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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 US 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 US to China are significant and originate from both through the real and financial sectors of the US economy.

Keywords: spillovers, monetary policy in China, dynamic factor models, credit.
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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 in recent decades. 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 that impact economies around the globe. 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 for 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 not only apparent 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.

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 simultaneously 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 in dealing with China's growing global economic influence. Second, whereas the U.S. has engaged in unconventional monetary policies over the past five years, while being constrained by the zero lower bound, 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 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 in order.

The rest of the paper is structured as follows. The next section summarizes the extant literature. The methodology and some stylized facts are described in section three. We estimate dynamic factor models as well as factor augmented VARs to evaluate the size of potential spillover effects from the U.S. to China's economy. 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, 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. 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 US to China are significant and originate from both through the real and financial sectors of the US 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.[1]

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 of 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

[1] 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.

other economies with similar levels of development or even compared to the case of an advanced economy. Yet, China's monetary policy can be understood as being set relying on multiple instruments. 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)).[2] This stands in contrast with reliance on the single interest rate instrument, until recently, common in advanced economies.

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), Mehrotra and Sanchez-Fund (2010), Koivu et. al. (2009)). 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)). Indeed, Girardin et. al. (2013) propose a sophisticated way of combining the various monetary policy instruments that the PBOC has employed over time to create a new monetary policy index. 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 concluded 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. Of course, the earlier results likely do not capture subsequent changes in the monetary transmission mechanism in China.

[2] 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).

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 transmission mechanism in China is found to be not dissimilar from that reported for the U.S. He et.al. (2013) conclude otherwise. Indeed, the combination of 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. 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 in the extent 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 the specification of rich but 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.[3]

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

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 examined in this study is characterized by the years when inflation control was the dominant concern of policy makers at the Fed during the so-called Great Moderation (Bernanke 2004). 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. Paralleling these developments is the switch from robust and stable real GDP growth prior to 2008 to weak economic performance that some herald an era of stagnation. In other words, the U.S. macroeconomic experience is similarly defined by unique features in the data. The Eurozone crisis would further contribute to keep not only policy rates low for the foreseeable future but stunt the emerging global economic recovery.

Clearly, there are challenges in estimating models for both large economies considered in this study. Nevertheless, the modelling of the interdependence of China's and the U.S.'s economies also reveals policy relevant questions about the level of cooperation or coordination at the international level.

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 which adhere to a modelling strategy that is broadly 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 impairment into the financial system to create the opportunity 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, and for different reasons, 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 mis-specification 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, due to an imbalance between the span of typical macroeconomic time series and the number of available variables, 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 weight 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 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. (2014) 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 consists in estimating a standard VAR followed by dynamic factor and factor-augmented or FAVAR models. The benchmark model contains variables that would appear in any standard macro model, including ones of the NK variety. We were motivated by the need to preserve degrees of freedom while utilizing a rich set of macroeconomic indicators for 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. While the different specifications are intended as a test for robustness there exists other ways of estimating the simultaneous relationship between two economies.[4] Nevertheless, partly to facilitate comparisons with the extant literature reviewed above, we restrict our estimates to factor models.

A conventional macroeconomic model, expressed in the vector autoregressive (VAR) format, assumes that the chosen variables are temporally related to each other in the following manner

$$\mathbf{y}_t^j = \mathbf{A}_0^j + \mathbf{A}_1^j \mathbf{y}_{t-1}^j + \boldsymbol{\varepsilon}_t^j \qquad (1)$$

where **y** is a vector of variables that include the macroeconomic time series that summarize the key economic relations of interest to policy makers. The index *j= US, CN* indicates that the same type of model can be estimated using either data from the US or China (CN). Initially at least, (1) is separately estimated for data from each economy.[5] Typically, the contents of the vector would consist of real GDP growth or the output gap, the price level or 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 four variables in the vector **y** affects all the other variables in the model, with a lag.[6]

The drawback with the standard macro-model formulation is that when the financial sector is believed to have macroeconomic consequences equation (1) will produce misleading inferences since variables that define credit conditions, such as the volume of loans, and other indicators of tightness or ease in credit conditions are omitted. If we incorporate these omitted variables into the vector **y** then we can rewrite equation (1) as follows

$$\mathbf{y}_t^{*j} = \mathbf{A}_0^{*j} + \mathbf{A}_1^{*j} \mathbf{y}_{t-1}^{*j} + \boldsymbol{\varepsilon}_t^{*j} \qquad (2)$$

where equation (1) has been modified to incorporate additional variables that proxy overall credit conditions. In other words, $\mathbf{y}^* = [\mathbf{y}, \mathbf{z}]'$, where **z** is a vector of variables proxying credit conditions. As we shall see below, there exist several proxies for both the US and

[4] 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.
[5] This approach does not prevent us from, say, estimating an open economy-type VAR for each economy.
[6] 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.

China. Equation (2) can be considered a benchmark model that captures the essence of real-financial links in either economy.

Next, we consider spillovers effects between the U.S. and China. To do so, and maintain the integrity of models such as (1) or (2), the following strategy is adopted. Suppose that we estimate U.S. and Chinese 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 other words, instead of estimating equation (2) for the U.S. and China, two new variables are created labelled, respectively, 'real' and 'financial' factors separately for the U.S. economy.[7] Assume also that U.S. factors are exogenous to China economy. This means the U.S. impacts China's economy but not vice-versa. If we now posit that it takes at least one quarter for U.S. economic shocks to affect China's macroeconomic conditions, a fairly common assumption under the circumstances, then one way of expressing the sources of spillovers into the Chinese economy is to estimate the following specification:

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

Equation (3) contains the six variables from China defined in equation (2), all of which are endogenous, with two additional exogenous variables capturing spillovers from the US, each lagged one period. Note that if we also estimate:

$$\mathbf{y}_t^{*US} = \mathbf{A}_0^{*US} + \mathbf{A}_1^{*US}\mathbf{y}_{t-1}^{*US} + \boldsymbol{\varepsilon}_t^{*US} \qquad (4)$$

we are effectively blocking macroeconomic effects from China to the US. This is merely a simplifying assumption which can be relaxed. However, to conserve space, this restriction is maintained in some of the results reported below.

If still more parsimony is deemed desirable, we can replace $\mathbf{y}^{*CN}$ with real and financial factors equivalents based on Chinese data only. In this case the following specification for China is estimated

[7] 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 a large number of variables can potentially influence the real and financial sectors of either economy.

$$\mathbf{y}_t^{*CN} = \alpha_0 + \alpha_1^{'}\mathbf{\Gamma}_{t-1}^{*j} + \varepsilon_t^{'CN} \qquad (5)$$

where $\mathbf{\Gamma}_t^{*j}$, j=CN, US, captures the real and financial factors estimated for each economy. Their construction follows from statistically combining several individual time series, via principal components analysis. More generally, we can estimate the relationship between the factors in a VAR framework by writing

$$\mathbf{\Gamma}_t^{CN} = A(L)\mathbf{\Gamma}_{t-1}^{CN} + B(L)\mathbf{\Gamma}_{t-1}^{US} + \mathbf{\eta}_t^{CN} \qquad (6)$$

where $\mathbf{\Gamma}$ is the vector of real and financial factors extracted from data from each economy. Equation (6) is a dynamic factor VAR (DFVAR).

Of course, real and financial factors are unobservable while some policy variables (e.g., policy rates, money supply) are observable. In yet another variant, if the factors summarizing U.S. and China's real and financial conditions are summarized by $\mathbf{\Lambda}$**,** then we instead can estimate the following specification written as

$$\begin{bmatrix} \mathbf{\Gamma}_t^j \\ \mathbf{X}_t^j \end{bmatrix} = B(L)\begin{bmatrix} \mathbf{\Gamma}_{t-1}^j \\ \mathbf{X}_{t-1}^j \end{bmatrix} + \mathbf{\zeta}_t^j \qquad (7)$$

where $\mathbf{\Gamma}_t^j = \{\phi_t^{R,j}, \phi_t^{F,j}\}$ are the real and financial factors, exclusive of monetary policy variables, while $\mathbf{X}_t^j$ represent the observable policy variables for *j= CN, US*. Equation (7) is the dynamic factor-augmented VAR (DFAVAR) model.[8] Equation (7) 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 US (i.e., the fed funds rate). In any event, we can still retain the essential structure of (7) by assuming that the only observable policy variable(s) are for the US. In this case we would rewrite (7) as follows

$$\begin{bmatrix} \mathbf{\Gamma}_t^j \\ \phi_t^{MP,CN} \\ \mathbf{X}_t^j \end{bmatrix} = B(L)\begin{bmatrix} \mathbf{\Gamma}_{t-1}^j \\ \phi_{t-1}^{MP,CN} \\ \mathbf{X}_{t-1}^j \end{bmatrix} + \mathbf{\zeta}_t^{'j} \qquad (8)$$

[8] 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.

where $ø_t^{MP,CN}$ is a monetary indicator for China. Note that in (7) and (8) we effectively relax the restriction that shocks from China cannot influence the US economy. Like the estimates of real and financial factors described above the monetary policy factor is estimated via the method of principal components. To estimate the various foregoing specifications, in a first step, the first two principal components extracted from the data set[9] such that

$$P_t^j \mathbf{Y}_t^j = \mathbf{\Gamma}_t^j + \mathbf{e}_t^j \qquad (9)$$

where P is a (linear) transformation of the series, represented by $\mathbf{Y}_t^j$ that make-up the macro model and, as previously defined, $\mathbf{\Gamma}$ are the estimated factors while **e** is a zero mean, constant variance error term.

The recursive ordering assumes that Chinese block comes first so that U.S. shocks are relatively more exogenous than are shocks from China. Formulations (7) or (8) provide challenges, as noted above, since it is not obvious that there exists a clearly observable policy instrument even for the US post-crisis. In the case of Fed policy substantial changes took place after that central bank reduced the fed funds rate 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 where their relative importance may have changed over time. Accordingly, we assume that the nominal exchange rate, money growth, reserve requirements for financial institutions, credit or window guidance (i.e., base money growth) or, alternatively, either open market operations or the total assets of the PBOC, at one time or other represent the policy instrument for China.

In view of the above characteristics of China's monetary policy, as well as prompted by a need to economies 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 US 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.

[9] Continuing with our earlier example this would constitute 6 series. However, there is nothing preventing us from considering a larger set of data (see below).

[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) provides one illustration. We consider this possibility below.

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 in the FAVAR are stationary the raw data were either differenced or log differenced if a unit root is detected (tests not shown).

Nevertheless, even as seems probable, the global financial crisis (GFC) of 2008–9 clearly dominates the behavior of key time series there is still the question of how to deal with this period. 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.[11] 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 influence the 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.[12]

4 Empirical results

Since a variety of models are estimated it is useful to begin by providing additional details about the core and other series that are included in various specifications. In the case of China the core series used in the benchmark VAR model 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. As noted previously alternatives were considered (e.g., a measure of the output gap instead of real GDP growth or an interest rate to replace base money growth). We comment below on the sensitivity of the results to these changes. For the U.S., following a long line of studies that estimate a small scale macro model, the core version includes real GDP growth PCE (personal consumption expenditures) inflation, inflation in oil prices (annualized; West Texas Intermediate crude), and the fed funds rate. Once again, alternative series are considered

[11] Dominguez, Hashimoto, and Ito (2012) date the GFC for China as starting 2008Q3 and ending 2009Q1. For the US the dates are: 2008Q4-2009Q2.
[12] Based on previous work (e.g., see Borio and Lowe (2002), and references therein) we rely on a large smoothing parameter ($\lambda = 100{,}000$).

such as an output gap measure (either based on an HP filter or derived from the Congressional Budget Office's measure of potential output) as well as a shadow fed funds rate after 2008 from Wu and Xia (2013).

An augmented version of the benchmark model adds the required reserve ratio and credits advanced by financial institutions while the US equivalent adds the data from the Senior Officer Loan Survey (SLOS) as well as the volume of commercial loans. For China the additions recognize the role of reserve ratios and loans made by financial institutions as instruments of PBOC policy and as indicators of financial conditions. The same applies to the U.S. case which is inspired by relevant work suggesting that financial sector conditions are well proxied by these two variables (e.g., see Siklos and Lavender (2015), and Lown and Morgan (2006)).

In deriving the real and financial factors via principal components analysis we considered several other variables, in addition to the ones described above. For China they are: an indicator of the business climate, a measure of property prices, share prices using the index for stocks in Shanghai, an indicator of energy consumption, the current account to GDP ratio, an indicator of economic policy uncertainty due to Baker, Bloom and Davis (2013) adapted for China[13], and the rate of change (annualized) in foreign exchange reserves. For the U.S. the following time series were added: 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 core series listed above these series combine to form the basis of the principal components analysis used to extract the real and financial factors (i.e., $\mathbf{\Gamma}_t^j$ defined above). Finally, the monetary policy variables for China used in the DFVAR and DFAVAR models consist of the required reserve ratio, credits from financial institutions and money base growth.[14] In the case of the U.S., **X** (see equation (8)) is given either by the fed funds rate or the fed funds rate replaced by its shadow rate after 2008.[15]

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

[14] We also estimated a version with the real exchange rate but the conclusions were unaffected. Hence, we did not pursue this version in estimating $\phi^{MP,CN}$.

[15] 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.

As noted above the sample limits the lag lengths that can be used in the various specifications considered. However, relying on the Schwarz or final prediction error (FPE) criteria it was generally found that all the specifications can be reliably estimated with 2 or 3 lags. Figure 1 shows a selection of impulse responses (IRFs) from the benchmark model for China which augments traditional a macro model with a proxy for developments in the financial sector.[16] To conserve space we omit discussion of U.S. results. These are relegated to an appendix.

The top portion of the Figure reveals a positive relationship between inflation and real GDP growth for at least 3 quarters. Figure 1 reveals, however, that inflation initially responds positively to a required reserve ratio shock although the effect is temporary falling to insignificance after 4 quarters. Inflation responds positively, however, to a credit shocks and the impact seems permanent even if the (analytic) confidence bands suggest the effect may not be significant. Nevertheless, as shown in the top portion of the Figure real GDP growth responds positively to a credit shock. Clearly then, even the benchmark model highlights an important role for the financial sector in explaining the evolution of economic activity in China.

Figure 2 shows additional IRFs from the same model for the monetary policy variable, namely the required reserve ratio. Assuming this is the principal policy instrument of the PBOC (see, however, below) a one-time shock to the ratio is not seen as reducing real GDP growth. Nevertheless, an inflation shock and a 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. Not shown is the IRF that indicates a rise in inflation following a required reserve ratio shock suggestive 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. The bottom line then, so far, is that there are several 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 other economies.

[16] Not shown are IRFs that show real exchange rate appreciations as 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 shocks is considered.

We next turn to the analysis of the various factor VAR models. Figure 3a plots two versions of the estimated real and financial factors for China. In one case the three monetary policy instruments are excluded while in another case all candidate series (a total of 15) are considered for China; fewer for the U.S. (not shown) are included in the other estimates. While both versions are comparable there are subtle differences between the two versions. The real factor exhibits a larger fall when the monetary policy instruments are excluded than when they are included. This represents an indirect indication of the ability of monetary policy to mitigate the impact of the global financial crisis. Similarly, omitting a role for monetary policy instruments would imply a monetary policy that is tighter than otherwise would have been the case during 2008–9. This confirms that monetary policy was indeed loose during the global financial crisis. Figure 3b shows estimates of the monetary policy factor based on a principal component analysis applied to the three selected monetary policy instruments. A rise in the factor here implies a tightening of policy. The tightening of policy by the PBOC leading up to the global financial crisis is clearly evident as is 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. Our estimates are also not too dissimilar from the ones proposed by Girardin et al (2013, Graph 1) who rely on different sources to derive an indicator of monetary policy.

Tables 1 and 2 show selected estimates of spillover effects from U.S. macroeconomic policy on China's economy. Table 1 shows the case where the benchmark model for China is augmented with estimated real and financial U.S. factors (i.e., equation (8)). 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 tightening of the financial sector in the U.S. is similarly seen as prompting a real appreciation of the renminbi.

Table 2 presents spillover estimates for the case where the most parsimonious macro model is estimated (i.e., equation (6)). The results here are somewhat different from the less restricted model as no statistically significant links are found between real U.S. and Chinese factors. Nevertheless, as in the case above, there is a small but significant cumulative impact from a change in U.S. financial conditions on financial conditions in China.

We also conducted a number of sensitivity tests (not shown). For China and the U.S. we re-estimated 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 were 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 replaced consumer price inflation in China with a retail price index or the GDP deflator. This change had almost no impact on the conclusions. To deal with the price puzzle we added inflation expectations, again relying on the Consensus inflation forecasts. The results shown above were 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.

Although we do not separately discuss the U.S. results there are a couple of results 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 response both countries in 2008–9. Similarly, the drop in real economic conditions in 2008–9 and the subsequent recovery is also a feature of the China's and 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 than in China's case as shown in Figure 3b. 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 had 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 the zero lower bound was hit. As pointed out above we faced 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 were found from the U.S. to China the reverse was not found. Hence, at least in the period investigated, macroeconomic conditions in China did not impact U.S. real or financial conditions.

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, were not found to be statistically significant. A second objective was 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, the case of the U.S., lending conditions as reflected in the Fed's loan officer survey. The latter, in particular, have been found to be useful in improving our understanding of the impact of monetary policy (e.g., see Siklos and Lavender (2015), Lown and Morgan (2006)).

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 policy in both countries helped reduce the severity of the negative shock that became 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.

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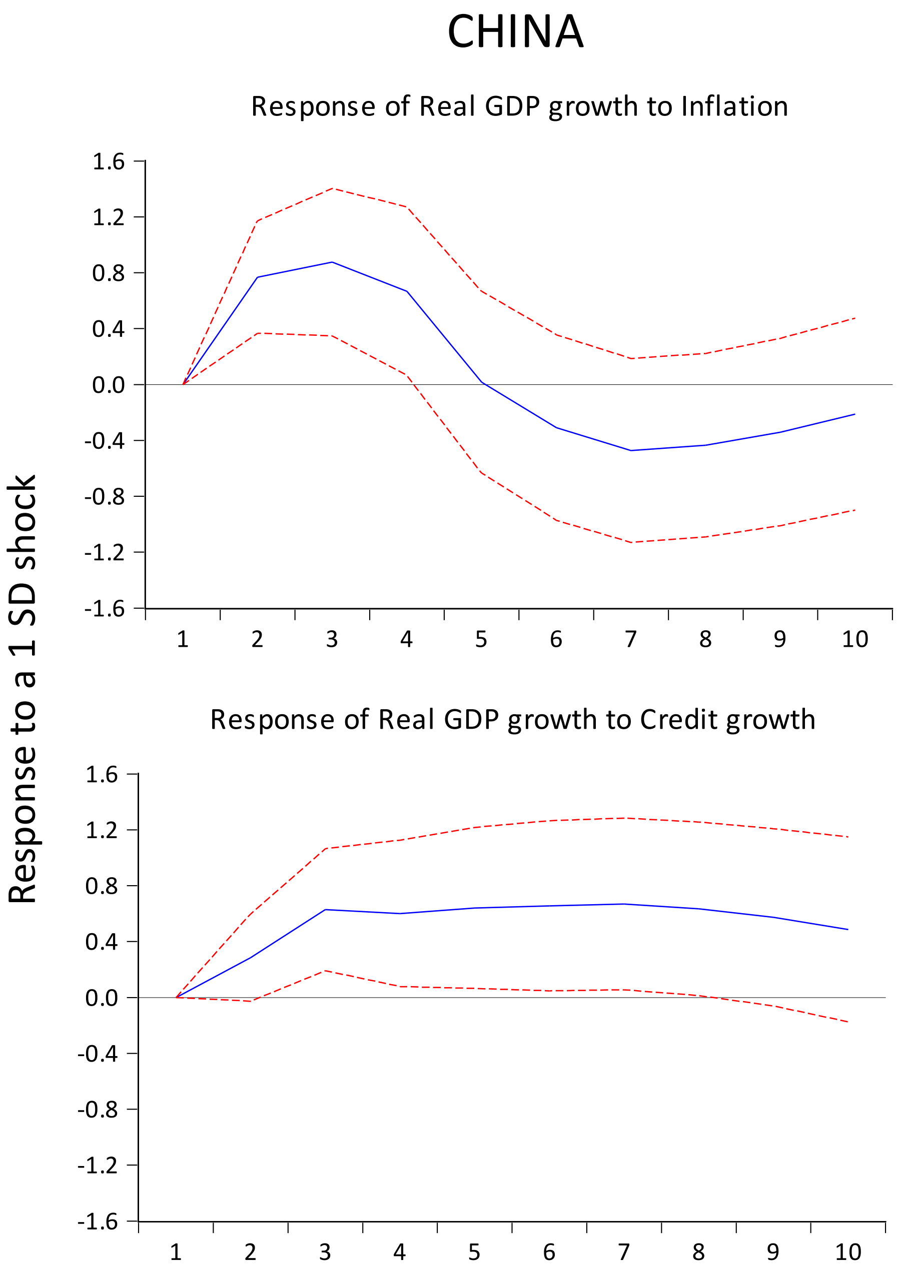
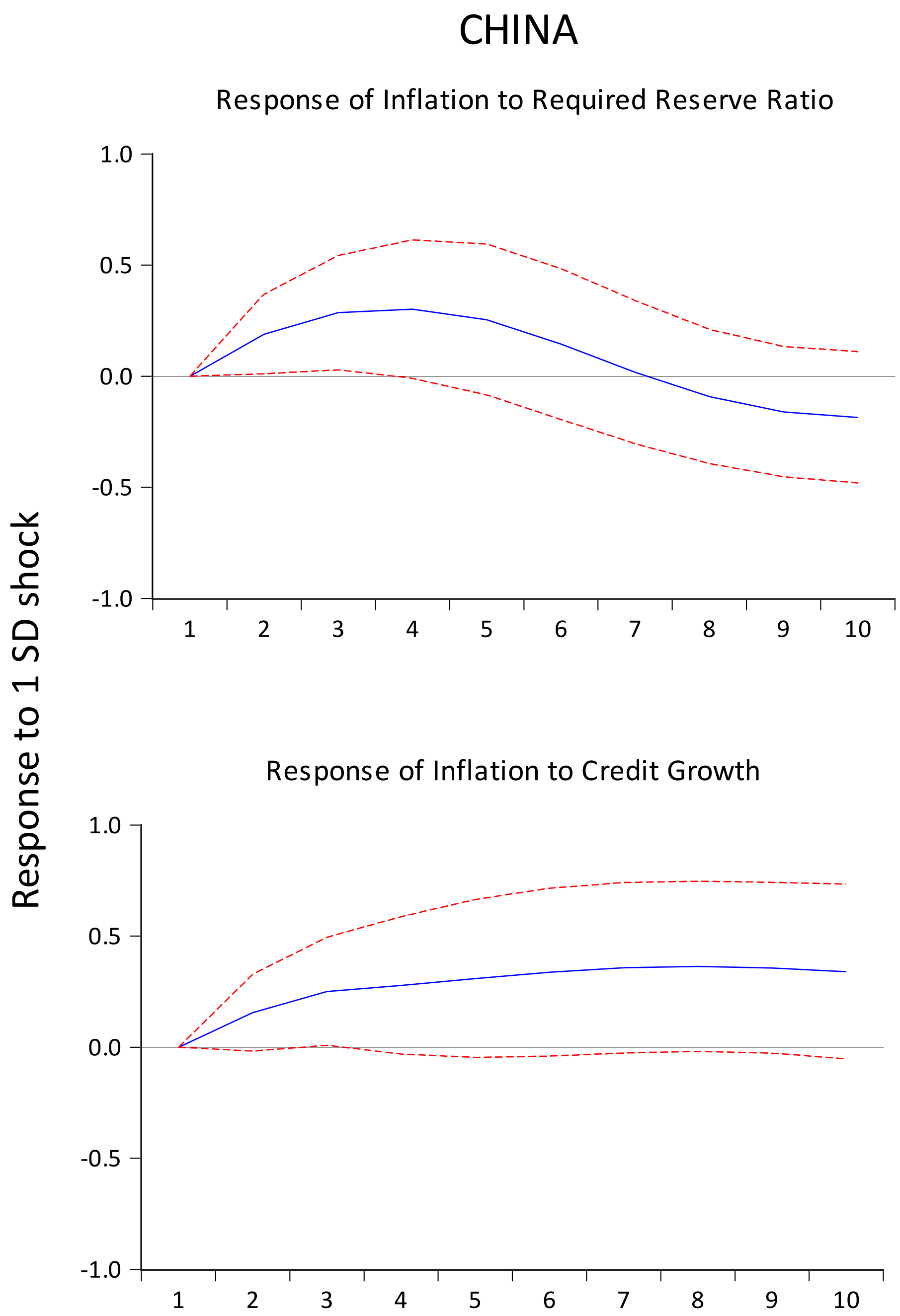
Figures and tables

Figure 1a Impulse response functions: China, benchmark model



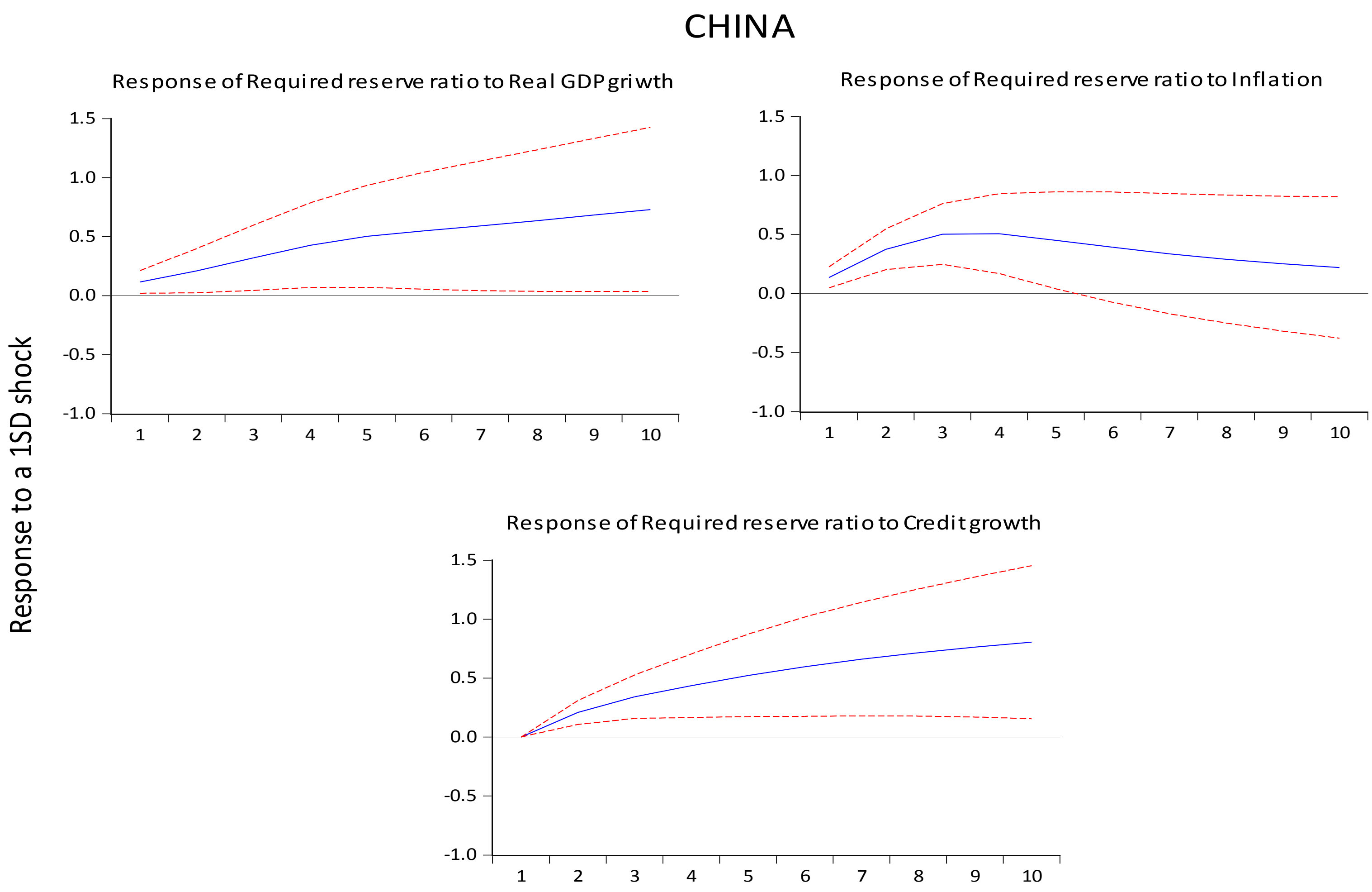
Note: Quarters are labelled on the horizontal axis. The benchmark model is equation (2). Only selected IRFs shown. Confidence intervals are based on bootstrapped standard errors (1000 replications).

Figure 1b Impulse response functions: China, benchmark model (cont'd)



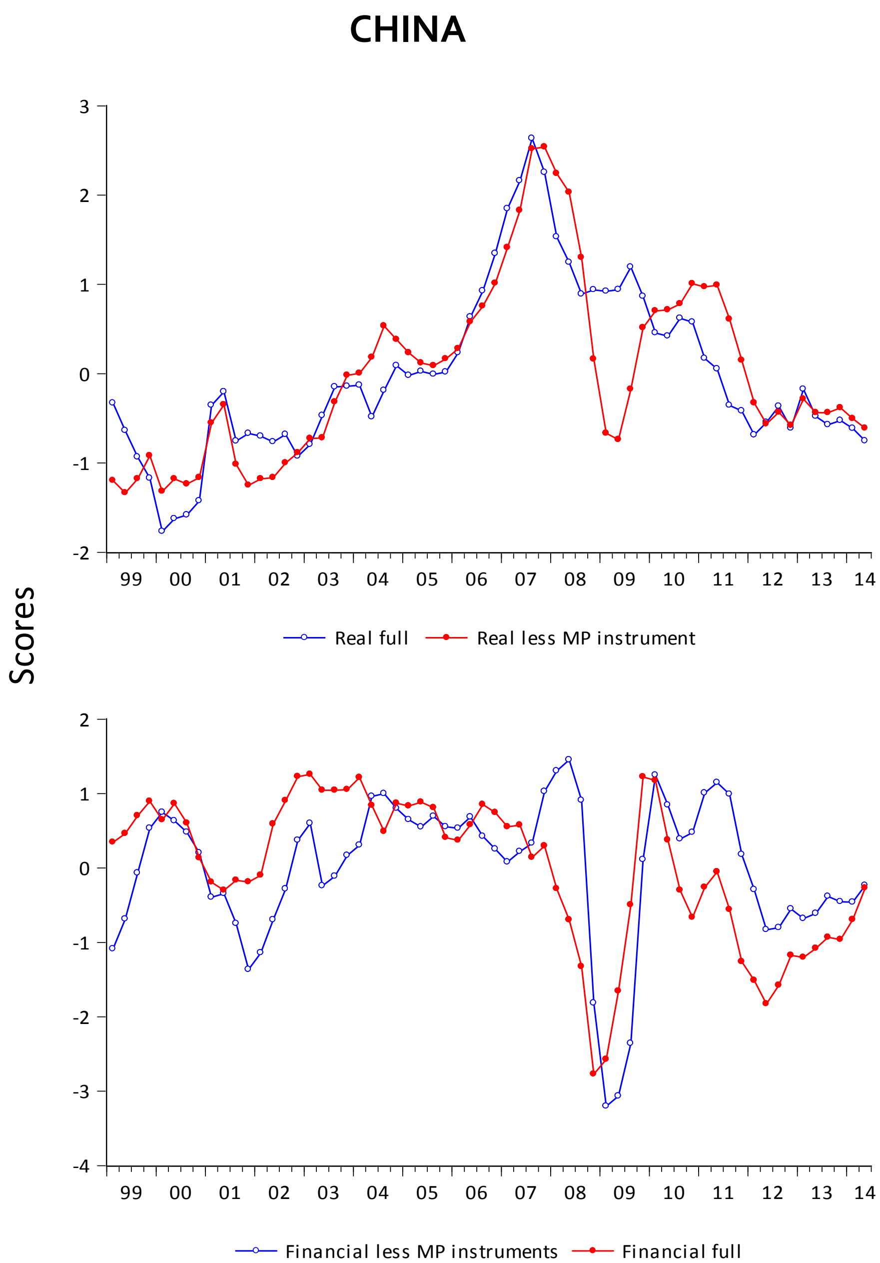
Note: see note to Figure 1a.

Figure 2 Impulse response functions: China, monetary policy



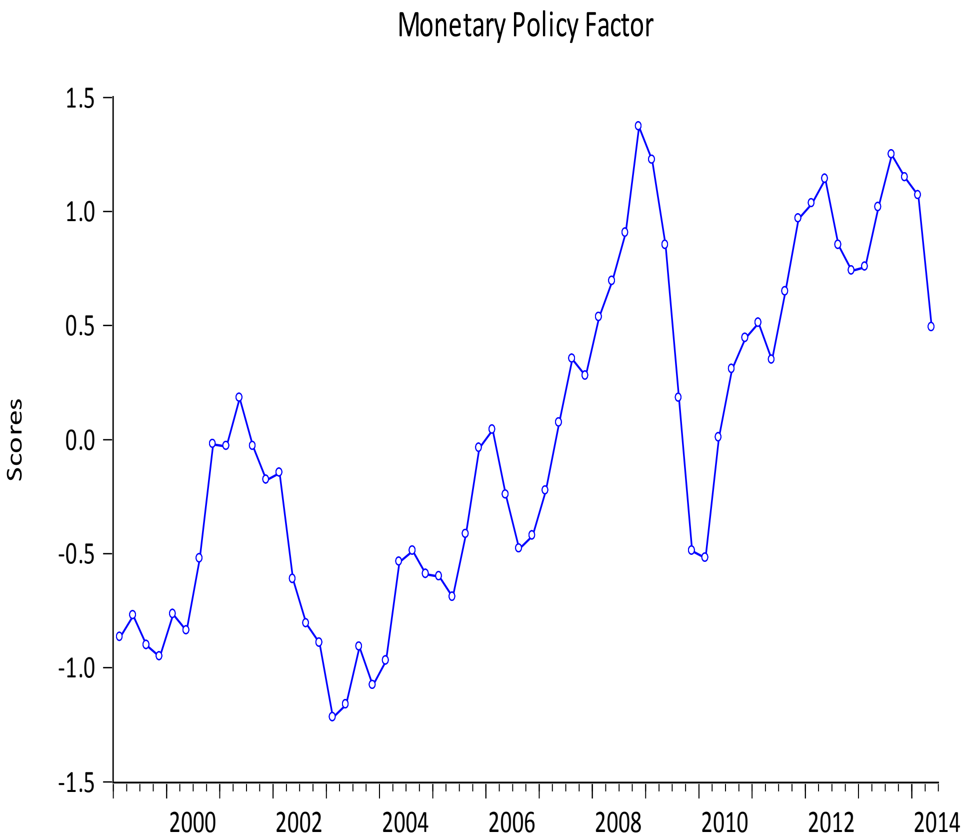
Note: IRFs are for the benchmark model (2). Also, see notes to Figure 1.

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 (listed in the text) while the other is for all real and financial variables.

Figure 3b Monetary policy factor, China



Note: see note to Figure 3a.

Table 1 Spillovers from the U.S. to China, benchmark estimates

	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).

Table 2 Spillovers from U.S. real and financial factors to China

	Financial factor CHINA	Real 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 select estimates of equation (6) through (8). See the text for the estimation of real and financial factors as well as Figure 3.

Appendix – Variables employed

A China

Real economy	**Financial**	**Monetary policy**
Real exchange rate	90 day interest rate (PBOC)	Exchange rate (nominal vis-à-vis US dollar)
Consumer price index	**Foreign exchange reserves (US dollars)**	Discount rate (PBOC)
Recession indicator	Domestic sovereign debt	24 hr central bank rate (PBOC)
Consumer confidence index	**Total credit: households /non-financial firms**	M2
Exports	**Stock market index (Shanghai**/Shenzhen)	**Required reserve ratio**
Imports	**Property prices**	**Monetary base**
Real GDP		
Earnings indicator		
Construction activity indicator		
Energy production indicator		
Economic policy uncertainty		
Inflation forecast (one year ahead)		
Real GDP growth forecast (one year ahead)		
Oil prices (international)		
Current account balance (to GDP)		
Foreign direct investment		
Industrial production		
Commodity prices		
Business climate index		

Note: In bold the series used to derive factors (see Figure 3).

B US

Real economy	Financial	Monetary policy
PCE deflator	**3 month commercial paper rate**	**Fed funds rate**
Real GDP	Total credit	Excess reserves of the banking system
Economic policy uncertainty	Financial conditions index	Central bank total assets (US Fed)
Inflation forecast (one year ahead)	**Total commercial loans (volume)**	Shadow fed funds rate (Wu-Xia version)
Real GDP growth forecast (one year ahead)	**Long-term interest rate (US govt, 10 years and over)**	
National financial conditions index	3-month Treasury bill rate	
Oil prices	**Senior loan officer survey indicators**	
Output gap (CBO, HP)	VIX	
Unemployment rate gap (relative to ‘natural’ rate)	**Housing prices**	
NBER recession dates	Stock market index (S&P, Wilshire)	
Private non-residential fixed investment	Debt/GDP ratio	

Note: See note to part A. Sources given in the main body of the text. Generally samples begin in 1998Q1 and end anywhere from 2013.4 to 2014.2. Daily and monthly data converted to quarterly via arithmetic averaging. Generally real indicators are available at the quarterly frequency while financial and monetary policy indicators are available at higher sampling frequencies.

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