates of equation (6). To conserve space only estimates of B(L) are shown. Estimates of the other parameters are available on request. Real and financial factors for China and the U.S. are the endogenous variables with China's monetary policy indicator and the U.S. fed funds rate lagged one period. The VAR has 2 lags.