BANK OF CANADA
BANQUE DU CANADA
CELEBRATING 75 YEARS
CÉLÉBRONS 75 ANS

Working Paper/Document de travail
2010-17

The Transmission of Shocks to the Chinese Economy in a Global Context: A Model-Based Approach

by Jeannine Bailliu and Patrick Blagrave

www.bank-banque-canada.ca

Bank of Canada Working Paper 2010-17

July 2010

The Transmission of Shocks to the Chinese Economy in a Global Context: A Model-Based Approach

by

Jeannine Bailliu and Patrick Blagrave

International Economic Analysis Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
jbailliu@bankofcanada.ca
pblagrave@bankofcanada.ca

ISSN 1701-9397

Acknowledgements

We wish to thank Douglas Laxton and Ondra Kamenik for all their assistance in preparing this paper. We benefited from comments received during presentations at the 2009 Meetings of the Canadian Economics Association, the 2009 Central Bank Macroeconomic Modelling Workshop, the 2009 Meetings of CEMLA's Researchers Network, the Banco Central de Chile, and the Hong Kong Monetary Authority. We also benefited from discussion with, and comments from, Don Coletti, Brigitte Desroches, Ali Dib, Robert Lafrance, René Lalonde, Philipp Maier, Eric Santor, and Larry Schembri. Any remaining errors are the responsibility of the authors. The authors would like to thank Maggie Jim for excellent research assistance.

Abstract

To better understand the dynamics of the Chinese economy and its interaction with the global economy, the authors incorporate China into an existing model for the G-3 economies (i.e., the United States, the euro area, and Japan), paying particular attention to modelling the exchange rate and monetary policy in China. Their findings suggest that the Chinese economy adjusts more slowly to shocks, compared to the large advanced economies, because monetary policy is less effective and the real exchange rate more persistent. In addition, the authors' model underscores the importance of spillovers from China to the G-3 economies, and vice versa, thus highlighting the need to analyze the Chinese economy in a global context.

JEL classification: E32, E52, F41
Bank classification: Economic models; International topics; Business fluctuations and cycles; Exchange rate regimes

Résumé

Pour mieux comprendre la dynamique de l'économie chinoise et la manière dont elle interagit avec le reste du monde, les auteurs intègrent la Chine à un modèle qui englobe les économies du « G3 » (États-Unis, zone euro et Japon) en prêtant une attention particulière à la modélisation de la politique monétaire de ce pays et du taux de change du yuan. Leurs résultats indiquent que l'économie chinoise s'ajuste plus lentement aux chocs que les grandes économies avancées parce que la politique monétaire y est moins efficace et le taux de change réel plus persistant. Le modèle des auteurs fait également ressortir l'importance des influences réciproques entre la Chine et les économies du G3, d'où la nécessité de situer l'analyse de l'économie chinoise dans un cadre mondial.

Classification JEL : E32, E52, F41
Classification de la Banque : Modèles économiques; Questions internationales; Cycles et fluctuations économiques; Régimes de taux de change

1 Introduction

In recent years, China's importance to the global economy has increased rapidly. China's gross domestic product (GDP) is now the second largest in the world, and in 2009 China surpassed Germany and the United States as the world's largest exporter.[1] Given China's rising economic importance and extensive international linkages, it is important to develop a better understanding of the dynamics of the Chinese economy and its interactions with the global economy. Surprisingly, there are few studies that provide a model-based analysis of the transmission and propagation of shocks to the Chinese economy in a global setting. This paper contributes in that regard by incorporating China into an existing global model for the G-3 economies (i.e., the United States, the euro area, and Japan) and using the new extended model to study how shocks, both domestic and external, are transmitted and propagated in the Chinese economy.

To our knowledge, our paper is the first to examine this question with a global model whose parameters are estimated. Our model is based on the framework developed by Carabenciov et al. (2008) for the G-3 economies: the Global Projection Model (GPM).[2] Given that this model is designed for a typical advanced economy, we modify its structure to better capture the key characteristics of the heavily managed Chinese economy. Our work pays particular attention to modelling the exchange rate and monetary policy. In particular, monetary policy in China is modelled using a combination of two monetary policy reaction functions: a Taylor-type rule, and a monetary policy rule based on the control of the money supply in the spirit of McCallum (1988). An exchange rate variable is included in both equations to account for the fact that the Chinese authorities place considerable weight on controlling the exchange rate when setting monetary policy. And the real exchange rate is modelled taking into account the presence of a trend in both the actual and equilibrium real exchange rates, as well as China's exchange rate regime, where the authorities control, to a large extent, movements in the exchange rate.

Modelling the Chinese economy is a challenging undertaking given its rapid, but as-of-yet incomplete, transformation from a command to a market economy. We believe the framework used in the paper is particularly well suited to study the Chinese economy, for four reasons. First, the benchmark model is sufficiently flexible that it can be adapted to better capture the key characteristics of the Chinese economy. And, despite this flexibility, the framework used has solid theoretical underpinnings, since it is based on richer models with microfoundations.

[1] China's GDP is ranked second, after the United States, when measured in purchasing-power parity. China was the world's largest exporter in 2009, according to the World Trade Organization.

[2] The GPM is a simple reduced-form model that is intended to capture the main ingredients behind richer models with microfoundations. It blends New Keynesian elements with the real business cycle tradition methods of dynamic stochastic general equilibrium (DSGE) modelling with rational expectations.

Second, the global nature of the model enables us to capture the important international linkages between China and the three largest advanced economies. With this framework, we are able to capture not only the direct effects of each shock on the Chinese economy (for example, a shock to U.S. inflation), but also the indirect effects that are transmitted to China via the response of the other countries to each shock. Third, the global model is simple enough that it can be estimated using Bayesian methods, which enables us to incorporate information from our priors with that contained in the data. The Bayesian approach is particularly useful in the case of China, since some of the parameters in the model may be weakly identified by the data, given the short sample period available and the nature of the Chinese economy. The use of priors can help add structure to these otherwise uninformative data, thus giving rise to more sensible posterior parameter estimates. And finally, the model also yields interesting insights into the determinants of Chinese monetary policy, the evolution of Chinese inflation, and the factors driving movements in the Chinese output gap over history.

Our paper should be viewed as complementing related work. Although China isn't explicitly modelled, emerging Asia is one of the regions in the Global Economy Model (GEM), a multi-country DSGE model based on a fully defined optimizing framework (see Laxton 2008 for more information on the GEM). Our work also complements a recent paper by Straub and Thimann (2009), who develop an open-economy model for China with a focus on analyzing both the domestic and the external implications of a change in the Chinese exchange rate regime. The focus of those two papers differs from ours, and the models in both are calibrated, whereas our model is estimated. However, all three papers emphasize the need to adapt macroeconomic models developed for the advanced economies in order to better capture the key characteristics of the Chinese economy, as well as emphasize the importance of studying the Chinese economy in a global setting.

Our paper yields several interesting findings. First, we find that foreign demand shocks have more important effects on the Chinese economy than on the large advanced economies. Moreover, a historical decomposition of our model-based estimate of the Chinese output gap suggests that external demand has played an important role in explaining movements in the Chinese output gap over the past decade. These results are not surprising, given that China is a very open economy. They also highlight the importance of modelling the Chinese economy in a global setting that can properly account for key linkages across the major economies. Second, we find that Chinese shocks, particularly real equilibrium exchange rate shocks, are not only a key driver of the Chinese economy, but they also play an important role in the other advanced economies. This is consistent with the view that shocks to the Chinese economy have had important effects on the global economy in recent years, and underscores the importance of including China in global models given its key role in the world economy. Third, our results suggest that the Chinese economy adjusts more slowly to shocks, compared to the large advanced economies, because monetary policy is less effective and the real exchange rate more persistent. Overall, our model displays sensible properties and does a reasonably good job of replicating the key dynamics of the Chinese economy, suggesting that it is a useful framework for analyzing China.

This paper is organized as follows. In section 2, we describe the framework used to model the Chinese economy in a multi-country setting. In section 3, we discuss the estimation methodology and parameter estimates. In section 4, we use the estimated model to analyze the effects of shocks on the Chinese economy, and compare them to the advanced economies by using both impulse-response functions and variance decompositions. In section 5, we consider the model's interpretation of history, and in section 6 we offer some conclusions.

2 Model

We model the Chinese economy in a multi-country setting by incorporating it into an existing 3-country model, the GPM, developed by Carabenciov et al. (2008). This framework is intended to capture the main elements of richer models with microfoundations. It blends New Keynesian elements – namely, an emphasis on nominal and real rigidities and a central role for aggregate demand in output determination – with the real business cycle tradition methods of DSGE modelling with rational expectations. The GPM integrates a series of country models into a single global model, where the key features of the macroeconomic structure of each economy are characterized by a small number of behavioural equations. These also capture linkages across countries, and, in addition, exogenous stochastic processes for the unobservable variables are specified.

Given that the value-added of our paper is that it extends Carabenciov et al.'s (2008) model for the G-3 countries to include China, this section focuses on the model for the Chinese economy. In doing so, we make modifications to the structure of the benchmark country model, designed for a typical advanced economy, to better capture the key characteristics of the heavily managed Chinese economy and to successfully replicate both its macroeconomic dynamics and the effects of Chinese shocks on the major advanced economies.[3] We pay particular attention to how the exchange rate and monetary policy process are modelled, to ensure that the model adequately captures how monetary and exchange rate policy are conducted in China.

[3]More details on the structure of the benchmark country model, used to model the economies of the United States, the euro area, and Japan, are provided in Appendix A.

2.1 Behavioural equations

There are four behavioural equations at the core of the model for the Chinese economy. The first behavioural equation is an aggregate demand, or IS, curve that relates the level of Chinese real activity to expected and past real activity, the real interest rate, the rate of money growth, the real exchange rate, and the level of real activity in the economies of its trading partners. All variables are expressed as deviations from their equilibrium values so that the aggregate demand equation relates the output gap to its determinants as follows:

$$\begin{aligned} y_{ch,t} &= \beta_{ch,1} y_{ch,t-1} + \beta_{ch,2} y_{ch,t+1} - \beta_{ch,3}(R_{ch,t-1} - \overline{R}_{ch,t-1}) \\ &+ \beta_{ch,4}((\Delta M_{ch,t-1} - \pi 4_{ch,t-1}) - (\Delta \overline{M}_{ch,t-1} - \pi^{tar}_{ch})) + \beta_{ch,5} \sum_j w_{ch,j,4}(Z_{ch,j,t-1} - \overline{Z}_{ch,j,t-1}) \\ &+ \beta_{ch,6} \sum_j w_{ch,j,5} y_{j,t-1} + \varepsilon^y_{ch,t} \end{aligned} \tag{1}$$

where y is the output gap, R is the real interest rate, $\overline{R}$ is the equilibrium real interest rate, ΔM is the quarterly growth rate of the money supply (at annual rates), $\pi 4$ is the 4-quarter moving-average inflation rate, $\Delta \overline{M}$ is the growth rate of the equilibrium level of the money supply, π^{tar} is the inflation target, $Z_{ch,j}$ is the bilateral real exchange rate of the Chinese renminbi (RMB) relative to that of country j (such that an increase in $Z_{ch,j}$ represents a real depreciation of the Chinese RMB relative to the currency of country j), $\overline{Z}_{ch,j}$ is the equilibrium bilateral real exchange rate of the Chinese currency relative to that of country j, and ε^y is a disturbance term.[4] The foreign output-gap term is defined as a weighted average of the foreign output gaps, where the weights ($w_{ch,j,5}$) used are the ratios of Chinese exports to country j to its total exports to all the countries in the model.

The lead term captures the forward-looking elements in aggregate demand that arise in a framework where forward-looking households optimize their consumption. Thus, expectations of the future performance of the economy are assumed to influence current aggregate demand, because of the forward-looking nature of decisions made by individual households and firms. The own-lag term allows for inertia in the system and permits shocks to have persistent effects. As discussed in Clarida et al. (1999), the primary justification for allowing some form of lagged dependence in the IS curve is empirical, although it may be possible to explicitly motivate its presence by appealing to some form of adjustment costs. The real interest rate and money gap terms provide the crucial link between monetary policy actions and the real economy. Given the sluggish adjustment of prices, by varying the nominal interest rate or the growth

[4] The weights used to construct the effective real exchange rate term ($w_{ch,j,4}$) are the ratios of the sum of Chinese exports and imports with country j to the sum of its exports and imports with all the countries in the model.

rate of money the central bank is able to influence the real interest rate (or credit-growth) gap, and hence aggregate demand. The foreign activity variable and the real exchange rate term allow for critical links between the Chinese economy and the other economies in the model.

The second equation is an inflation equation, or Phillips curve, which links inflation to its past and future values, the lagged output gap, the effective exchange rate gap, and oil-price inflation. The Chinese inflation equation is thus assumed to take the following form:

$$\begin{aligned} \pi_{ch,t} &= \lambda_{ch,1}\pi 4_{ch,t+4} + (1-\lambda_{ch,1})\pi 4_{ch,t-1} + \lambda_{ch,2} y_{ch,t-1} \\ &+ \lambda_{ch,3}\sum_j w_{ch,j,3}\Delta(Z_{ch,j,t} - \overline{Z}_{ch,j,t}) + \nu_{ch,1}\pi^{RPOIL}_{ch,t} + \nu_{ch,2}\pi^{RPOIL}_{ch,t-1} - \varepsilon^{\pi}_{ch,t} \end{aligned} \tag{2}$$

where π is the quarterly rate of inflation (at annual rates), π^{RPOIL} is the rate of inflation of real oil prices (denominated in the domestic currency), and ε^{π} is a disturbance term. The weights ($w_{ch,j,3}$) used to construct the effective exchange rate term are the ratios of Chinese imports from country j to its total imports from all the countries in the model.

This inflation equation is in the spirit of the New Keynesian Phillips curve (NKPC), which evolves from the optimal price-setting behaviour of forward-looking firms in an environment of imperfect competition and price stickiness (i.e., it is assumed that firms set prices on a staggered basis). Equation (2) thus emphasizes the forward-looking process for inflation. And, as discussed in Gali and Gertler (1999), lagged inflation can also influence inflation dynamics in the NKPC framework if it is assumed that a fraction of firms set prices using a backward-looking rule of thumb. Inflation is also a function of the output gap, which in the NKPC set-up would be a proxy for marginal cost.[5]

In an open-economy setting, it is also appropriate to include an exchange rate term in the inflation equation. da Silveira, M. (2006) derives a version of the NKPC from a 2-country DSGE model in which the deviation of the terms of trade from its equilibrium value enters as a determinant of inflation to capture shifts in marginal cost that arise as a result of changes in the terms of trade. In our inflation equation for China, we use the exchange rate to proxy for the terms of trade, and hence include the change in the effective exchange rate gap as a determinant of inflation. We would expect a depreciation of the exchange rate above its equilibrium value to put upward pressure on prices, because of the resulting increase in marginal cost.

Equations (3) and (4) depict the monetary policy process in China. The third equation is the interest rate reaction function, where the short-term nominal interest rate is determined

[5] Since it is assumed in the NKPC framework that firms adjust their prices in response to expected movements in marginal cost.

as a function of its own lag and of the central bank's policy responses to movements of the output gap, deviations of the expected inflation rate from its target, and deviations of the rate of depreciation of the bilateral exchange rate of the Chinese RMB (relative to the U.S. dollar) from its targeted value.[6] One key difference between the Chinese monetary policy reaction function and that for the advanced economies (shown in Appendix A) is that Chinese policy rates also respond to deviations in the nominal exchange rate from a targeted path for appreciation or depreciation, unlike policy rates in the advanced economies. This Taylor-type rule for China takes the following form:

$$\begin{aligned} I_{ch,t} &= (1-\gamma_{ch,1})[\overline{R}_{ch,t} + \pi 4_{ch,t+3} + \gamma_{ch,2}(\pi 4_{ch,t+3} - \pi^{tar}_{ch}) \\ &+ \gamma_{ch,4} y_{ch,t}] + \gamma_{ch,5}(\Delta S_{ch,t} - \Delta \overline{Z}_{ch,t} - \Delta S^{tar}_{ch,t}) + \gamma_{ch,1} I_{ch,t-1} + \varepsilon^{I}_{ch,t} \end{aligned} \tag{3}$$

where I is the short-term nominal interest rate, ΔS is the nominal bilateral rate of depreciation of the Chinese RMB relative to the U.S. dollar, ΔS^{tar} is the targeted value of the nominal bilateral rate of depreciation of the Chinese RMB relative to the U.S. dollar, and ε^{I} is a disturbance term.

This specification for the monetary policy rule assumes that the central bank smooths interest rates, adjusting them gradually to the desired value. This behaviour is widely observed in practice and has been shown by Woodford (2003) to be a desirable outcome in a model for optimizing private sector behaviour, because it can help to steer private sector expectations of future policy.

The inclusion of an exchange rate term in the Chinese monetary policy reaction function accounts for the fact that the authorities put substantial weight on controlling the exchange rate when setting monetary policy. Monetary policy in China is therefore likely to respond to unwanted pressures or changes in the exchange rate. The Chinese interest rate reaction function captures the multidimensional nature of their mandate, where the authorities react not only to movements in the output gap and deviations of inflation from its target, but also to deviations of the rate of change of the exchange rate from its target. Thus, the Chinese central bank can be thought of as having a triple mandate, in contrast to the more conventional dual mandate that is assumed for the G-3 economies. As a result of this approach, Chinese monetary policy is less precise in its ability to control any one of the three components of its mandate.

It has become quite standard to characterize monetary policy in macroeconomic models via the implementation of an interest rate rule such as this one, which assumes that the

[6] The inflation target in China is assumed to be 3 per cent. This value is roughly consistent with the average over the sample period of the inflation target of the People's Bank of China, which is stated annually in its *Annual Report* (various years).

central bank's main instrument is the short-term interest rate. Although this assumption clearly applies to most advanced economies, it is not clear that, on its own, an interest rate rule would adequately describe the monetary policy process in China, because the People's Bank of China (PBoC) uses several monetary policy instruments.[7] We thus augment the Taylor-type rule with a monetary policy rule based on the control of the money supply, in the spirit of McCallum (1988). Such a rule is intended to capture monetary policy responses based on monetary aggregates, rather than interest rates. The focus on money as one of the key monetary policy instruments is consistent both with the PBoC's emphasis on monetary targeting and with empirical work investigating the fit of McCallum-type rules for China.[8]

Our money-based monetary policy rule takes the following form:

$$\begin{aligned} \Delta M_{ch,t} &= \varsigma_{ch,1}\Delta M_{ch,t-1} + (1-\varsigma_{ch,1})[\Delta \overline{M}_{ch,t} - \varsigma_{ch,2}(\pi 4_{ch,t+3} - \pi^{tar}_{ch}) - \varsigma_{ch,3} y_{ch,t}] \\ &- \varsigma_{ch,4}(\Delta S_{ch,t-1} - \Delta \overline{Z}_{ch,t} - \Delta S^{tar}_{ch,t}) + \varepsilon^{\Delta M}_{ch,t} \end{aligned} \quad (4)$$

where M is the money supply and $\varepsilon^{\Delta M}$ is a disturbance term.

The objectives of this money-based policy rule are similar to those set out in the interest rate reaction function defined above. Specifically, in the short run, the authorities deviate from the equilibrium growth rate for M2[9] in response to deviations of inflation from its targeted value, movements in the output gap, and changes in the exchange rate beyond the targeted rate of appreciation. The response of this variable to any given shock is precisely the opposite of what we saw in the interest rate reaction function, since an increase in M2 is expansionary, while an increase in interest rates is contractionary.

Modelling the behaviour of China's real exchange rate is a challenging undertaking. In contrast to the G-3 economies that have flexible exchange rates, China has an exchange rate regime with extensive capital controls where the authorities control, to a large extent, movements in the exchange rate. As shown in Appendix B, both the nominal and real effective exchange rates in China appreciated steadily starting in July 2005, following the liberalization of the exchange rate regime, until the onset of the global financial crisis in 2008. It has been argued that the equilibrium real exchange rate also appreciated over this period, although not to the same extent as the actual real exchange rate, as a result of strong productivity growth in the tradable-goods sector.[10] As a result of these Balassa-Samuelson effects, there is a trend in China's equilibrium real exchange rate.[11] Thus, an important characteristic of

[7]For more on the different monetary policy instruments used by the PBoC, see Goodfriend and Prasad (2006).

[8]For examples of the latter, see Burdekin and Siklos (2008), and Koivu et al. (2008).

[9]M2, or money growth, is used as a proxy for the growth of credit in the Chinese economy.

[10]For instance, see Straub and Thimann (2009).

[11]According to the Balassa-Samuelson effect, based on Balassa (1964) and Samuelson (1964), if productivity

the Chinese exchange rate regime is the presence of a trend in both the equilibrium and the actual real exchange rates.

Following Carabenciov et al. (2008), we model the exchange rate in the three advanced economies using a version of uncovered interest rate parity (UIP), the approach typically used to model the exchange rate in standard open-economy macroeconomic models; the equilibrium exchange rate for the advanced economies is modelled as a random walk. This approach is clearly not appropriate for China, because it could not replicate the sustained – and controlled – appreciation of the actual exchange rate that we have witnessed in recent years and that we expect to continue in years to come. Nor could it account for the sustained appreciation of the equilibrium real exchange rate that has resulted from strong productivity growth in the tradable-goods sector. We thus modify the UIP and equilibrium exchange rate equations for China so that we are better able to capture the behaviour of China's real exchange rate, both equilibrium and actual.

The Chinese bilateral real exchange rate is thus modelled using the following version of UIP:

$$4(Z^e_{ch,t+1} - Z_{i,t}) - \Delta\overline{Z}_{ch,t+1} = (R_{ch,t} - R_{us,t}) - (\overline{R}_{ch,t} - \overline{R}_{us,t}) + \varepsilon^{Z-Z^e}_{ch,t}, \tag{5}$$

where the expected real exchange rate is assumed to evolve as follows:

$$Z^e_{ch,t+1} = \phi_{ch} Z_{ch,t+1} + (1-\phi_{ch})(Z_{ch,t-1} + 0.5\Delta\overline{Z}_{ch,t}). \tag{6}$$

Equations (5) and (6) differ from the exchange rate equations used for the advanced economies (shown in Appendix A). We include an additional term in each equation to account for the effects of movements in the equilibrium exchange rate on the formation of exchange rate expectations, as well as on the dynamics of the actual exchange rate. Equation (5) states that the difference between the real exchange rate and its expected value is a function of the real interest rate differential, the equilibrium real interest rate differential between the two countries, and the rate of change of the equilibrium real exchange rate. In this way, strict UIP does not hold in our model for China. Still, any deviation in the real interest rates across the two countries should result in either an expected change in the exchange rate, a change in the rate of depreciation of the equilibrium real exchange rate, and/or a deviation in the equilibrium real interest rates in the two countries. Any other movement in the exchange rate is captured by the residual in the equation (which can be thought of as a temporary shock to

in the tradables sector grows faster than in the non-tradables sector, the resulting higher wages in the tradables sector will put upward pressure on wages in the non-tradables sector, resulting in a higher relative price of non-tradables (i.e., a real appreciation of the exchange rate). For empirical evidence of Balassa-Samuelson effects, see Ricci et al. (2008), among others.

the risk premium).

As shown in Equation (6), in this "hybrid" version of UIP, the expected real exchange rate is not fully model-consistent, but also depends in part on past values of the real exchange rate. And, in contrast to the expectations-formation process for the G-3 economies, the expected real exchange rate for China is also a function of movements in the equilibrium real exchange rate. The equation for China's equilibrium real exchange rate, which also differs from that used in the G-3 economies, is presented in the next section.

2.2 Stochastic processes

As part of the model structure, exogenous stochastic processes that govern the path of the unobservable variables are also specified. More specifically, exogenous stochastic processes for potential output, the equilibrium real interest rate, the equilibrium real exchange rate, and the equilibrium level of the real oil price are specified. We first present two equations that describe the process for potential output. The first equation relates the level of potential output to its own lagged value, its quarterly growth rate, and the rate of inflation in real oil prices as follows:

$$\overline{Y}_{ch,t} = \overline{Y}_{ch,t-1} + g^{\overline{Y}}_{ch,t}/4 - \sigma_{ch}(\sum_{j=0}^{3} \pi^{RPOIL}_{ch,t-j}) + \varepsilon^{\overline{Y}}_{ch,t} \tag{7}$$

where $\overline{Y}$ is the level of potential output, and $g^{\overline{Y}}/4$ is the quarterly growth rate of potential. Equation (7) also includes a disturbance term that can cause permanent shifts in the level of potential output. The relationship between potential output and oil prices is such that higher inflation in real oil prices is expected to result in a permanent decline in the level of potential output.

The second equation relates the growth rate of potential to its steady-state growth rate as follows:

$$g^{\overline{Y}}_{ch,t} = \tau_{ch} g^{\overline{Y}ss}_{ch} + (1 - \tau_{ch}) g^{\overline{Y}}_{ch,t-1} + \varepsilon^{g^{\overline{Y}}}_{ch,t}. \tag{8}$$

Therefore, the growth rate of potential can diverge from its steady-state growth rate following a disturbance, and it is assumed that it will return to steady state gradually, with a speed of return based on (1-τ). Thus, there can be shocks to both the level and the growth rate of potential output in our model. Shocks to the level of potential output can be permanent, whereas shocks to the growth rate result in highly persistent deviations in potential growth from the long-run steady-state growth rate.

Equation (9) defines the equilibrium real interest rate as a function of the steady-state real interest rate level:

$$\overline{R}_{ch,t} = \rho_{ch}\overline{R}_{ch}^{ss} + (1-\rho_{ch})\overline{R}_{ch,t-1} + \varepsilon_{ch,t}^{\overline{R}}. \tag{9}$$

The above specification allows for persistent deviations in the equilibrium real interest rate from its steady-state value in response to a stochastic shock.

Equation (10) relates the equilibrium level of the money supply to its steady-state value:

$$\Delta\overline{M}_{i,t} = \zeta_i\Delta\overline{M}_i^{ss} + (1-\zeta_i)\Delta\overline{M}_{i,t-1} + \varepsilon_{i,t}^{\Delta\overline{M}}, \tag{10}$$

where the steady-state growth rate of equilibrium money supply is defined as:

$$\Delta\overline{M}_{i,t}^{ss} = g^{\overline{Y}_i^{ss}} + \pi_i^{tar}. \tag{11}$$

Next, we turn to the process for the evolution of the equilibrium exchange rate in China, an important equation in our model. As shown in Appendix A, the equilibrium exchange rate in the benchmark model is assumed to follow a random walk. As discussed earlier, this assumption is clearly not appropriate in the case of China. Instead, for China, we assume that the rate of change of the equilibrium exchange rate is a function of its own lagged value and the deviation of the growth rate of potential output from its steady-state value as follows:

$$\Delta\overline{Z}_{ch,t} = \omega_{ch}\Delta\overline{Z}_{ch,t-1} - \psi(g_{ch,t}^{\overline{Y}} - g_{ch}^{\overline{Y}ss}) + \varepsilon_{ch,t}^{\overline{z}}. \tag{12}$$

The deviation of the growth rate of potential output from its steady-state value can be thought of as a "catch-up" term, and its inclusion in Equation (12) is intended to capture the link between ongoing productivity growth in the tradables sector in China and the sustained appreciation of its equilibrium real exchange rate.[12] Potential output growth shocks are thus transmitted to the Chinese economy through their effects on the real exchange rate. This is in contrast to the framework for the advanced economies, where shocks to potential output growth are transmitted to the rest of the economy via a cross-correlation between shocks to potential output growth and shocks to the output gap intended to capture the effects of the

[12]This type of Balassa-Samuelson result linking productivity growth in the tradables sector to a real exchange rate appreciation is typically found in 2-goods models. However, our framework is flexible enough to enable us to capture this channel, which we believe is an important one for China.

former shocks on aggregate demand via their influence on expected permanent income.[13]

3 Estimation

3.1 Estimation methodology

Our model is estimated using a Bayesian approach building on the methodology used in Carabenciov et al. (2008). In contrast to that study, however, we adopt a 2-step estimation procedure. First, we estimate the model for the G-3 economies as in Carabenciov et al. (2008), using data over the period 1994Q1–2008Q3. Second, we impose the posterior estimates from this first stage on the parameters for the G-3 economies and then estimate the global model, allowing only the parameters of the Chinese economy to be estimated. We adopt this approach because of the technical difficulties involved in estimating all of the parameters in the 4-country model at once.

For each country, we use the following data series in our estimation: real GDP, a short-term interest rate, consumer prices, and exchange rates. In addition, for the G-3 economies we use data on the unemployment rate, and for the United States we use a measure of bank lending tightness that is based on data from the Federal Reserve Board's quarterly *Senior Loan Officer Opinion Survey on Bank Lending Practices*. We also use data on world oil prices. Appendix C provides more details on the sources of the data and on the variable definitions.

In the second stage of our estimation, we use data for the Chinese economy over the period from 2000Q1 to 2008Q3. We use a shorter sample period for China because data prior to the year 2000 are not very informative for estimating the key relationships in our model, given the significant structural changes in the Chinese economy since the 1990s. And, while economic reforms have continued in China since 2000, they have been more modest.

The methodology that we use allows us to jointly estimate the model's behavioural parameters and the stochastic processes that govern the low-frequency movements in the data. We do not need to pre-filter the data, and so we do not lose important information contained in the trends. We use Bayesian methods and are hence able to incorporate the information from our priors, appropriately weighted, with the information contained in the sample. As previously mentioned, this approach is particularly useful when estimating a model over a short sample period where some parameters may be weakly identified by the data. In the case of China, the data may not be very informative for certain parameters, because of changes to the exchange rate and monetary policy regimes over the sample period. This framework also enables us to capture heterogeneity across countries, because both the priors and sample periods used in the estimation can vary across countries.

[13] See Carabenciov et al. (2008) for more details.

3.2 Parameter estimates

In establishing our priors for the structural parameters for the Chinese equations in our model, we use the priors for the G-3 economies set out in Carabenciov et al. (2008) as a starting point. We then make adjustments where needed to capture those aspects of the Chinese macroeconomy that we would expect to be different. The priors and estimated results are shown in Appendix D.

The only parameter whose prior we modify in the Chinese IS curve (Equation (1)) is β_6, which captures the degree of openness of the economy. We increase the prior on β_6 to 0.4, to reflect the fact that the Chinese economy is more open than the economies of the United States, the euro area, and Japan.[14] The posterior estimate for β_6 indicates that the data are supportive of our prior. As such, we would expect foreign demand shocks to have a larger impact on the Chinese economy than on the G-3 economies, all else equal.

The prior for β_5, the coefficient that relates M2 growth to the output gap, is set lower than the prior for the impact of the interest rate gap on the Chinese output gap. This reflects the fact that M2 growth is more volatile than the real interest rate gap.

Even though the priors for the other parameters in the Chinese IS curve are the same as those for the advanced economies, the parameter estimates for both β_2 and β_3 are not. Indeed, the posterior estimate for β_2, the coefficient on the lead of the output gap, is substantially lower in China. This suggests that agents are much less forward looking in China than in more advanced economies, perhaps because financial markets are not as developed, and agents are less able to smooth consumption over time.

Turning to the parameters in Equation (2), the Phillips curve, we lower the prior on λ_2 slightly to reflect the fact that, over recent history, we have seen a persistently positive output gap in China, which has been met with little in the way of persistently elevated inflation. We take this as evidence that the inflation process in China is less responsive to fluctuations in the output gap than is the case in typical industrialized economies. Our posterior estimate for this parameter falls well below our prior, thus confirming our intuition. Next, λ_1, the coefficient on the lead of inflation, is smaller in our model for China, relative to the estimates for the other G-3 economies, suggesting that inflation expectations are less well anchored in China. This result is not surprising, given the evolving nature of the monetary policy framework in China.

As discussed in section 2.1, we have made one important modification to the interest rate rule for China (Equation (3)), in that we include an exchange rate term to account for the fact that the authorities put considerable weight on stabilizing the exchange rate when setting monetary policy. This exchange rate term measures deviations of the rate of depreciation of

[14] The prior on β_6 for the G-3 economies ranges between 0.03 and 0.05.

the bilateral exchange rate of the Chinese RMB (relative to the U.S. dollar) from its targeted value, and γ_5 is the coefficient that captures the importance the authorities accord to this term when setting policy rates.[15] We assign a prior of 0.20 to γ_5, which is slightly lower than our prior for the weight that the authorities put on deviations of inflation from target.[16] This seems reasonable, given that the authorities are unlikely to have to put a very large weight on stabilizing the exchange rate when setting policy interest rates, since extensive capital controls were in place over the sample period in China. The posterior estimate for γ_5, at around 0.11, suggests that policy rates in China respond somewhat less to changes in the exchange rate than we would have anticipated, perhaps because capital controls were particularly effective over the sample period and/or because other monetary policy instruments were also used to stabilize the exchange rate.[17]

There are two other differences between the interest rate reaction function in China and that used for the more advanced economies. First, the prior on γ_2, the weight on deviations of expected inflation from target, is set lower in China because it is assumed that the Chinese central bank is less concerned with inflation movements than their counterparts in the United States, the euro area, and Japan. The posterior estimate for γ_2 is actually lower than the prior, thus providing support for this view. Second, we calibrate γ_1, the coefficient on the lagged interest rate, because we believe that the data are not very informative in determining the value for this parameter. Policy interest rates in China did not move much over the early part of the sample (from 2000 to 2005), most likely because the authorities were concerned about the fragility of the banking sector. We thus believe that the posterior estimate for this parameter overestimates the degree of interest rate smoothing in the Chinese interest rate reaction function over the sample period, and in particular since 2006, when the Chinese authorities started changing policy rates much more frequently.

Concerning the parameter estimates for the second lever of monetary policy in China, the target for M2 growth, it appears that the authorities assign approximately equal weight to their output-gap and inflation objectives when setting their target for M2 growth (posterior estimates of ς_2 and ς_3 are virtually identical).

[15] This coefficient is assumed to follow a gamma distribution, since values for γ_5 should be non-negative, but need not have a constrained positive domain.

[16] Our prior for the weight the authorities put on deviations of inflation from target is 0.3 (i.e., $(1-\gamma_1)\gamma_2$).

[17] Many studies in the literature treat China as having a purely fixed exchange rate regime (for example, see Straub and Thimann 2009). In our model, this would entail a very high value for γ_5, alongside a value of zero for γ_2 and γ_3. We do not feel that such a specification adequately captures the Chinese situation, since capital controls and extensive sterilization efforts have given the Chinese authorities the ability to partially control inflation and output over the sample period, while still exerting control over the exchange rate. We tried estimating our model with a completely fixed exchange rate, and the resulting model fit for nominal interest rates was very poor; the model properties were also suspect, since policy could not respond to movements in inflation or the output gap.

One final coefficient that is worthy of mention is ψ, the coefficient on the catch-up term in the Chinese equilibrium real exchange rate equation. We set a prior of 0.12 for this coefficient, with a tight standard deviation of 0.01. To assist with the interpretation of this parameter, consider a potential growth rate of 9 per cent (quarter-over-quarter, at annualized rates) in China. This growth rate differs from our assumed steady-state growth rate of 5 per cent for China. Thus, with Chinese potential growth at 9 per cent, we would expect the Chinese RMB to appreciate against the U.S. dollar by roughly 0.5 per cent per quarter (in real terms), ceteris paribus. The degree of appreciation of the real equilibrium exchange rate in our model is therefore in line with what is included in work by Straub and Thimann (2009). This appreciation would continue until the Chinese economy had converged to its steady-state growth rate.

In Appendix D, we provide the same information for the standard deviation of the structural shocks as we did for our coefficient estimates.[18] The prior mean on the standard deviation of the real equilibrium interest rate variable is higher for China than elsewhere.

Taken together, our parameter estimates indicate that the output-gap process in China is heavily dependent on foreign demand, and is less forward looking than in a typical advanced economy. Chinese inflation in our model is less influenced by the output gap than elsewhere. Monetary policy is conducted using two instruments, and responds to three variables. And our posterior estimates underscore an important role for the exchange rate, in both reaction functions.

4 What Shocks Drive the Chinese Economy?

In this section, we use the estimated model to analyze the effects of the key structural shocks, both domestic and foreign, on the Chinese economy, and compare them to the effects in the advanced economies. We first present impulse-response functions (IRFs) for a selection of the model's most important shocks. We then provide a decomposition of the forecast error variance for the endogenous variables.

4.1 Impulse-response analysis

Figures 2 to 10 in Appendix E plot the IRFs for a selection of the model's most important shocks.[19] For each shock presented, we show the IRFs for both China and one of the advanced countries, to highlight the differences in how shocks are transmitted between the two types of economies.

[18] All shock terms are assumed to follow an inverted gamma distribution, which guarantees a positive variance.

[19] All impulse responses shown in Figures 2 through 10 are for a temporary 1 per cent shock (i.e., lasting one period).

Figure 2 shows the effects of a Chinese demand shock on the key variables in the Chinese economy. As expected, a positive shock to the output gap results in an increase in the Chinese output gap, a rise in inflation, an increase in the nominal and real interest rates, and a real appreciation of the Chinese RMB. The effect of a domestic demand shock in China is broadly similar to the effects of a domestic demand shock in the G-3 economies. Figure 3 depicts the effects of a U.S. demand shock. There are three important differences between the U.S. and Chinese responses. First, the response of the real exchange rate in China is more long-lived after a demand shock in China, as a result of the persistence in China's real exchange rate. Second, inflation responds by less than in the United States, in part because the Phillips curve in China is less sensitive to movements in the output gap than elsewhere, and in part because of the larger currency appreciation that takes place in China, which tends to dampen the inflationary impact of the positive demand shock. Third, the Chinese authorities respond to this shock by contracting M2 growth, which implies that interest rates need not increase by as much as they do elsewhere in order to close the output gap. This result – that interest rates respond somewhat less to demand shocks in China than is the case in developed economies – is consistent with the relatively sluggish movement of Chinese nominal interest rates in recent years (see Figure 13 in Appendix J).

The response of the Chinese economy to a negative domestic inflation shock, shown in Figure 4, is qualitatively similar to the response of the G-3 economies (Figure 5 focuses on the U.S. response to a domestic inflation shock). Monetary authorities respond quickly to the fall in inflation by cutting the benchmark interest rate, and increasing M2 growth. These responses cause an output gap to open up. The exchange rate depreciates, due to the negative interest rate differential that emerges, providing further upward pressure on the output gap. The positive output gap creates inflationary pressures, thereby triggering the adjustment back to equilibrium. One important difference between the Chinese and U.S. responses to this negative inflation shock is the amount of excess supply that is required to bring inflation back to target. As Figure 4 shows, the Chinese economy requires an output gap that is roughly double the size of the U.S. gap in order to bring inflation to target. This is because inflation in China responds a good deal less to movements in the output gap than is the case elsewhere in the model. This result is consistent with recent historical outcomes in China, where we have seen a situation of excess demand emerge over the past several years without giving rise to high inflation.[20]

The response of the Chinese economy to a shock to potential output growth differs markedly from that of the G-3 economies. As Figure 7 shows, the euro area output gap starts to increase immediately in response to a shock to potential output growth. This move-

[20]Note that our measure of Chinese inflation, headline CPI, does not include housing price inflation.

ment in the output gap arises as a result of the cross-correlation between shocks to the output gap and potential output growth that we have imposed for the euro area. As discussed earlier, this cross-correlation is intended to capture the fact that aggregate demand should increase even before potential output starts to rise, in response to a persistent positive shock to potential output growth, because of the associated increase in expected permanent income (i.e., households and businesses will increase spending immediately in response to the shock, thus creating a positive output gap). Hence, for a typical advanced economy, the output gap increases immediately in reaction to the shock, and therefore the path of the other key variables in response to the shock is similar to that following a demand shock.

For China, we do not think that the channel through which a shock to potential growth affects aggregate demand is via its effect on permanent income. In our view, credit-constrained Chinese households are less likely to be able to borrow to increase their consumption, to the extent that the increase in consumption is financed through debt. For this reason, we have not imposed this cross-correlation of shocks for China. Instead, the channel of transmission for a potential growth shock in China is through the exchange rate, rather than through the output gap. Indeed, a positive shock to potential output growth creates a positive catch-up term in the equilibrium exchange rate equation, thus causing a steady appreciation of the equilibrium exchange rate. This channel is designed to capture Balassa-Samuleson-type effects in China, where large productivity shocks in the tradables sector are expected to lead to a steady appreciation of the equilibrium real exchange rate. And, over time, as the Chinese authorities allow the exchange rate to adjust, this should translate into a gradual appreciation of the actual exchange rate.

Thus, as Figure 7 shows, the creation of a positive output gap in the euro area causes a rise in inflation, an increase in the policy rate, and a real appreciation of the euro. In contrast, as Figure 6 shows, a shock to potential output growth in China causes a wedge to open between the potential growth rate and its steady-state level, leading to a gradual and persistent appreciation of both the equilibrium and the actual real exchange rates. The sustained appreciation of the exchange rate gives rise to some deflation, and the authorities respond by enacting stimulative monetary policy.

Figures 8 and 9, respectively, compare the Chinese and euro area responses to a 1 per cent U.S. demand shock. The foreign shock has a much larger effect on the Chinese economy, which results from the fact that the Chinese economy is much more open.

Figure 10 shows the response of the Chinese economy to a shock to M2 growth. The shock is not very persistent, and as a result it does not have a long-lived effect on Chinese output. The peak response of the output gap to a 1 per cent shock to M2 growth is a mere 0.1 per cent. Thus, the sensitivity of Chinese output to M2 growth shocks is smaller than with respect to interest rate shocks. This is to be expected, given that credit-growth shocks are likely to be considerably larger, and less persistent, than are interest rate shocks.[21]

4.2 Variance decomposition

In Appendix F, we provide the contribution of each of the structural shocks to the forecast error variance of the Chinese endogenous variables at several different horizons. In Appendices G–I, we provide the same information for the endogenous variables of each of the G-3 economies, to compare the importance of the different shocks in the Chinese economy relative to the advanced economies.

First, we examine the key shocks that drive the output gap. In the short run, a large proportion of the variation in the output gap in all four economies is attributable to domestic demand shocks (ε^y). Consistent with the impulse-response analysis, the variance decomposition suggests that foreign demand shocks are a more important driver of the output gap in China than in the advanced economies. In addition to foreign demand shocks, shocks to Chinese M2 growth ($\varepsilon_{ch}^{\Delta M}$) as well as Chinese inflation (ε_{ch}^{π}) play an important role in explaining most of the remaining short-run variation in the Chinese output gap. For the advanced economies, domestic shocks account for most of the short-run variation in the output gaps. In the medium term, domestic inflation and interest rate shocks (ε^I) become increasingly important, and there is also an important role for exchange rate shocks ($\varepsilon^{\bar{z}}$), both between the domestic economy and the United States and in the RMB/U.S.-dollar exchange rate. As a result of the persistence in the equilibrium exchange rate process, and the control that the Chinese authorities exert on the real exchange rate, shocks to Chinese exchange rates have an important impact on the Chinese economy, as well as on the other economies in our global model.

Next, we consider the key shocks that explain the variation in inflation rates. For all four economies, domestic inflation shocks dominate all other shocks as the short- and medium-term source of variation, and more so in China than elsewhere. Given that inflation expectations are assumed to be less forward looking in China, it is not surprising that domestic inflation shocks play such an important role in explaining the variation in Chinese inflation. In other words, inflation is modelled as a fairly backward-looking and sluggish process in China, and thus large inflation shocks are needed in order to replicate the volatility in the Chinese inflation data. This finding is consistent with the results of estimated DSGE models, such as in Smets and Wouters (2003), where large price-markup shocks are needed to replicate the volatility in inflation rates that is present in the data.

[21] In Appendix D, we show that shocks to M2 growth ($\varepsilon^{\Delta M}$) are much larger than shocks to interest rates (ε_{ch}^{I}).

Although inflation shocks remain the key driver of inflation in all four economies in the medium term, they decrease in importance over time, especially in the advanced economies, and other shocks take on a more prominent role. For the euro area and Japan, shocks to equilibrium exchange rates become a more important source of variation in the medium term.

Turning to policy interest rates, our results suggest that variation in Chinese rates is largely driven by shocks to domestic inflation, and to a lesser degree by shocks to the Chinese exchange rate. This is in contrast to the advanced economies, where domestic monetary policy shocks are more important in explaining the variation in policy rates.

Concerning the shocks that drive exchange rates in the model, it comes as little surprise that the real effective exchange rate is driven almost exclusively by shocks to domestic equilibrium exchange rates, as well as those of trading partners.

5 How Well Does the Model for China Perform over History?

5.1 Historical decomposition of the key Chinese variables

In Figures 11 through 14 in Appendix J, we provide the historical decomposition of four key Chinese variables into their main determinants based on the model's estimates: the output gap, the inflation rate, the interest rate, and the M2 growth rate.

Figure 11 depicts the evolution of the Chinese output gap. The model suggests that external demand has played an important role in explaining movements in the Chinese output gap since 2000, particularly during certain episodes. For instance, external demand was the key factor driving the positive output gap in China in the period leading up to mid-2001. And, when global demand slowed in 2001, external pressure on the Chinese output gap turned negative. Another important determinant of the Chinese output gap over history has been the real exchange rate gap, or the deviation of the actual real exchange rate from its equilibrium value. For virtually the entire sample, the model estimates that the Chinese equilibrium real exchange rate has been stronger than the actual real exchange rate, and that this exchange rate gap has put upward pressure on the output gap. A negative real interest rate gap has also played a role recently; the model interprets rates as having been stimulative through early 2008. This is not surprising, since rates were very slow to respond to the excess demand conditions that began to appear in mid-2005. Interestingly, though, the model suggests that contractionary M2 growth offset some of the excess stimulus provided by the Chinese interest rate policy, in the post-2007 period. M2 growth was also allowed to expand rapidly in the post-2001 period as external demand acted as a drag on the Chinese output gap.

The historical decompositions of inflation and the interest rate are shown in Figures 12 and 13, respectively. The inflation process appears to be quite volatile in China, and much of the volatility is captured by inflation shocks, rather than the endogenous variables in the model. The exchange rate gap, however, does play a small role throughout the sample period, particularly in accounting for some of the upward pressure on inflation. The same is true for the output gap in the latter part of the sample period. Note that both of the episodes of elevated inflation (late 2003 and late 2007) were driven almost exclusively by food-price inflation, which was driven by supply shocks. As such, we should not expect the model to explain the behaviour of inflation particularly well over these periods.[22]

As Figure 13 shows, there has been substantial inertia in the interest rate process in China over the sample period. Towards the end of the sample period, authorities did increase interest rates, and this seems to have been driven by inflation considerations. Figure 14 shows the historical decomposition of the M2, or credit growth, equation. Examining the period following the 2001 recession in the United States, we see that the Chinese authorities opted for expansionary money growth in response to low inflation rates. Later in the sample, in response to elevated inflation alongside a substantial positive output gap, it is clear that the authorities attempted to slow the economy by reigning in M2 growth from early 2007 through mid-2008.

5.2 The evolution of the Chinese output gap, real interest rate gap, and real exchange rate gap over history

In Figure 15 in Appendix K, we provide the model's interpretation of four key unobservable variables: the output gap, the real interest rate gap, the real exchange rate gap, and the real money gap. Because of the estimation technique that we employ, these gaps are computed using the entire state-space of the model, thus providing a much richer, model-consistent, view of these variables than would a simple filtering of the data.

Starting with the real exchange rate gap, the model suggests that, from 2002 onwards, the level of the Chinese RMB was above its equilibrium level. Initially, the gap was relatively modest. However, starting in the second half of 2004, the real exchange rate gap began to widen. Perhaps in response to this mounting pressure for the RMB to appreciate, the Chinese authorities liberalized their exchange rate regime in July of 2005, allowing for a one-time appreciation of 2.1 per cent. The stated policy from this point forward was that the RMB would follow a managed float against a basket of international currencies.

[22]It has been argued that Chinese inflation should be somewhat more responsive to fluctuations in the output gap, since the exchange rate is managed. However, this need not be the case if sterilization measures are widely used, as in China. Also, as noted previously, our measure of inflation does not include housing price inflation, which has been rising rapidly in China recently.

The model's interpretation of the real exchange rate gap over this period suggests that the change of policy from mid-2005 through mid-2006 had no discernible impact in reducing the size of the gap. In fact, the real exchange rate gap continued to grow until mid-2006. Perhaps as a result of this continuing pressure on the Chinese currency, the authorities began to allow a more rapid appreciation of the RMB, beginning in late 2006. A more rapid pace of nominal appreciation, alongside a pickup in inflation, arrested the widening of the real exchange rate gap. By mid-2008, the gap had been reduced substantially.

Turning to the model's interpretation of the real interest rate gap, it is clear that, since mid-2003, policy rates have been stimulative. Notably, the movements in this gap are primarily attributable to variations in inflation, since nominal rates over the sample period were relatively unchanged.

Clearly, the real exchange rate and real interest rate gaps have played a pivotal role in shaping the path of the output gap. From early 2002 until early 2005, the Chinese economy was in a situation of mild excess supply, but, since then, the output gap has turned positive. In our view, the Chinese authorities have the ability to mobilize factors of production in an exceptionally timely and efficient manner. In the period leading up to 2005, it was relatively easy to shift productive resources from the agricultural sector to the urban industrial sector that services China's growing export market. Thus, high growth could be achieved without encountering a situation of excess demand. From mid-2005 onwards, the model indicates that the Chinese economy moved into a situation of excess demand, which appears to have been driven by the negative real interest rate gap mentioned earlier, and also by a widening real exchange rate gap that fuelled export growth. It is also plausible that some of the early gains in potential output growth associated with resource reallocation by the Chinese authorities have become harder to replicate in recent years, as resources have become relatively more scarce.

6 Conclusions

In order to better understand the shocks that drive the Chinese economy, and how these shocks are transmitted to the large advanced economies, we incorporate China into a global model, based on the framework developed by Carabenciov et al. (2008) for the G-3 economies. The model is estimated using Bayesian techniques, which helps address the challenges posed when attempting to estimate a model using Chinese data, namely a short sample period and data with limited information content.

Our paper yields several interesting findings. First, we find that foreign demand shocks have more important effects on the Chinese economy than on the large advanced economies. Moreover, a historical decomposition of our model-based estimate of the Chinese output gap suggests that external demand has played an important role in explaining movements in the Chinese output gap over the past decade. These results are not surprising, given that China is a very open economy. They also highlight the importance of modelling the Chinese economy in a global setting that can properly account for key linkages across the major economies. Second, we find that Chinese shocks, particularly real equilibrium exchange rate shocks, are not only a key driver of the Chinese economy, but they also play an important role in the other advanced economies. This is consistent with the view that shocks to the Chinese economy have had important effects on the global economy in recent years, and underscores the importance of including China in global models given its key role in the world economy. Third, our results suggest that the Chinese economy adjusts more slowly to shocks compared to the large advanced economies, because monetary policy is less effective and shocks have a more persistent effect on the real exchange rate. And finally, our model displays sensible properties and does a reasonably good job of replicating the key dynamics of the Chinese economy, thus suggesting that our approach in modelling the exchange rate and monetary policy process in China is appropriate.

China's exchange rate and monetary policy regimes in macroeconomic models are interesting, albeit challenging, topics for ongoing research. Indeed, many studies in the literature treat China as having a purely fixed exchange rate regime. However, in theory, such an approach does not allow monetary policy to respond to movements in the output gap and inflation. Over the past several years, Chinese monetary policy has clearly responded to such movements while still exerting control over the exchange rate. This has been accomplished through the use of capital controls, as well as extensive sterilization measures. Explicitly incorporating these processes into macroeconomic models of the Chinese economy would be an interesting topic for future research.

References

Balassa, B. 1964. "The Purchasing-Power Parity Doctrine: A Reappraisal." *Journal of Political Economy* 72: 584–96.

Burdekin, R. and P. Siklos. 2008. "What Has Driven Chinese Monetary Policy Since 1990? Investigating the People's Bank's Policy Rule." *Journal of International Money and Finance* 27: 847–59.

Carabenciov, I., I. Ermolaev, C. Freedman, M. Juillard, O. Kamenik, D. Korshunov, D. Laxton, and J. Laxton. 2008. "A Small Quarterly Multi-Country Projection Model with Financial-Real Linkages and Oil Prices." IMF Working Paper No. 280.

Clarida, R., J. Gali, and M. Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature* 37: 1661–1707.

da Silveira, M. 2006. "Two-Country New Keynesian DSGE Model: A Small Open Economy as a Limit Case." IPEA Discussion Paper No. 1157.

Gali, J. and M. Gertler. 1999. "Inflation Dynamics: A Structural Econometric Analysis." *Journal of Monetary Economics* 44: 195–222.

Goodfriend, M. and E. Prasad. 2006. "A Framework for Independent Monetary Policy in China." IMF Working Paper No. 111.

International Monetary Fund. 2006. "Direction of Trade Statistics." Washington, DC.

Koivu, T., A. Mehrotra, and R. Nuutilainen. 2008. "McCallum Rule and Chinese Monetary Policy." Bank of Finland Discussion Paper No. 15.

Laxton, D. 2008. "Getting to Know the Global Economy Model and Its Philosophy." *IMF Staff Papers* 55: 213–42.

McCallum, B. 1988. "Robustness Properties of a Rule for Monetary Policy." *Carnegie-Rochester Conference Series on Public Policy* 29: 173–204.

People's Bank of China. various years. "Annual Report." Beijing: China.

Ricci, L., G. Milesi-Ferretti, and J. Lee. 2008. "Real Exchange Rates and Fundamentals: A Cross-Country Perspective." IMF Working Paper No. 13.

Samuelson, P. 1964. "Theoretical Notes on Trade Problems." *Review of Economics and Statistics* 46: 145–54.

Smets, F. and R. Wouters. 2003. "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area." *Journal of the European Economic Association* 1: 1123–75.

Straub, R. and C. Thimann. 2009. "The External and Domestic Side of Macroeconomic Adjustment in China." European Central Bank Working Paper No. 1040.

Woodford, M. 2003. "Optimal Interest-Rate Smoothing." *Review of Economic Studies* 70: 861–86.

Appendix A: Benchmark Country Model

Key behavioural equations

Output-gap equation:

$$y_{i,t} = \beta_{i,1} y_{i,t-1} + \beta_{i,2} y_{i,t+1} - \beta_{i,3}(R_{i,t-1} - \overline{R}_{i,t-1}) + \beta_{i,4} \sum_j w_{i,j,4} z_{i,j,t-1}$$

$$+\beta_{i,5} \sum_j w_{i,j,5} y_{j,t-1} + \varepsilon^y_{i,t}$$

Inflation equation:

$$\pi_{i,t} = \lambda_{i,1} \pi 4_{i,t+4} + (1 - \lambda_{i,1}) \pi 4_{i,t-1} + \lambda_{i,2} y_{i,t-1} + \lambda_{i,3} \sum_j w_{i,j,3} \Delta Z_{i,j,t}$$

$$+\nu_{i,1} \pi^{RPOIL}_{i,t} + \nu_{i,2} \pi^{RPOIL}_{i,t-1} - \varepsilon^\pi_{i,t}$$

Monetary reaction function equation:

$$I_{i,t} = (1 - \gamma_{i,1})[\overline{R}_{i,t} + \pi 4_{i,t+3} + \gamma_{i,2}(\pi 4_{i,t+3} - \pi^{tar}_i) + \gamma_{i,4} y_{i,t}] + \gamma_{i,1} I_{i,t-1} + \varepsilon^I_{i,t}$$

Exchange rate equations:

$$4(Z^e_{i,t+1} - Z_{i,t}) = (R_{i,t} - R_{us,t}) - (\overline{R}_{i,t} - \overline{R}_{us,t}) + \varepsilon^{Z-Z^e}_{i,t}$$

$$Z^e_{i,t+1} = \phi_i Z_{i,t+1} + (1 - \phi_i) Z_{i,t-1}$$

Potential output process:

$$\overline{Y}_{i,t} = \overline{Y}_{i,t-1} + g^{\overline{Y}}_{i,t}/4 - \sigma_i(\sum_{j=0}^{3} \pi^{RPOIL}_{i,t-j}) + \varepsilon^{\overline{Y}}_{i,t}$$

$$g^{\overline{Y}}_{i,t} = \tau_i g^{\overline{Y}ss}_i + (1 - \tau_i) g^{\overline{Y}}_{i,t-1} + \varepsilon^{g^{\overline{Y}}}_{i,t}$$

Equilibrium real interest rate process:

$$\overline{R}_{i,t} = \rho_i \overline{R}^{ss}_i + (1 - \rho_i) \overline{R}_{i,t-1} + \varepsilon^{\overline{R}}_{i,t}$$

Equilibrium real exchange rate process:

$$\overline{Z}_{i,t} = \overline{Z}_{i,t-1} + \varepsilon^{\overline{z}}_{i,t}$$

Real oil-price equations:

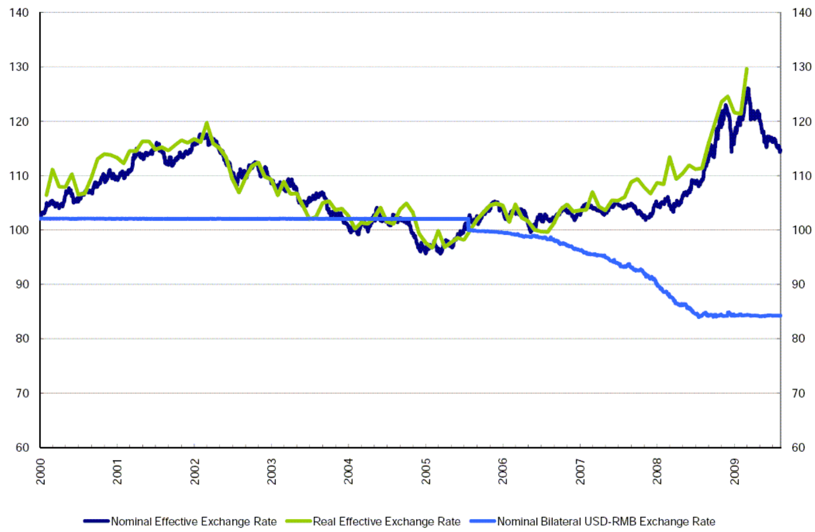
$$\overline{RPOIL}_{US,t} = \overline{RPOIL}_{US,t-1} + g^{\overline{RPOIL}}_{US,t} + \varepsilon^{\overline{RPOIL}}_{US,t}$$

$$g^{\overline{RPOIL}}_{US,t} = (1 - \rho_{g,US}) g^{\overline{RPOIL}}_{US,t-1} + \varepsilon^{g^{\overline{RPOIL}}}_{US,t}$$

$$rpoil_{US,t} = \rho_{rpoil,us} rpoil_{US,t-1} + \varepsilon^{rpoil}_{US,t}$$

Appendix B: The Exchange Rate

Figure 1: Movements in the Chinese Exchange Rate



Appendix C: Data Definitions

China

GDP China	Real quarterly GDP (SAAR, Bil. of Chinese renminbi, Base year=2000)
Interest rates	People's Bank of China 1-year base lending rate (per cent) (period average).
CPI China	Consumer price index (SA, 1994=100)
Exchange rate	Period averages; increase is depreciation

United States

GDP U.S.	Gross domestic product (SAAR, Bil.Chn.2000.Dollars)
Interest rates	Federal Open Market Committee: Fed funds target rate (per cent) (period average)
CPI U.S.	Consumer price index (SA, 1982–84=100)
Unemployment	Civilian unemployment rate (SA, per cent)
Bank lending tightening (BLT)	Average of (all expressed in per cent): FRB Sr Officers Survey: Banks Tightening C.I. Loans to Large Firms FRB Sr Officers Survey: Banks Tightening C.I. Loans to Small Firms FRB Sr Loan Off Survey: Tightening Standards for Comm. Real Estate FRB Sr Loan Survey: Res. Mortgage: Net Share, Banks Tightening

Euro area

GDP Euro Area 15	Gross domestic product (SA/WDA, Mil.Chn.00.Euros)
Interest rates	Euro Area 11-15: 3-Months EURIBOR Rate (AVG, per cent)
CPI Euro Area 15	Monetary Union index of consumer prices (SA, 2005=100)
Unemployment	Euro Area15: Unemployment rate (SA, per cent)
Exchange rates	Period averages; increase is depreciation

Japan

GDP Japan	Gross domestic product (SAAR, Bil.Chn.2000.Yen)
Interest rates	Japan: Call rate: Uncollateralized 3-month (EOP, per cent)
CPI Japan	Consumer price index (SA, 2005=100)
Unemployment	Japan: Unemployment rate (SA, per cent)
Exchange rates	Period averages; increase is depreciation

Oil Price

Oil price	Crude oil (petroleum), simple average of three spot prices; Dated Brent, West Texas Intermediate, and the Dubai Fateh, U.S.-dollar per barrel (period average)

Real Effective

Exchange rates	Weighted averages of the bilateral exchange rates. Weights are based on bilateral trade data from the International Monetary Fund (2006). The rates in the inflation equations are defined with import weights, while the rates in the output-gap equations use total trade (imports + exports) weights.
Foreign output gaps	Weighted averages of the foreign output gaps. Weights are based on bilateral trade data (exports) from the International Monetary Fund (2006).

Appendix D: Results of Posterior Maximization

	Prior			Posterior	
	Mean	**S.D.**	**Distribution**	**Mode**	**S.D.**
IS curve					
$\beta_{ch,1}$	0.750	0.0500	Beta	0.6900	0.0509
$\beta_{ch,2}$	0.150	0.1000	Beta	0.0267	0.0292
$\beta_{ch,3}$	0.250	0.0500	Gamma	0.1939	0.0377
$\beta_{ch,4}$	0.100	0.0100	Gamma	0.0903	0.0089
$\beta_{ch,5}$	0.050	0.0100	Gamma	0.0348	0.0073
$\beta_{ch,6}$	0.400	0.0500	Gamma	0.4284	0.0513
Phillips curve					
$\lambda_{ch,1}$	0.500	0.0500	Beta	0.4894	0.0423
$\lambda_{ch,2}$	0.200	0.0500	Gamma	0.1275	0.0343
$\lambda_{ch,3}$	0.120	0.0500	Gamma	0.1394	0.0561
Monetary policy reaction functions					
$\gamma_{ch,1}$	0.7	0	Beta	0.7	0
$\gamma_{ch,2}$	1.200	0.3000	Gamma	0.8042	0.1905
$\gamma_{ch,4}$	0.200	0.0500	Gamma	0.1864	0.0477
$\gamma_{ch,5}$	0.200	0.1000	Gamma	0.1139	0.0217
$\varsigma_{ch,1}$	0.030	0.0050	Beta	0.0290	0.0049
$\varsigma_{ch,2}$	0.500	0.0500	Gamma	0.4930	0.0494
$\varsigma_{ch,3}$	0.500	0.0500	Gamma	0.4916	0.0493
$\varsigma_{ch,4}$	0.250	0.0500	Gamma	0.2324	0.0469
Stochastic processes					
$g_{ch}^{\overline{Y}ss}$	5.000	0.2000	Normal	5.1251	0.1994
$\overline{R}_{ch}^{ss}$	3.900	0.2000	Normal	4.0536	0.1766
ρ_{ch}	0.900	0.0100	Beta	0.9011	0.0100
τ_{ch}	0.030	0.0050	Beta	0.0245	0.0042
ϕ_{ch}	0.500	0.2000	Beta	0.7885	0.0346
κ_{ch}	0.050	0.0050	Beta	0.0493	0.0050
ψ_{ch}	0.120	0.0100	Gamma	0.1178	0.0098
ω_{ch}	0.900	0.0200	Beta	0.8802	0.0210
ζ_{ch}	0.030	0.0050	Beta	0.0247	0.0042
$\upsilon_{ch,1}$	0.002	0.0010	Gamma	0.0017	0.0010
$\upsilon_{ch,2}$	0.002	0.0010	Gamma	0.0015	0.0009
σ_{ch}	0.002	0.0010	Gamma	0.0013	0.0007

	Prior			Posterior	
	Mean	**S.D.**	**Distribution**	**Mode**	**S.D.**
$\varepsilon_{ch}^{g^Y}$	0.250	0.0300	Inverted gamma	0.3016	0.0438
$\varepsilon_{ch}^{\overline{Y}}$	0.200	0.0500	Inverted gamma	0.1785	0.0386
$\varepsilon_{ch}^{\overline{z}}$	1.500	0.2000	Inverted gamma	2.3343	0.2894
ε_{ch}^{π}	1.000	Inf	Inverted gamma	2.2972	0.2819
$\varepsilon_{ch}^{\overline{R}}$	0.500	0.0500	Inverted gamma	0.5063	0.0735
$\varepsilon_{ch}^{Z-Z^e}$	1.000	Inf	Inverted gamma	0.4245	0.1490
ε_{ch}^{I}	0.500	Inf	Inverted gamma	0.1085	0.0165
ε_{ch}^{y}	0.300	Inf	Inverted gamma	0.6284	0.0898
ε_{ch}^{LS}	0.500	Inf	Inverted gamma	0.2204	0.0809
$\varepsilon^{\Delta\overline{M}}$	1.000	0.2000	Inverted gamma	1.2882	0.2235
$\varepsilon^{\Delta M}$	3.000	0.5000	Inverted gamma	3.3086	0.3492

Appendix E: Impulse-Response Functions

Y = Output gap

GROWTH = Growth of real GDP (q/q at annualized rates)

GROWTH4_BAR = Growth rate of potential output (average annual)

PIE4 = Inflation rate (average annual)

RS = Nominal interest rate

RR = Real interest rate

LZ = Real bilateral exchange rate (vs. U.S. dollar)

DM = Growth rate of money supply (China only)

REER_T = Trade-weighted real effective exchange rate

UNR = Unemployment rate

BLT = Bank lending tightening (United States only)

LZ_BAR = Equilibrium real exchange rate

Figure 2: Chinese Response to a Chinese Demand Shock

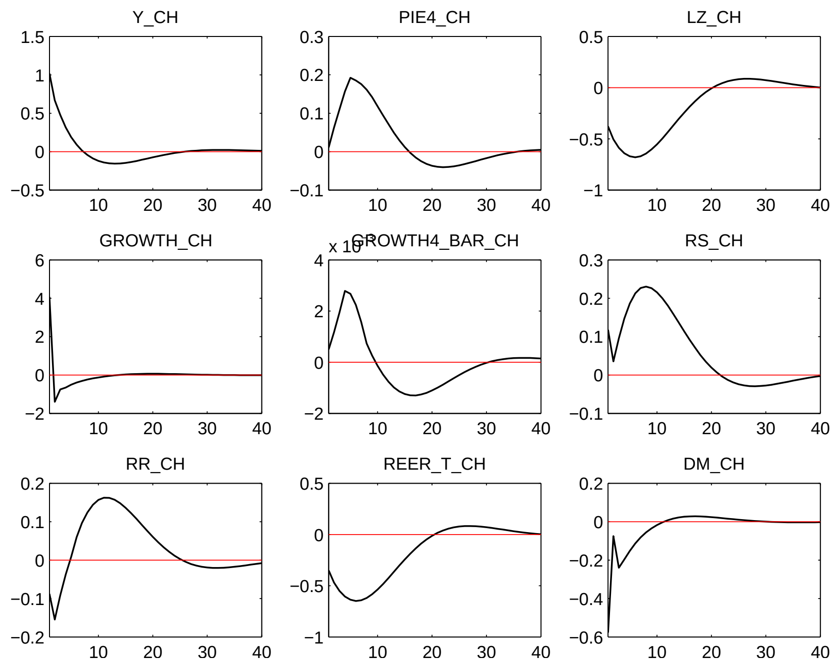


Figure 3: U.S. Response to a U.S. Demand Shock

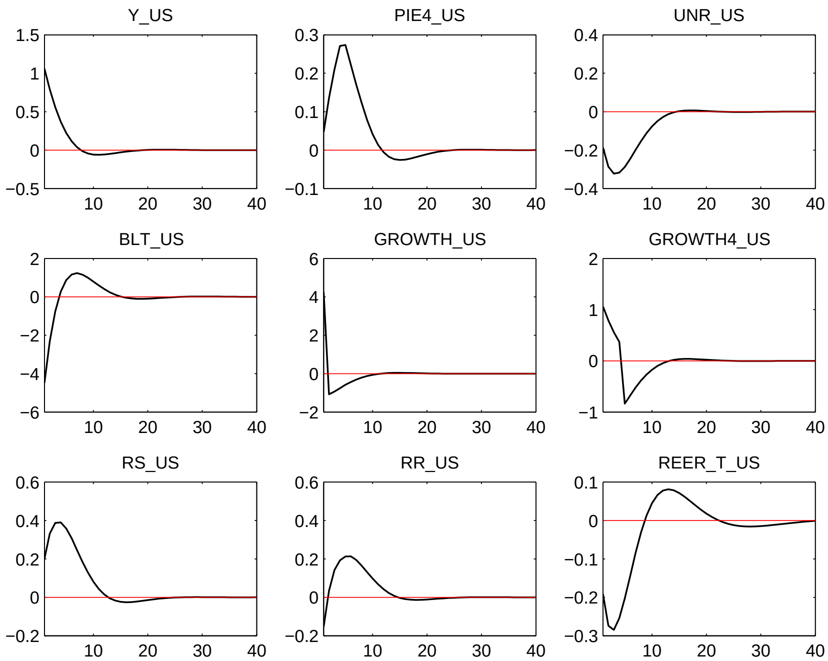


Figure 4: Chinese Response to a Chinese Inflation Shock

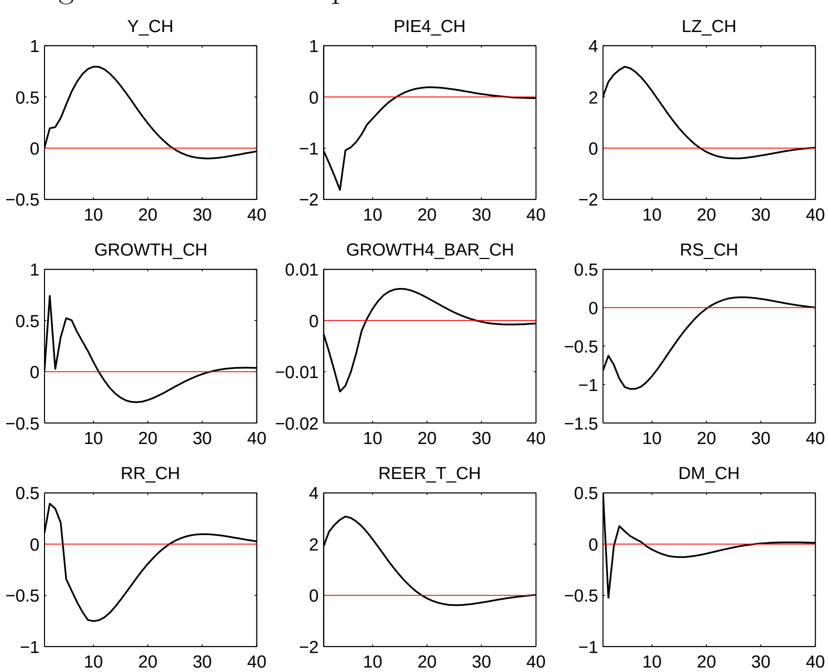


Figure 5: U.S. Response to a U.S. Inflation Shock

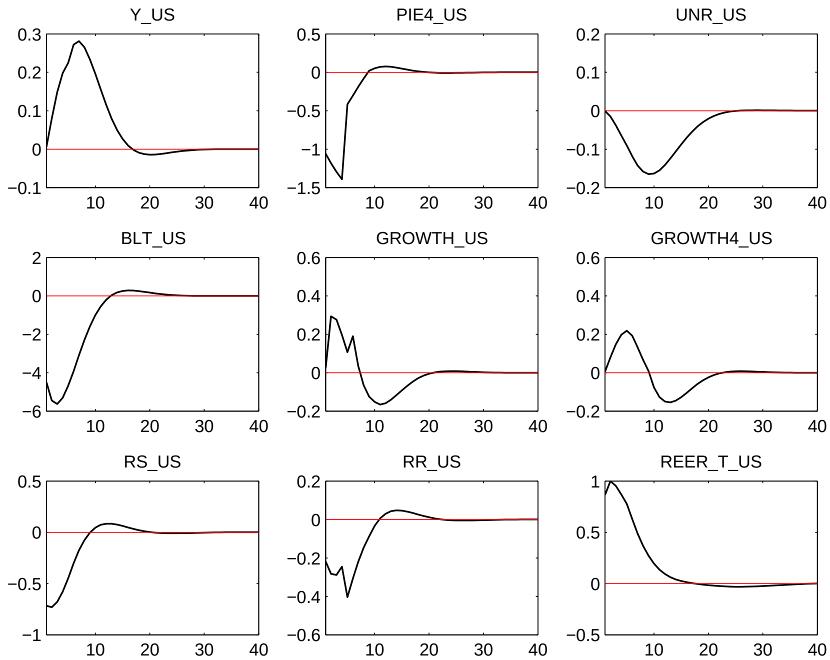


Figure 6: Chinese Response to a Chinese Potential Output Growth Shock

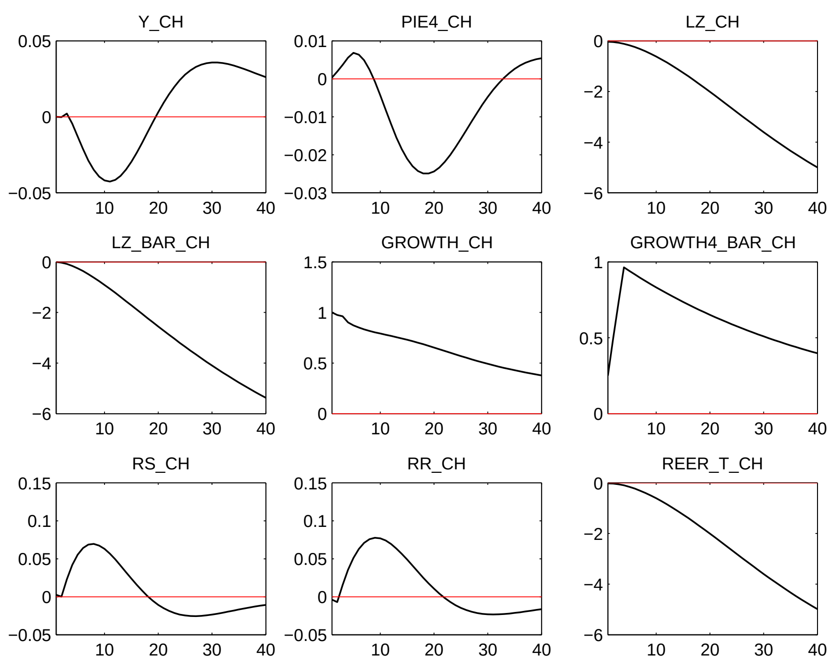


Figure 7: Euro Area Response to a Euro Area Potential Output Growth Shock

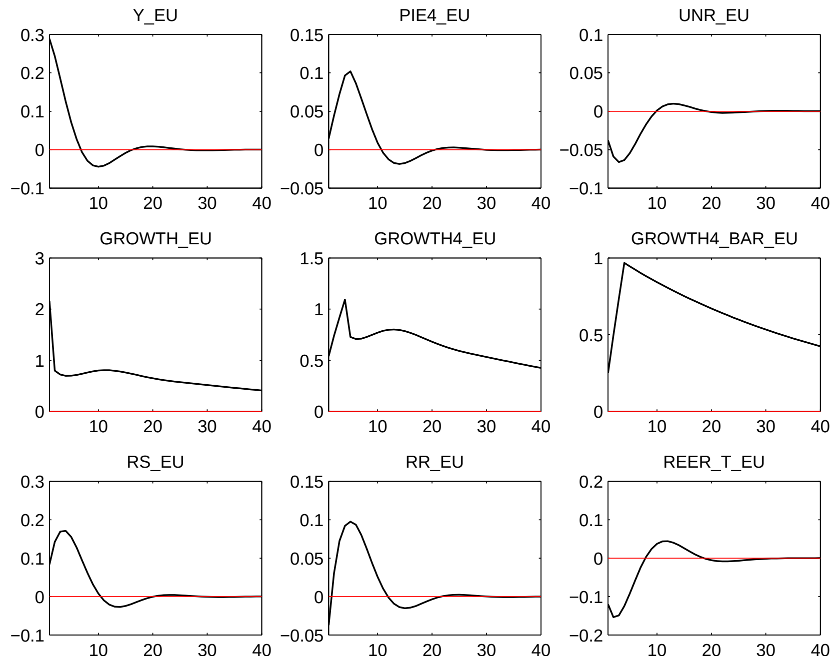


Figure 8: Chinese Response to a U.S. Demand Shock

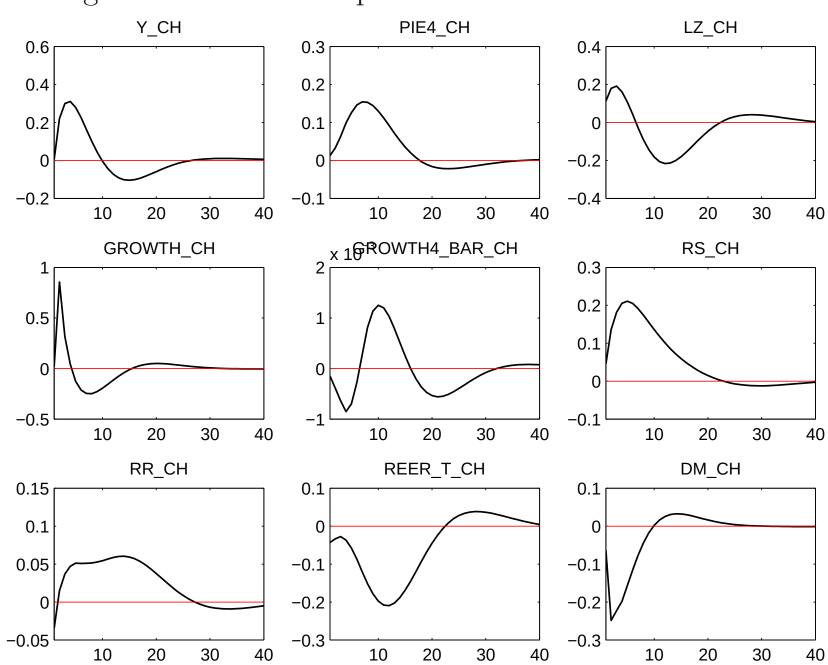


Figure 9: Euro Area Response to a U.S. Demand Shock

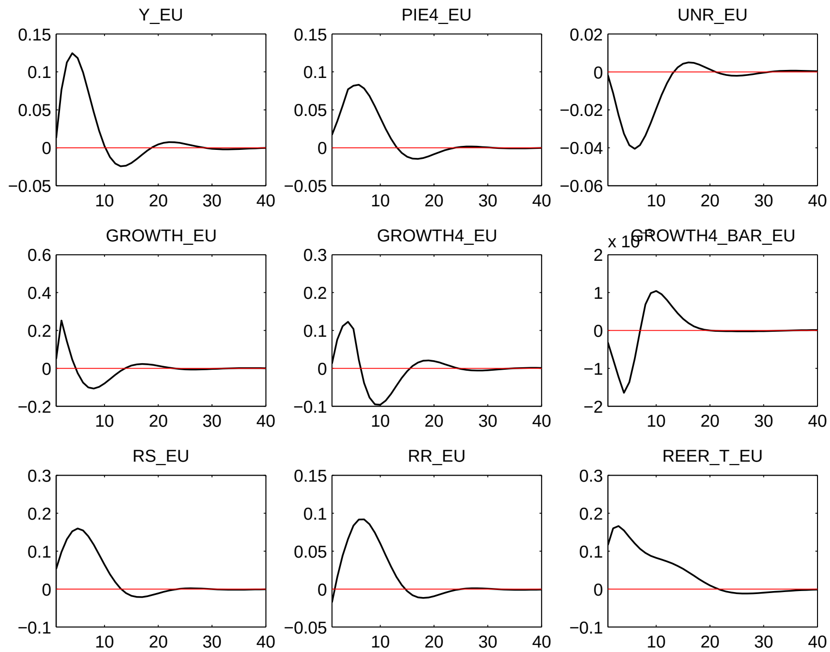
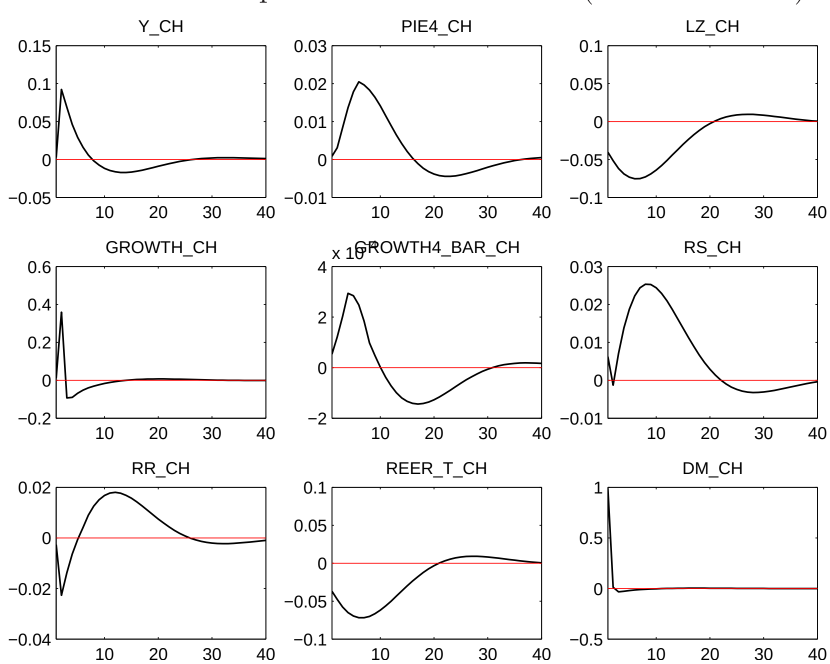


Figure 10: Chinese Response to a Chinese M2 (Credit Growth) Shock



Appendix F: Variance Decomposition of Chinese Variables

	Output gap	Inflation	Nominal interest rate	Real effective exchange rate		Output gap	Inflation	Nominal interest rate	Real effective exchange rate
t=0					**t=4**				
$\varepsilon_{ch}^{\overline{z}}$	0.00	0.06	22.75	0.13	$\varepsilon_{ch}^{\overline{z}}$	8.23	0.10	20.75	9.59
ε_{ch}^{π}	0.00	99.36	67.92	24.55	ε_{ch}^{π}	11.27	97.58	59.28	27.55
$\varepsilon_{ch}^{\overline{R}}$	0.00	0.00	5.27	0.01	$\varepsilon_{ch}^{\overline{R}}$	0.73	0.00	1.85	0.09
ε_{ch}^{I}	0.00	0.18	1.88	5.00	ε_{ch}^{I}	0.29	0.35	1.59	4.39
ε_{ch}^{y}	99.97	0.01	1.30	0.74	ε_{ch}^{y}	55.29	0.60	1.24	1.01
$\varepsilon_{eu}^{\overline{z}}$	0.00	0.01	0.00	22.88	$\varepsilon_{eu}^{\overline{z}}$	0.07	0.03	0.01	18.92
ε_{eu}^{y}	0.00	0.00	0.02	0.00	ε_{eu}^{y}	1.91	0.03	0.08	0.01
$\varepsilon_{ja}^{\overline{z}}$	0.00	0.12	0.00	43.36	$\varepsilon_{ja}^{\overline{z}}$	0.00	0.13	0.00	35.61
ε_{ja}^{y}	0.00	0.00	0.03	0.00	ε_{ja}^{y}	1.56	0.03	0.08	0.00
ε_{us}^{BLT}	0.00	0.01	0.12	0.05	ε_{us}^{BLT}	0.12	0.18	5.55	0.21
$\varepsilon_{us}^{g^{\overline{Y}}}$	0.00	0.01	0.09	0.03	$\varepsilon_{us}^{g^{\overline{Y}}}$	0.08	0.13	3.90	0.15
$\varepsilon_{us}^{\overline{R}}$	0.00	0.00	0.01	0.19	$\varepsilon_{us}^{\overline{R}}$	0.89	0.03	1.70	0.04
ε_{us}^{y}	0.00	0.00	0.07	0.00	ε_{us}^{y}	3.48	0.10	0.80	0.00
$\varepsilon_{ch}^{\Delta M}$	0.02	0.00	0.11	0.25	$\varepsilon_{ch}^{\Delta M}$	14.62	0.17	0.29	0.34
Other shocks	0.00	0.22	0.44	2.79	Other shocks	1.44	0.52	2.87	2.09
t=8					**t=20**				
$\varepsilon_{ch}^{\overline{z}}$	6.02	0.33	11.32	22.78	$\varepsilon_{ch}^{\overline{z}}$	6.50	0.49	11.65	55.21
ε_{ch}^{π}	40.85	95.74	69.00	23.40	ε_{ch}^{π}	58.42	93.39	68.57	8.29
$\varepsilon_{ch}^{\overline{R}}$	0.45	0.01	1.05	0.06	$\varepsilon_{ch}^{\overline{R}}$	0.27	0.01	0.79	0.02
ε_{ch}^{I}	0.47	0.53	1.10	3.56	ε_{ch}^{I}	1.72	1.27	1.15	1.35
ε_{ch}^{y}	31.94	0.87	2.29	0.96	ε_{ch}^{y}	17.65	0.91	2.82	0.38
$\varepsilon_{eu}^{\overline{z}}$	0.19	0.05	0.05	16.04	$\varepsilon_{eu}^{\overline{z}}$	0.18	0.06	0.12	11.08
ε_{eu}^{y}	1.43	0.07	0.22	0.02	ε_{eu}^{y}	0.96	0.08	0.25	0.01
$\varepsilon_{ja}^{\overline{z}}$	0.01	0.13	0.00	30.61	$\varepsilon_{ja}^{\overline{z}}$	0.02	0.13	0.04	21.97
ε_{ja}^{y}	1.06	0.06	0.18	0.00	ε_{ja}^{y}	0.64	0.06	0.20	0.00
ε_{us}^{BLT}	2.22	0.57	5.35	0.28	ε_{us}^{BLT}	2.71	1.16	4.74	0.10
$\varepsilon_{us}^{g^{\overline{Y}}}$	1.56	0.40	3.76	0.19	$\varepsilon_{us}^{g^{\overline{Y}}}$	1.91	0.82	3.33	0.07
$\varepsilon_{us}^{\overline{R}}$	0.58	0.04	1.58	0.05	$\varepsilon_{us}^{\overline{R}}$	0.44	0.06	1.30	0.03
ε_{us}^{y}	2.57	0.21	0.83	0.01	ε_{us}^{y}	1.53	0.24	0.74	0.01
$\varepsilon_{ch}^{\Delta M}$	8.55	0.28	0.74	0.35	$\varepsilon_{ch}^{\Delta M}$	4.89	0.30	1.01	0.14
Other shocks	2.12	0.71	2.55	1.67	Other shocks	2.16	1.01	3.28	1.34

Appendix G: Variance Decomposition of Euro Area Variables

	Output gap	Inflation	Nominal interest rate	Real effective exchange rate		Output gap	Inflation	Nominal interest rate	Real effective exchange rate
t=0					**t=4**				
$\varepsilon^{\overline{z}}_{eu}$	0.12	13.85	9.51	94.11	$\varepsilon^{\overline{z}}_{eu}$	8.18	13.74	6.41	93.43
ε^{π}_{eu}	0.08	81.70	38.33	0.13	ε^{π}_{eu}	9.88	72.71	25.29	0.05
$\varepsilon^{\overline{R}}_{eu}$	0.05	0.00	3.01	0.00	$\varepsilon^{\overline{R}}_{eu}$	0.99	0.01	4.14	0.00
ε^{I}_{eu}	0.28	0.29	35.53	0.08	ε^{I}_{eu}	15.15	1.74	11.83	0.02
ε^{y}_{eu}	99.37	0.26	5.74	0.12	ε^{y}_{eu}	57.19	3.25	20.94	0.10
$\varepsilon^{\overline{z}}_{ch}$	0.00	0.03	0.09	0.12	$\varepsilon^{\overline{z}}_{ch}$	0.54	0.08	0.09	0.81
ε^{π}_{ch}	0.02	0.49	1.84	0.38	ε^{π}_{ch}	1.94	1.71	9.54	0.61
ε^{I}_{ch}	0.00	0.10	0.34	0.08	ε^{I}_{ch}	0.33	0.32	1.87	0.09
ε^{y}_{ch}	0.00	0.03	0.17	0.01	ε^{y}_{ch}	0.31	0.16	1.03	0.02
$\varepsilon^{\overline{z}}_{ja}$	0.01	0.62	0.36	4.31	$\varepsilon^{\overline{z}}_{ja}$	0.57	0.59	0.20	4.37
ε^{BLT}_{us}	0.01	0.19	0.89	0.19	ε^{BLT}_{us}	1.17	0.85	5.42	0.18
$\varepsilon^{g^{\overline{Y}}}_{us}$	0.01	0.14	0.62	0.14	$\varepsilon^{g^{\overline{Y}}}_{us}$	0.82	0.60	3.81	0.13
$\varepsilon^{\overline{R}}_{us}$	0.00	0.01	0.14	0.02	$\varepsilon^{\overline{R}}_{us}$	0.71	0.13	0.77	0.07
ε^{y}_{us}	0.02	0.04	0.25	0.01	ε^{y}_{us}	1.49	0.24	1.61	0.01
$\varepsilon^{g^{\overline{RPOIL}}}_{us}$	0.01	1.47	2.83	0.00	$\varepsilon^{g^{\overline{RPOIL}}}_{us}$	0.15	2.59	4.31	0.00
$\varepsilon^{g^{RPOIL}}_{us}$	0.00	0.59	0.01	0.01	$\varepsilon^{g^{RPOIL}}_{us}$	0.05	0.91	1.39	0.00
Other shocks	0.01	0.19	0.34	0.31	Other shocks	0.51	0.39	1.34	0.10
t=8					**t=20**				
$\varepsilon^{\overline{z}}_{eu}$	10.08	13.38	5.17	92.62	$\varepsilon^{\overline{z}}_{eu}$	9.30	13.26	5.15	90.47
ε^{π}_{eu}	17.09	70.01	18.41	0.03	ε^{π}_{eu}	16.37	69.16	17.84	0.01
$\varepsilon^{\overline{R}}_{eu}$	0.87	0.02	2.96	0.00	$\varepsilon^{\overline{R}}_{eu}$	0.87	0.04	2.59	0.00
ε^{I}_{eu}	12.99	2.41	12.00	0.02	ε^{I}_{eu}	12.13	2.43	10.69	0.01
ε^{y}_{eu}	41.72	3.42	17.97	0.05	ε^{y}_{eu}	38.19	3.49	15.67	0.02
$\varepsilon^{\overline{z}}_{ch}$	2.75	0.18	0.92	1.71	$\varepsilon^{\overline{z}}_{ch}$	5.63	0.46	3.66	4.40
ε^{π}_{ch}	3.69	2.36	13.27	0.67	ε^{π}_{ch}	4.61	2.47	13.41	0.35
ε^{I}_{ch}	0.57	0.48	2.82	0.09	ε^{I}_{ch}	0.67	0.53	3.13	0.05
ε^{y}_{ch}	0.39	0.24	1.42	0.02	ε^{y}_{ch}	0.39	0.24	1.39	0.02
$\varepsilon^{\overline{z}}_{ja}$	0.68	0.57	0.18	4.40	$\varepsilon^{\overline{z}}_{ja}$	0.64	0.57	0.18	4.42
ε^{BLT}_{us}	2.86	1.42	8.97	0.14	ε^{BLT}_{us}	3.42	1.58	9.76	0.06
$\varepsilon^{g^{\overline{Y}}}_{us}$	2.01	0.99	6.30	0.10	$\varepsilon^{g^{\overline{Y}}}_{us}$	2.40	1.11	6.86	0.04
$\varepsilon^{\overline{R}}_{us}$	1.31	0.16	0.87	0.05	$\varepsilon^{\overline{R}}_{us}$	1.33	0.19	0.94	0.02
ε^{y}_{us}	1.47	0.32	1.98	0.01	ε^{y}_{us}	1.35	0.33	1.78	0.00
$\varepsilon^{g^{\overline{RPOIL}}}_{us}$	0.63	2.51	3.04	0.00	$\varepsilon^{g^{\overline{RPOIL}}}_{us}$	0.78	2.53	2.94	0.00
$\varepsilon^{g^{RPOIL}}_{us}$	0.19	1.03	1.83	0.00	$\varepsilon^{g^{RPOIL}}_{us}$	0.93	1.06	1.87	0.00
Other shocks	0.71	0.49	1.90	0.08	Other shocks	0.98	0.54	2.14	0.11

Appendix H: Variance Decomposition of Japanese Variables

	Output gap	**Inflation**	**Nominal interest rate**	**Real effective exchange rate**		**Output gap**	**Inflation**	**Nominal interest rate**	**Real effective exchange rate**
t=0					**t=4**				
$\varepsilon_{ja}^{\bar{z}}$	0.00	10.22	8.47	94.78	$\varepsilon_{ja}^{\bar{z}}$	2.85	11.90	12.89	94.62
ε_{ja}^{π}	0.00	88.54	44.27	0.83	ε_{ja}^{π}	3.14	83.77	57.98	0.77
$\varepsilon_{ja}^{\overline{R}}$	0.00	0.00	0.25	0.01	$\varepsilon_{ja}^{\overline{R}}$	0.22	0.01	1.19	0.00
ε_{ja}^{I}	0.00	0.09	42.71	0.30	ε_{ja}^{I}	4.55	0.29	13.69	0.10
ε_{ja}^{y}	99.99	0.11	2.38	0.07	ε_{ja}^{y}	83.27	1.50	7.63	0.09
$\varepsilon_{ch}^{\bar{z}}$	0.00	0.01	0.07	0.01	$\varepsilon_{ch}^{\bar{z}}$	1.02	0.09	0.28	0.19
ε_{ch}^{π}	0.00	0.25	0.48	0.84	ε_{ch}^{π}	2.20	0.56	1.93	1.07
ε_{ch}^{I}	0.00	0.05	0.10	0.15	ε_{ch}^{I}	0.37	0.12	0.47	0.15
$\varepsilon_{eu}^{\bar{z}}$	0.00	0.20	0.17	2.51	$\varepsilon_{eu}^{\bar{z}}$	0.04	0.24	0.30	2.54
ε_{us}^{BLT}	0.00	0.05	0.12	0.22	ε_{us}^{BLT}	0.62	0.14	0.56	0.19
$\varepsilon_{us}^{g^{\overline{Y}}}$	0.00	0.04	0.08	0.15	$\varepsilon_{us}^{g^{\overline{Y}}}$	0.44	0.10	0.40	0.13
$\varepsilon_{us}^{g^{\overline{RPOIL}}}$	0.00	0.28	0.72	0.00	$\varepsilon_{us}^{g^{\overline{RPOIL}}}$	0.04	0.82	1.60	0.00
Other shocks	0.00	0.16	0.19	0.13	Other shocks	1.24	0.47	1.08	0.15
t=8					**t=20**				
$\varepsilon_{ja}^{\bar{z}}$	4.53	11.84	12.47	94.59	$\varepsilon_{ja}^{\bar{z}}$	4.88	11.82	11.82	93.66
ε_{ja}^{π}	11.24	82.99	56.47	0.54	ε_{ja}^{π}	14.31	82.77	53.56	0.22
$\varepsilon_{ja}^{\overline{R}}$	0.22	0.01	2.30	0.00	$\varepsilon_{ja}^{\overline{R}}$	0.20	0.01	4.69	0.00
ε_{ja}^{I}	4.85	0.47	9.92	0.05	ε_{ja}^{I}	4.25	0.51	9.48	0.02
ε_{ja}^{y}	65.64	1.69	8.88	0.06	ε_{ja}^{y}	57.26	1.70	8.74	0.02
$\varepsilon_{ch}^{\bar{z}}$	3.69	0.10	0.30	0.67	$\varepsilon_{ch}^{\bar{z}}$	7.48	0.10	0.29	2.83
ε_{ch}^{π}	4.44	0.68	2.90	1.03	ε_{ch}^{π}	5.00	0.75	3.22	0.50
ε_{ch}^{I}	0.73	0.17	0.85	0.14	ε_{ch}^{I}	0.82	0.18	1.11	0.07
$\varepsilon_{eu}^{\bar{z}}$	0.03	0.24	0.35	2.56	$\varepsilon_{eu}^{\bar{z}}$	0.03	0.24	0.36	2.48
ε_{us}^{BLT}	1.43	0.21	1.13	0.13	ε_{us}^{BLT}	1.58	0.23	1.59	0.05
$\varepsilon_{us}^{g^{\overline{Y}}}$	1.01	0.15	0.79	0.09	$\varepsilon_{us}^{g^{\overline{Y}}}$	1.11	0.16	1.12	0.04
$\varepsilon_{us}^{g^{\overline{RPOIL}}}$	0.22	0.83	1.55	0.00	$\varepsilon_{us}^{g^{\overline{RPOIL}}}$	0.41	0.83	1.48	0.00
Other shocks	1.98	0.63	2.08	0.14	Other shocks	2.66	0.68	2.55	0.10

Appendix I: Variance Decomposition of U.S. Variables

	Output gap	Inflation	Nominal interest rate	Real effective exchange rate		Output gap	Inflation	Nominal interest rate	Real effective exchange rate
t=0					**t=4**				
ε_{us}^{BLT}	0.01	0.88	3.46	2.39	ε_{us}^{BLT}	16.54	7.68	15.98	2.82
$\varepsilon_{us}^{g^{\overline{Y}}}$	0.01	0.62	2.43	1.68	$\varepsilon_{us}^{g^{\overline{Y}}}$	11.62	5.39	11.23	1.98
ε_{us}^{π}	0.00	91.43	20.27	1.42	ε_{us}^{π}	1.64	73.35	9.62	1.02
$\varepsilon_{us}^{\overline{R}}$	0.12	0.01	42.04	0.39	$\varepsilon_{us}^{\overline{R}}$	15.81	0.05	48.79	0.61
ε_{us}^{I}	0.02	0.15	25.05	0.87	ε_{us}^{I}	5.13	0.63	4.31	0.24
ε_{us}^{y}	99.83	0.27	2.38	0.11	ε_{us}^{y}	46.87	2.06	4.10	0.11
$\varepsilon_{us}^{g^{\overline{RPOIL}}}$	0.00	3.77	3.47	0.03	$\varepsilon_{us}^{g^{\overline{RPOIL}}}$	0.26	6.46	3.27	0.06
$\varepsilon_{us}^{g^{RPOIL}}$	0.00	1.29	0.00	0.11	$\varepsilon_{us}^{g^{RPOIL}}$	0.03	2.42	1.45	0.16
$\varepsilon_{ch}^{\overline{z}}$	0.00	0.00	0.01	0.00	$\varepsilon_{ch}^{\overline{z}}$	0.24	0.01	0.01	1.30
ε_{ch}^{π}	0.00	0.20	0.21	5.32	ε_{ch}^{π}	0.87	0.38	0.46	6.42
ε_{ch}^{I}	0.00	0.05	0.06	1.15	ε_{ch}^{I}	0.18	0.11	0.15	1.13
$\varepsilon_{eu}^{\overline{z}}$	0.00	0.59	0.22	57.41	$\varepsilon_{eu}^{\overline{z}}$	0.04	0.55	0.17	55.86
$\varepsilon_{ja}^{\overline{z}}$	0.00	0.35	0.11	28.12	$\varepsilon_{ja}^{\overline{z}}$	0.08	0.30	0.06	27.37
Other shocks	0.00	0.38	0.29	1.00	Other shocks	0.69	0.61	0.42	0.91
t=8					**t=20**				
ε_{us}^{BLT}	35.28	13.44	27.03	2.46	ε_{us}^{BLT}	34.88	14.27	29.93	1.07
$\varepsilon_{us}^{g^{\overline{Y}}}$	24.79	9.44	18.99	1.73	$\varepsilon_{us}^{g^{\overline{Y}}}$	24.51	10.02	21.03	0.75
ε_{us}^{π}	2.61	63.82	6.11	0.64	ε_{us}^{π}	2.86	62.08	5.53	0.26
$\varepsilon_{us}^{\overline{R}}$	8.28	0.24	36.15	0.51	$\varepsilon_{us}^{\overline{R}}$	9.01	0.76	32.44	0.20
ε_{us}^{I}	3.22	0.80	2.83	0.12	ε_{us}^{I}	2.93	0.80	2.60	0.05
ε_{us}^{y}	22.39	1.96	3.32	0.06	ε_{us}^{y}	20.34	1.92	3.00	0.03
$\varepsilon_{us}^{g^{\overline{RPOIL}}}$	0.51	5.65	2.17	0.04	$\varepsilon_{us}^{g^{\overline{RPOIL}}}$	0.66	5.53	1.97	0.02
$\varepsilon_{us}^{g^{RPOIL}}$	0.23	2.76	2.06	0.18	$\varepsilon_{us}^{g^{RPOIL}}$	1.01	2.73	2.03	0.10
$\varepsilon_{ch}^{\overline{z}}$	0.62	0.02	0.03	3.79	$\varepsilon_{ch}^{\overline{z}}$	1.37	0.03	0.11	13.71
ε_{ch}^{π}	1.13	0.39	0.51	5.91	ε_{ch}^{π}	1.37	0.40	0.51	2.77
ε_{ch}^{I}	0.22	0.13	0.20	1.00	ε_{ch}^{I}	0.27	0.14	0.23	0.50
$\varepsilon_{eu}^{\overline{z}}$	0.02	0.49	0.13	55.41	$\varepsilon_{eu}^{\overline{z}}$	0.02	0.47	0.12	52.71
$\varepsilon_{ja}^{\overline{z}}$	0.07	0.27	0.03	27.34	$\varepsilon_{ja}^{\overline{z}}$	0.07	0.26	0.03	27.27
Other shocks	0.64	0.59	0.44	0.80	Other shocks	0.71	0.59	0.46	0.57

Appendix J: Historical Decomposition of Key Variables

Figure 11: Chinese Output Gap

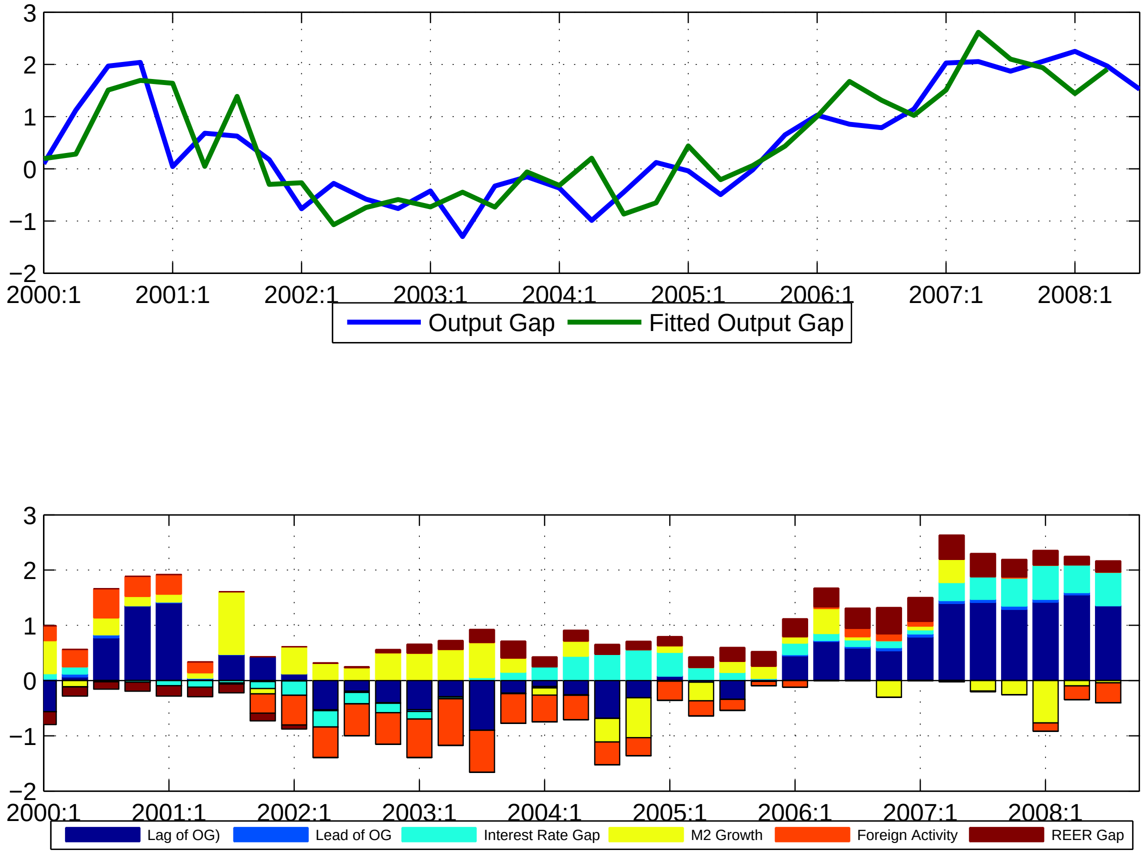


Figure 12: Chinese Inflation

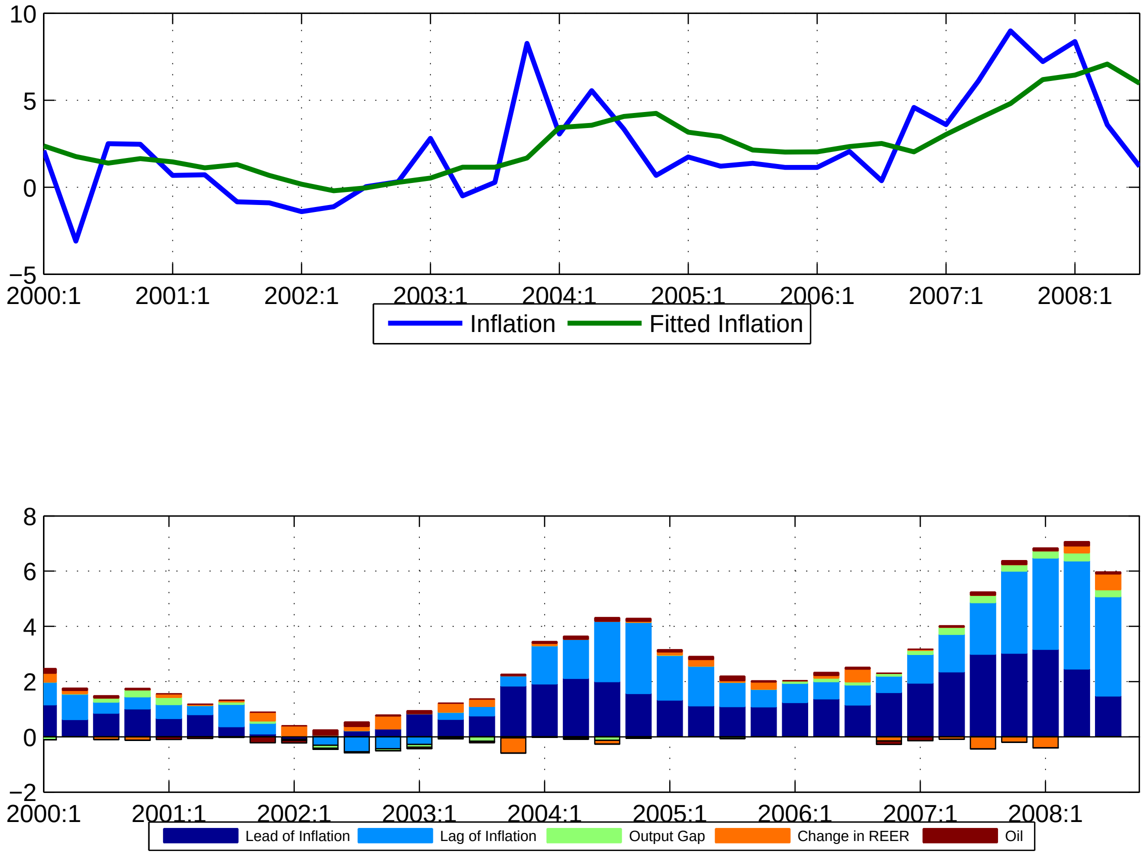


Figure 13: Chinese Nominal Interest Rate

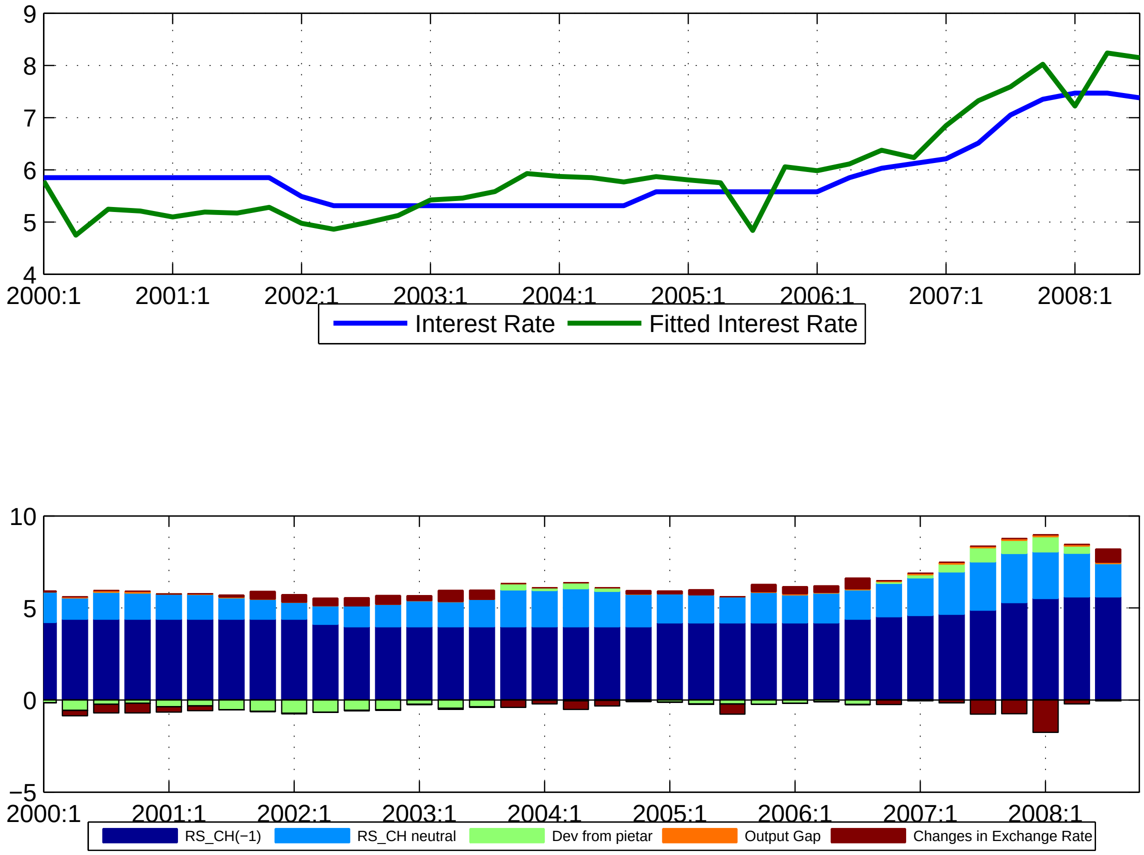
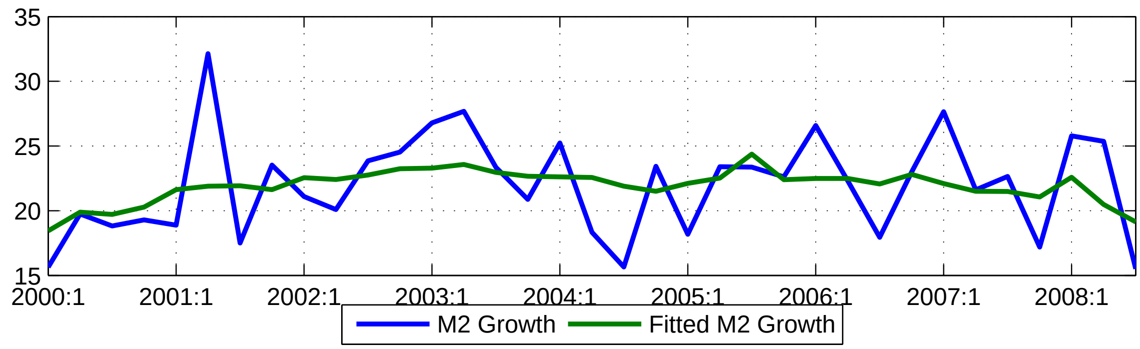
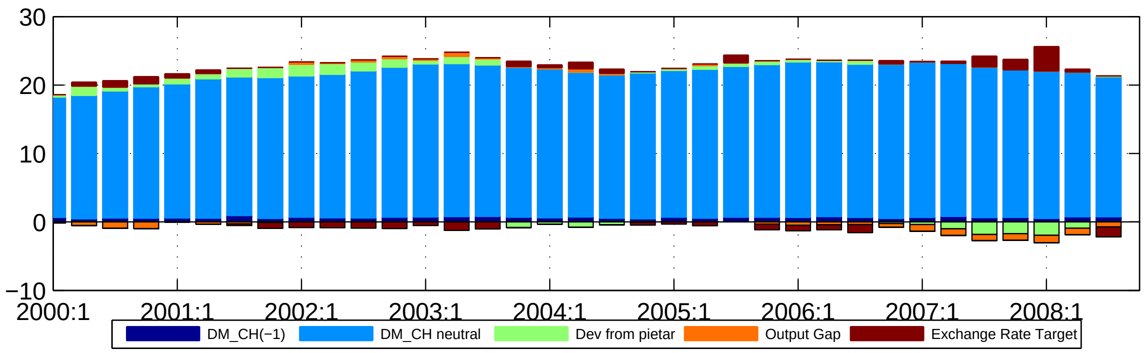


Figure 14: Chinese M2 Growth Rate





Appendix K: Evolution of Key Unobservable Variables over History

Figure 15: Chinese Output Gap, Real Interest Rate Gap, and Real Exchange Rate Gap