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Abstract

This paper analyzes the joint dynamic processes of macroeconomic and monetary variables and bond yields in China. We show that macroeconomic variables as well as monetary policy variables have a significant impact on two factors that capture the variation in yields. An increase in the inflation rate and economic growth result in a rise in the yield curve. Similarly, an increase in the money supply causes a rise in the yield curve, albeit with a delayed effect. Finally, when official rates are raised, the long yield shows signs of a delayed decline. Overall, the long yield is more sensitive to most changes in macroeconomic and monetary variables. These results differ from an earlier study on bond yields by Ang and Piazzesi (2003), who show that the U.S. short-term rate is more sensitive to changes in macroeconomic variables. Possible explanations for the difference include certain unique structural features in the domestic financial system and the way monetary policy is conducted in China.

Keywords: China; yield curve; macroeconomic factors; monetary policy.

JEL Classification: E43; E44; E52; E58; G12.

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1 Introduction

Understanding the behavior of the yield curve and the factors that make it move and change in shape is important for public policy makers, bond pricing, and investment management. The yield curve is used as a benchmark and thus has a close relationship with other fixed-income assets, including corporate bonds. The yield curve is also closely related to the general economy. This is because it affects the cost of capital for firms, which means that movements in the yield curve influence the ability for firms to raise capital for their investments. The relationship between economic variables and market rates has been analyzed in numerous studies. On the one hand, we know that monetary authorities in the U.S. and Europe focus on the short-term rate but, while, at the same time, it is the medium- and long-term rates that are relatively more influential for economic variables. One of the key issues for monetary policy makers as well as investors is therefore how the medium- and long-term rates are affected by macroeconomic fundamentals as well as monetary policy. On the other hand, since the longer term interest rates are affected by expected changes in macroeconomic variables, the yield curve may contain information on macroeconomic variables' future value, something that has attracted the attention of researchers as well. The results in previous studies on these issues show that the relationship between the yield curve and macroeconomic variables is strong. The inflation rate and real output tend to have an especially significant effect on short-term market rates, while they are not so important for long-term rates (e.g. Ang and Piazzesi, 2003). Also, the yield curve can be used to forecast future inflation and real output (e.g. Mishkin, 1990).

This paper differs from earlier studies on macroeconomic variables and bond yields in several ways. First, we use a novel method to extract the slope and the level from data on market interest rates. Instead of using an affine structure with latent variables as in Ang and Piazzesi (2003), we model the different yields as functions of the two most important factors (slope and level) and random errors.

Second, instead of looking at the U.S. or European yield curves, we focus on the emerging Chinese government bond market. While still relatively modest in size, the Chinese bond market is growing in importance and the behavior of Chinese bond yields is yet to be well understood. The relationship between the yield curve and macroeconomic and monetary variables in China is not necessarily the same as in the U.S. and Europe. The financial markets in China are still a relatively new phenomenon, and the fixed-income assets are particularly late to arrive on the scene. The interbank bond market in China was established as late as in 1996. At that point, trading in bonds was already taking place, although the volumes were very small. After 1996, bond trading developed gradually, with the interbank market and the exchanges in Shanghai and Shenzhen constituting the main trading locations. Besides the young and in some ways still immature nature of the domestic bond market, the monetary policy conducted by the People's Bank of China has its own characteristics and differs significantly from its counterparts in U.S. and Europe. The People's Bank of China uses a number of different tools when it conducts its monetary policy. One of the most important monetary instruments is that of narrow money, M1. However, it also sets the term structure for deposit and savings rates. The market interest rate is thus heavily influenced not only by monetary policy in the form of money supply, but also by the official rates, and perhaps especially by the one-year deposit rate which is often used as a benchmark rate.

The rest of this paper is organized as follows: Section 2 discusses the related literature on the relationship between bond yields and macroeconomic and monetary variables. Section 3 gives a brief introduction to monetary policy and the bond market in China. Section 4 introduces the econometric model and the estimation procedure. Section 5 first discusses the data and then presents and analyzes the empirical results. Finally, Section 6 concludes the paper.

2 Related Literature

This study is related to a recently emerging and quickly growing literature that takes macroeconomic and monetary variables into account when modeling yield curves. Early studies on yield curve behavior favored the identification of a few latent factors. One of the reasons for why factor models became so popular is that empirical studies indicate that two or three factors can explain almost all of the movements in yield curves. Litterman and Scheinkman (1991) find that three factors explain 99% of the variability in the yield curve. Similarly, Knez, Litterman, and Scheinkman (1994) show that a small number of factors can explain most of the movements in U.S. money markets. These empirical results have been used as an argument for models that use a limited number of factors to explain movements in the yield curve in numerous studies. For example, Pearson and Sun (1994) use two factors called the short rate and inflation to explain yield curve movements. Dai and Singleton (2000) instead focus on three factors.

Even though factor models improve our understanding of the behavior of the yield curve, they do not help us to understand the underlying economic factors behind yield curve movements. In a response to the absence of a clear understanding of underlying forces behind changes in the yield curve, researchers began to analyze the connection between bond yields and macroeconomic variables. Early literature on the relationship between macroeconomic variables and movements in yields tended to focus almost exclusively on the short-term interest rate. In a study by Furher and Moore (1995), the long-term rate was included in the analysis of the relationship between bond yields and macroeconomic variables. However, the focus of the study was still on the short-term rate. Later studies on yields and macroeconomic and monetary variables that focus more on movements in yields of different maturities include Evans and Marshall (1998). Their results show that monetary policy shocks have a significant effect on short-term rates but no effect on long-term rates. Ang and Piazzesi (2003) use a vector autoregression (VAR) model to study the relationship among macroeconomic variables and bond yields. Using a VAR in a no-arbitrage setup that incorporates economic growth, inflation, and latent factors, they show that by incorporating macroeconomic variables, the forecasting performance for bond yields improves significantly. Their results also indicate that macroeconomic variables mainly explain movements in the short- and medium-term (3-months and 1-year) yields, while the long-term (5-year) yield is mostly explained by latent variables. There is also a number of studies that focus on monetary policy variables and market rates (e.g. Cochrane and Piazzesi, 2002; Farnsworth and Bass, 2003; Piazzesi, 2005; Andersson, Dillén, and Sellin, 2006).

Besides studies on the influence that macroeconomic and monetary variables have on bond yields, there is a large literature that looks at how the yield curve provides information on related macroeconomic and monetary variables. For instance, Mishkin (1990a, 1990b) shows that bond yields contain information about future inflation. Estrella and Mishkin (1997) find that monetary policy is a significant determinant of the yield spread and that the yield spread can be used to forecast real growth and inflation not only in the U.S., but also in several European countries. Similarly, Estrella and Hardouvelis (1991) find that the slope of the yield curve exhibits information on economic growth and inflation. Ang, Piazzesi, and Wei (2006) use the information in the U.S. yield curve to forecast GDP in a no-arbitrage setting. These studies thus show that the yield curve contains information on different macroeconomic variables.

As mentioned earlier, this paper differs from earlier studies on macroeconomic variables and bond yields in two important ways. First, we use a novel method to extract the slope and the level from data on market interest rates. Instead of using an affine structure with latent variables as in Ang and Piazzesi (2003), we model the different yields as functions of the two most important factors (slope and level) and random errors. Second, instead of looking at the U.S. bond market, we focus on the emerging Chinese government bond market. There is only a very limited literature on the relationship between market rates and macroeconomic variables in China.[1] This study differs from previous studies on the Chinese bond market on several accounts. Firstly, it focuses on a more complete set of possible macroeconomic variables and monetary instruments and their possible effect on the term structure of interest rates. Secondly, the data sample in this study is significantly longer, with data spanning the period 1999 to the end of 2008. This means that we are able to analyze the relationship between the yield curve and macroeconomic and monetary variables during periods of different economic conditions, i.e. periods with different levels of GDP growth and inflation. This makes the results more relevant when it comes to understanding the relationship between the different variables over time. The only recent study that study the same issues is that of Fan and Zhang (2008). However, their approach is markedly different from ours. Finally, one closely related study is that of Fan and Johansson (2009), in which the official rate is used as a factor in an affine model of China's yield curve. Even though the market data still allows for only a shorter yield curve with maturities up to five years, their results indicate that the official rate has explanatory power for bond yields and that a model that takes this relationship into account improves the fitting of the yield curve. This paper can be seen as an extension of their study, in that we focus on a larger set of macroeconomic and monetary variables and their potential relationship with the yield curve in China.

3 China's Monetary Policy and Bond Market

In the end of the 1970s, the Chinese government initiated economic reforms and its open door policy. The reforms were gradual in nature and covered most areas of fiscal and monetary policy. In the mid-1980s, the State Council decided that the People's Bank of China should be the country's central bank. Initially, the main

[1]Most of these studies are published in Chinese journals. All of them have limitations such as short data samples, or a narrow focus such as the effect of money supply on the market rate.

goal of monetary policy was to balance economic growth and inflation. However, after several periods of very high inflation rates, it stood clear that it was difficult for the central bank to control inflation. In 1995, the Third Plenum of the 8th National People's Congress passed a new law that clarified the mandates of the People's Bank of China. It stipulated that the main objective of domestic monetary policy is to stimulate China's economic growth while keeping prices and the exchange rate stable. The new regulations thus made it clear that controlling the level of inflation was a top priority for the central bank, following a significant increase in inflation the year before (Fan and Johansson, 2009). However, the change in monetary policy soon coincided with a severe economic deterioration in the region as a result of the Asian financial crisis that begun in 1997. Even though China was largely spared the negative effects of the crisis when compared to its neighbors, economic growth was nevertheless affected and fell significantly during this period. Interest rates fell to very low levels and remained there until 2005. The initial focus on a balanced inflation was natural, since the Chinese currency renminbi was fixed against the U.S. dollar. The focus on the stability of the exchange rate has naturally increased after China shifted to a managed float exchange rate regime in July, 2005.

In 1998, further reforms were initiated during which the bank credit quota system was abolished. Since then, the People's Bank of China has been using different monetary instruments to fine tune the economy. Money supply constitutes one of the main tools for the central bank's monetary policy. Besides money supply, the official rates, a collective term for a number of deposit and lending rates of different maturities, have become very influential factors. The central bank sets the official lending rates which are used by commercial banks in their lending activities and official deposit rates that individuals receive when they put their savings in a bank account. The control over a whole range of official rates is thus very different from monetary policy in Europe and the U.S., where the focus of monetary policy tends to be on the short-term rate. The short-term deposit rates (maturities of less than one year) are usually kept very low compared to deposit rates with maturities of one year or longer. The one-year deposit rate is therefore often considered to be representing the official deposit rates.

Chinese banks have historically been relatively insensitive to monetary policy in the form of interest rates changes. The primary reason for this is that commercial banks have had ready access to large capital reserves that they have placed with the central bank. These reserves have been larger than official reserve requirements, mainly due to the high interest rate on reserves. The fact that commercial banks have had large reserves means that they have not had the need to borrow in the money market as banks do in Europe and the U.S. This have had obvious detrimental effects on the ability to conduct an effective monetary policy (Green, 2005). Since the end of the 1990s, the interest rates for reserves have declined significantly. As a result, commercial banks have been investing an increasing amount of excess reserve capital in the bond market, thus driving bond prices up. It can be expected that the volume of excess reserves will continue to decrease and that the trading volume and price mechanism in the bond market will continue to develop as a result of this.

Chinese authorities have tried to develop a well-functioning interbank market in several ways. For instance, China Interbank Offered Rates (CHIBOR) were established in 1996 to facilitate borrowing and lending in the interbank market.[2] However, official rates of different maturities are nevertheless still used as benchmarks by many market participants. Chinese government bonds are traded both in the interbank market and on the two domestic stock exchanges. Even though long-term bonds are issued on occasion, most treasury bonds tend to have a maturity of seven years or less. This means that it is difficult to create a complete yield curve with maturities longer than five to seven years. As mentioned, treasury bonds with longer maturities are traded in both the interbank market and over the exchanges. However,

[2] In January 2007, the Shanghai Interbank Offered Rates (SHIBOR) was introduced to the market. SHIBOR has some advantages over the older CHIBOR, including not being dependent on actual market trades and a more complete range of maturities.

bond trading is more frequent over the two exchanges compared to in the interbank market. Many of the investors trading in the two markets are basically the same, as are most of the bonds traded in them. This means that the price and yield behavior can be seen as approximately identical.

4 Methodology

4.1 The Model

We begin this section by introducing a system of equations that is meant to capture the time-varying patterns in Chinese government bond yields. Studies on the U.S. market have shown that it is often enough to use just two or three factors when explaining changes in the yield curve. For instance, Litterman and Scheinkman (1991) find that two factors are enough to explain most of the variability of the U.S. yield curve. They also show that the factors can be associated with the slope of the yield curve and the long-term yield. Similarly, Diebold, Piazzesi, and Rudebusch (2005) report that two factors are enough to explain 99% of the total variation in yields. Obviously, the U.S. yield curve is significantly different from China's yield curve. Due to the frequent issuance of governments with a wide range of maturities, studies on the U.S. market tend to include yields for maturities from three months up to 30 years.[3] In the case of China, on the other hand, there are only very infrequent issues of government bonds with maturities longer than seven years. Due to this limitation, we focus on bond yields of maturities between one and five years when analyzing China's yield curve. Principal component analysis shows that two factors are able to explain well over 99% of the total variation in different yields. We therefore conclude that two factors are enough to explain the movements in Chinese government bond yields. It should also be noted that related studies, including Ang

[3]The U.S. Federal government halted the issuance of 30-year Treasury bonds in 2001, but resumed it in 2006.

and Piazzesi (2003), often use yields of maturities of one to five years when studying the relationship between the yield curve and macroeconomic and monetary variables.

Following the standard convention in related studies, we look at two important components that influence the yield curve: the spread between the long-term and the short-term yield and the long-term yield. These two factors represent the slope and the level movement components, respectively. For the long-term yield, we use the five-year yield, and for the difference between the long-term and short-term yields we look at the difference between the five- and one-year yields. The slope and level are assumed to capture the complete behavior of the yields with different maturities. In total, we have yields of five different maturities. In order to model them as functions of the two factors discussed above, we add random errors in the specification of each of the five yields. More specifically, we model the yields in the following way:

$$y_t^{(1)} = l_t - s_t + \epsilon_t^{(1)}, \tag{1}$$

$$y_t^{(i)} = b_i l_t - c_i s_t + \epsilon_t^{(i)}, \qquad i = 2, 3, 4 \tag{2}$$

$$y_t^{(5)} = l_t + \epsilon_t^{(5)}, \tag{3}$$

where

$$\epsilon_t^{(n)} \sim N\left(0, \sigma_n^2\right). \tag{4}$$

Here, $y_t^{(n)}$ for $n = 1, 2, 3, 4, 5$, represents the n-year yield calculated from market prices of bonds at time t. l_t represents the level of the yield curve, while s_t represents the slope. $\epsilon_t^{(n)}$ is the random error assumed to follow a normal distribution with mean 0 and a variance of σ_n^2. Finally, b_i and c_i for $i = 2, 3, 4$ are the parameters that set the relationship between the two factors and yields of maturities two, three, and four years. A related study methodology is Diebold, Rudebusch, and Aruoba (2006).

Diebold, Rudebusch, and Aruoba use a modified Nelson-Siegel model to extract the level, slope, and curvature factors. We do not use their approach, because the level in the Nelson-Siegel model is the long-term rate and our longest yield to maturity is only five years. Also, the initial principal component analysis indicates that we only need two factors and the level and spread in our model has a clear meaning.

The aim of this paper is to analyze the influence of macroeconomic variables and monetary policy on the yield curve in China. We use the annual change in CPI as inflation, i_t. The real economy is represented by the real GDP output gap, p_t. The one-year savings deposit rate is used as the official rate, o_t, while the annual growth rate of M1 represents money supply, m_t. Narrow money as measured by M1 is used since the central bank explicitly focuses on it when it conducts its monetary policy with money supply. The market rates reflect changes in macroeconomic variables and monetary policy, which means that the market rate can be expected to be directly influenced by them. Furthermore, the market interest rate is related not only to the current economic situation and monetary policy, but also reflects investors' expectations of the future values for these variables. Therefore, the current market rates may have a significant effect on the future values for the macroeconomic variables and monetary policy. We assume that the four macroeconomic and monetary variables and the two yield variables follow a vector autoregressive (VAR) process. Likelihood ratios show that the optimal lag length in the VAR process is one. We model the VAR with the two macroeconomic variables first, then the two monetary variables, and finally the two yield variables. The VAR model we use is thus:

$$X_t = \mu + AX_{t-1} + \Gamma\eta_t, \tag{5}$$

where

$$X_t = \begin{pmatrix} i_t \\ p_t \\ o_t \\ m_t \\ l_t \\ s_t \end{pmatrix}, \quad \mu = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{pmatrix}, \quad A = \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & a_{46} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{56} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{pmatrix},$$

$$\Gamma = \begin{pmatrix} \gamma_{11} & 0 & 0 & 0 & 0 & 0 \\ \gamma_{21} & \gamma_{22} & 0 & 0 & 0 & 0 \\ \gamma_{31} & \gamma_{32} & \gamma_{33} & 0 & 0 & 0 \\ \gamma_{41} & \gamma_{42} & \gamma_{43} & \gamma_{44} & 0 & 0 \\ \gamma_{51} & \gamma_{52} & \gamma_{53} & \gamma_{54} & \gamma_{55} & 0 \\ \gamma_{61} & \gamma_{62} & \gamma_{63} & \gamma_{64} & \gamma_{65} & \gamma_{66} \end{pmatrix}, \quad \eta_t = \begin{pmatrix} \eta_{1,t} \\ \eta_{2,t} \\ \eta_{3,t} \\ \eta_{4,t} \\ \eta_{5,t} \\ \eta_{6,t} \end{pmatrix}.$$

In order to conduct tests on the relationship between the variables using impulse responses and variance decompositions, we need to specify a structure for the random shocks. Using a Choleski decomposition of the error variance-covariance matrix, we specify Γ as a lower triangular matrix. We thus assume that monetary variables do not have a contemporaneous effect on macroeconomic variables. We also assume that yields do not have a contemporaneous effect on the macroeconomic or monetary variables. Finally, $\eta_{i,t}$ $(i = 1, 2, 3, 4, 5, 6)$ are mutually independent errors that follow a standard normal distribution.

4.2 Estimation Procedure

We want to estimate the model in expressions (1) to (4) as well as the VAR in expression (5). To specify a likelihood function for the setup above is problematic. However, by using a Bayesian Markov chain Monte Carlo (MCMC) estimation procedure, we do not need to specify the likelihood function explicitly. Instead, we specify prior distributions for each of the parameters in the model. We use $y_t^{(5)}$ and $y_t^{(5)} - y_t^{(1)}$ to approximate l_t and s_t, and then estimate equation (5) using maximum likelihood estimation to get initial values for the parameters. These preliminary values for the parameters are used the as a reference for prior assumptions in the MCMC estimation. The following prior distributions are used for the parameters:

$$b_n \sim N(1,1), \quad c_n \sim N(0.5,1) \qquad (n = 2,3,4)$$

$$a_{ii} \sim N(0.7,1), \quad a_{ij} \sim N(0,1) \qquad (i = 1,2,...,6; j = 1,2,...,6; i \neq j)$$

$$\mu_1 \sim N(2,1), \quad \mu_2 \sim N(0,1), \quad \mu_3 \sim N(2,1)$$

$$\mu_4 \sim N(12,1), \quad \mu_5 \sim N(2,1), \quad \mu_6 \sim N(0.1,1)$$

$$\gamma_{ii} \sim Gamma(1,1), \quad \gamma_{ij} \sim N(0,1) \qquad (i = 1,2,...,6; j = 1,2,...,6, i \neq j)$$

$$1/\sigma_i^2 \sim Gamma(1,1) \qquad (i = 1,2,...,6)$$

As mentioned, by using an MCMC approach, we can identify the conditional distributions of the parameters without specifying the likelihood function. For instance, assume that $p_i(\theta_i|\theta_{j\neq i}, Y, M)$ is the distribution of the parameter θ_i conditional on all the other parameters, the data (Y), and the specified model (M). When applying MCMC, we do not need to know the explicit forms of the different conditional distributions. Instead, we draw random numbers from each of them. Using starting values for all parameters, $\theta_i^{(0)}$, the parameters can be sampled the following way:

1. draw $\theta_1^{(1)}$ from $p_1(\theta_1|\theta_2^{(0)}, \theta_3^{(0)}, ..., \theta_m^{(0)}, Y, M)$

2. draw $\theta_2^{(1)}$ from $p_2(\theta_2|\theta_1^{(1)}, \theta_3^{(0)}, ..., \theta_m^{(0)}, Y, M)$

$\vdots$

m. draw $\theta_m^{(1)}$ from $p_m(\theta_m|\theta_1^{(1)}, \theta_2^{(1)}, ..., \theta_{m-1}^{(1)}, Y, M)$

This completes one iteration. Using the new information from the last draw, the process is repeated n times so that we end up with a sequence of draws:

$$\left(\theta_1^{(1)}, \theta_2^{(1)}, ..., \theta_m^{(1)}\right), \left(\theta_1^{(2)}, \theta_2^{(2)}, ..., \theta_m^{(2)}\right), ..., \left(\theta_1^{(n)}, \theta_2^{(n)}, ..., \theta_m^{(n)}\right)$$

Under weak regularity conditions, as n becomes large, the drawn values for the parameters are approximately the same as the random draws from the joint distribution $p_i(\theta_1, \theta_2, ..., \theta_m|Y, M)$. We make a total of 20,000 draws. Using the first 10,000 as so-called "burn-ins", we then make inference on the final 10,000 draws.

5 Data and Empirical Results

5.1 Data

Since China's GDP is reported quarterly, we use quarterly data for all the variables in the empirical analysis. We use data from the first quarter of 1999 to the last quarter of 2008, which gives us a total number of ten years. The data for the market interest rates is based on prices of government bonds listed on the Shanghai Stock Exchange. Using the procedure explained in Fisher, Nychka and Zervos (1995), we fit the term structure by applying smoothing splines that incorporate a roughness penalty parameter. We thus obtain a yield curve for the Chinese government bond market. The roughness penalty parameter that sets the level of smoothing in term structure controls the tradeoff between the smoothness in the curve and the error in the pricing of input bonds, where 1 results in the smoothest fit. We use a roughness penalty parameter of 0.9, mainly because the number of bonds trading in the market is limited. Figure 1 shows the time series for the yields of maturities from one to five years. We can see that the yields changed markedly during the ten years and that the difference among the yields of different maturities varied significantly. This means that we can expect the slope to change over the sample period.

[FIGURE 1 HERE]

Next, we take a closer look at the macroeconomic and monetary policy variables. The time series of the four variables are shown in Figure 2. Because China only announces nominal accumulated GDP and its real annual growth rate, the output gap is obtained using the following approach: we assume that commodity price in 1999 are stable. The quarterly nominal accumulated GDP data is then considered the same as real accumulated data in 1999 (here, accumulated GDP in a quarter means the total GDP from the beginning of the year to the end of quarter, e.g. accumulated GDP in the second quarter is the GDP over the last six months). When we have the annual real growth rate of accumulated GDP, we then calculate the real GDP data for every quarter. Because the GDP data have strong seasonal features, we calculate the smoothed log GDP as a moving average of log GDP with four lags and then use a Hodrick-Prescott filter to obtain the trend of the smoothed log GDP. The difference in actual smoothed log GDP and the trend multiplied by 100 is then used as the gap of real GDP.

Looking at the first graph in the figure, we see that inflation spiked three times during the ten-year period, with the highest peak in 2008. The second graph shows that the Chinese economy began to heat up in 2007, with the real output gap reaching a very high level during 2008. The graphs also indicate that there seems to be a relationship among inflation, output and money supply. Comparing Figure 1 and Figure 2, we see that changes in bond yields are similar to changes in inflation. The one-year deposit rate, on the other hand, differs significantly from both market rates and inflation. The yields peaked three times during the sample period, with one smaller peak in 2000 and two large peaks in 2004 and 2007, respectively. The five-year yield peaked higher in the end of 2004 than in the end of 2007, even though the one-year deposit rate and the inflation rate were both higher in 2007.

[FIGURE 2 HERE]

5.2 Initial Results

The results from the MCMC estimation are reported in Table 1. Focusing first on l_t, it seems that none of the macroeconomic or monetary variables have a causal lagged effect. If we instead look at s_t, the picture is different, with inflation having a significant effect on the slope factor. When there is an increase in inflation, this causes the slope to increase in the following period. Keeping the other variables constant, a change in one macroeconomic or monetary variable does not cause a very strong immediate change in market interest rates with a one-period lag. To fully understand how the macroeconomic and monetary variables affect the different yields over time, we use impulse response functions and variance decompositions in the following sections.

[TABLE 1 HERE]

Before we move on to impulse responses and variance decompositions, we take a look at the estimations of l_t and s_t. Figure 3 shows the estimated values of the two variables. For comparison, the figure also includes the observed market rates $y_t^{(5)}$ and $y_t^{(5)} - y_t^{(1)}$, respectively. The difference between the long-term market interest rate and the estimated l_t is quite small. The estimated values of s_t and the observed yield spread differs quite significantly during several subperiods of the sample. This difference indicates that the yield spread $y_t^{(5)} - y_t^{(1)}$ is most likely contaminated by random errors.

[FIGURE 3 HERE]

5.3 Impulse Responses

Having discussed the initial estimation results, we now move on to more detailed analysis of the effects of macroeconomic and monetary variables on yields using impulse response functions. The following analysis focuses mainly on the effects that the macroeconomic and monetary variables have on the yield curve's slope and level, but we also discuss some effects among the former variables.

Figure 4 shows the response of the long-term market rate to shocks from the macroeconomic and monetary variables in the system. The solid line represents the effect of a one-percent shock in each of the four macroeconomic and monetary variables for up to 20 periods after the shock occurs. The dashed lines are 90% confidence intervals. Due to the small-sample properties of the data, the confidence intervals are estimated using bootstrapping with 3,000 iterations. Looking first at the upper left graph in Figure 4, a shock in inflation has a positive effect on level of the yield curve. However, the effect is lagging, reaching a maximum about six months after the shock. A sudden shock from the output gap has a very significant positive effect on the level. The effect is immediate and positive. This means that if there is an unexpected increase in economic growth, the level of the yield curve increases quickly. Looking instead at the effect of a sudden change in the official rate, the response is significant and negative. The response is delayed and reaches a maximum about one year after the shock in the official rate. The negative relationship between the official rate and the level of the yield curve is perhaps somewhat different from what we would expect. It would be natural to assume that an increase in the official rate pushes the market rates upwards, a common feature in the U.S. market. However, the official rate can be seen as responding primarily to changes in inflation and output. The official rate can be used to curb overheating and inflationary pressures in the economy. An increase in the official rate thus results in a decrease in inflation (as seen in Figure 6). The somewhat delayed negative effect on the level of the yield curve indicates that a shock emanating from a change in the official rate propagates through the level of inflation to the final delayed reaction in the level of the yield curve. Finally, a money supply shock results in an initial small negative effect on the level of the yield curve, which is then followed by a prolonged positive effect with the maximum effect occurring after one year. The initial decrease is not very large and is most likely a liquidity effect. The delayed increase is larger and lasts longer. The positive response can be seen as an indirect effect caused by the money supply's effect on inflation and economic growth, which then affects the long-term market rate.

[FIGURE 4 HERE]

Figure 5 presents the impulse responses of the slope of the yield curve to shocks from the four different macroeconomic and monetary variables. Looking at the response of the slope factor to an inflationary shock, the effect is positive and significant, indicating that the long-term rate is more responsive to inflationary changes than the short-term rate. This differs from studies on the U.S. (Ang and Piazzesi, 2003), where it mostly is the short-term interest rate that is affected by changes in inflation. There is also an initial positive response in the slope of the yield curve to an output gap shock. Again, the response of the short-term rate is smaller compared to the response in the long-term yield to an output shock, indicating that the long-term yield is more sensitive to changes in macroeconomic variables. The initial response of the yield spread to a shock from the official rate is small. However, there is a delayed negative effect that is quite significant one year after the shock takes place. Since there is a similar but larger shock to the level factor, it is clear that the long-term yield is more responsive to official rate shocks. Finally, money supply shocks do have a significant and positive effect on the slope of the yield curve.

Our results differ from those of Evans and Marshall's (1998). In their study on the U.S. yield curve, it is shown that monetary policy shocks have a significant effect on the short yield while the longer yields are virtually unaffected. One plausible reason for the difference is that the commercial banks have such a dominant position in the Chinese bond market. Commercial banks in China have access to large amounts of capital from short-term savings accounts. The cost for that capital is low, mainly because the short-term official rate is kept low. This means that the banks can afford to demand a relatively low market rate. When the banks invest in long-term bonds, they usually compare the yield to their long-term funding cost. This cost is significantly higher due to the higher long-term official rates. This explains why the longer yields are more sensitive to changes in monetary policy.

[FIGURE 5 HERE]

So far, we have focused on the effects that the macroeconomic and monetary variables have on bond yields. In Figure 6 and Figure 7, we take a closer look at the relationships among the macroeconomic and monetary variables. Looking first at Figure 6, we see that an inflation shock results in a significant but delayed response in the official rate. Similarly, a sudden positive output shock results in a quick and positive response in the official rate. How does the official rate affect inflation and output? We can see that when there is shock in the official rate, there is a strong effect on inflation with a maximum decrease in inflation occurring about six months after the change in the official rate. There is also a negative but insignificant effect on output following an increase in the official rate. Looking instead at Figure 7, an inflation shock results in a delayed negative response in money supply. This is expected, as the central bank decreases the money supply to control the rise in inflation. A sudden change in the output gap results in an initial strong positive effect on the money supply. The delayed response is negative, but insignificant. Finally, the effects of a money supply shock are positive on both inflation and output. The maximal effect occurs after about one year. To sum up, the official rate is affected by macroeconomic shocks, while itself only has a marginal effect on inflation and output. Inflation and real output have a delayed effect on money supply, which in turn also has a delayed effect on inflation and output.

[FIGURE 6 HERE]

[FIGURE 7 HERE]

5.4 Variance Decompositions

In addition to the impulse response functions in the previous studies, we compute and present the variance decomposition in Table 2. The prediction horizons are 0, 1, and 5 years, respectively. Focusing first on the level of the yield curve, the level factor itself has the largest immediate impact. However, output and to some extent money supply are also influential variables. When we allow for the prediction horizon to increase, the effect of the level factor itself decreases significantly. The effect of output is still at a significant 18.4%. The most prominent change is the increasing influence of the official rate and also to some extent inflation. In the five-year future variations, the effect of the official rate has decreased somewhat as has the effect of output. Inflation, on the other hand, is more important for longer forecast horizons. Looking instead at the slope of the yield curve, the picture is quite similar. The effect of inflation increases with the prediction horizon, while that of output stays relatively stable. The effects of shocks originating from the official rate are increasing at longer horizons. Also, the effect of money supply shocks, albeit relatively modest, are stable across future periods of different lengths. Again, we see that most of the effects on the slope of the yield curve are matched by similar effects on level of the yield curve. We thus conclude that the long yield is is more affected by macroeconomic and monetary variables compared to the short yield.

Focusing on the effects that shocks in the slope and the level factors have on the macroeconomic and monetary variables, the results are similar to those in the previous section on impulse responses. The level factor has no immediate effect on any of the four variables. However, as we allow for the prediction horizon to increase, the effect becomes more significant. The level factors has the largest effect on inflation, even though the effects on output and the official rate are quite similar in magnitude. The effects of shocks originating from the slope factor are more modest. It is only in the case of the money supply that the slope has an effect corresponding to that of the level of the yield curve when allowing for the forecast window to increase to one and five years, respectively. To conclude, the results of the variance decomposition support those in the previous section in that they show that the long-term interest rate is as much influenced by macroeconomic and monetary variables as the yield spread. These results differ from those of Ang and Piazzesi (2003) and may be contributed to country-specific factors.

[TABLE 2 HERE]

Overall, the results have important implications for both investors and policy makers. For investors, the fact that macroeconomic and monetary variables have an effect on the pricing of bonds is important and indicate that these factors should be taken into consideration when valuing treasury bonds. This means that term structure models that incorporate these features may improve the fit of the model. Fan and Johansson (2009) is the first study that analyzes the effect of the official rate on China's yield curve. The results in this paper indicate that inflation is another potential variable that can be included in a model for the Chinese yield curve. For policy makers, the result that yields are affected by macroeconomic and monetary policy and vice versa has direct implications on the continued development of the bond market as well as domestic fiscal and monetary policies.

6 Conclusion

The yield curve is a central component in financial markets in the U.S. and Europe. In China, on the other hand, the development of the government bond market is a recent phenomenon. Even though the bond market is still relatively modest compared to markets in the U.S. and Europe, it is developing fast. As a result, the relationship between bond yields and the Chinese economy is becoming important for investors who want to understand the underlying factors that influence bond prices. The relationship is also important for policy makers that focus on the sound and healthy development of the still relatively immature domestic debt market. In this paper, we use a VAR setup to study the effects of inflation, real output gap, money supply and the official rate on China's yield curve. The effects of the yield curve on the other four variables are also discussed. The results of the empirical analysis are threefold. First, the inflation rate and the real output are both important determinants of changes in level of the yield curve. When there is an increase in inflation or when economic growth increases, there is a significant increase in the level of the yield curve. Likewise, money supply also influences market rates. As the money supply increases, there is a significant but somewhat delayed positive effect on the level of the yield curve. When we use the one-year deposit rate as the official rate, the results show that the there is a negative relationship between the official rate and the level of the yield curve. Our findings thus indicate that the market rate is not following changes in the official rate.

Second, the slope of the yield curve also reacts to changes in the macroeconomic and monetary variables. The slope factor has a strong positive relationship to changes in both the inflation rate and the real output gap. As money supply expands, the slope increases. Furthermore, when the official rate is raised, the slope decreases. The effects of macroeconomic and monetary shocks on the yield spread are somewhat delayed. The size of the effects indicate that the response of the different yields to economic and monetary changes differ and that the long-term rate is more responsive than the short-term rate to most of such changes. Previous studies on developed markets show that it is the short-term rate that is more sensitive to changes in economic variables (e.g. Ang and Piazzesi, 2003). In the U.S. and Europe, the short-term rate is usually seen as being primarily influenced by the current economic situation, while the long-term rate is influenced by expectations of future economic development. One reason for the difference in results may be that the monetary authorities in China do not conduct their monetary policy focusing solely on the short-term rate, but instead use money supply as well as a range of official rates. Another plausible reason is that domestic commercial banks are the major investors in the Chinese government bond market. The banks have access to inexpensive short-term capital, which results in very low short-term rates. A third possible reason is that as inflation increases, this causes a significant increase in risk for holders of long-term bonds. This is because Chinese investors have limited possibilities of hedging interest rate risk. The change in risk results in an increase in the demand for short-term assets, thus forcing the short-term rates down.

Third, the results are useful for our understanding of the relationship between macroeconomic and monetary variables. Money supply and the official rates are two important tools for monetary policy in China and our results show how they influence the economy. Inflation and output seem to be more responsive to changes in the money supply than changes in the official rate. However, the official rate seems to be at least as responsive to changes in inflation and output as money supply.

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Table 1: **Parameter Estimates**

	μ_1	μ_2	μ_3	μ_4	μ_5	μ_6
	0.44	-0.23	3.24	11.39	1.92	-0.32
	(0.69)	(0.24)	(0.39)	(0.89)	(0.55)	(0.62)
			Matrix A			
	1	2	3	4	5	6
1	0.71	1.11	-0.66	0.18	-0.44	0.60
	(0.13)	(0.49)	(0.29)	(0.05)	(0.31)	(0.59)
2	0.03	0.71	0.00	0.04	-0.12	-0.01
	(0.04)	(0.18)	(0.09)	(0.02)	(0.10)	(0.21)
3	0.02	1.29	0.12	-0.03	-0.13	-0.30
	(0.06)	(0.30)	(0.15)	(0.03)	(0.15)	(0.30)
4	-0.06	1.36	-0.77	0.71	-1.15	-1.28
	(0.20)	(0.73)	(0.44)	(0.09)	(0.49)	(0.83)
5	0.06	0.42	-0.23	0.04	0.53	-0.43
	(0.08)	(0.37)	(0.20)	(0.03)	(0.19)	(0.36)
6	0.15	-0.36	0.17	0.01	0.14	0.03
	(0.07)	(0.36)	(0.18)	(0.03)	(0.18)	(0.28)
			Matrix Γ			
	1	2	3	4	5	6
1	1.01					
	(0.14)					
2	0.13	0.34				
	(0.07)	(0.04)				
3	0.05	0.31	0.36			
	(0.10)	(0.12)	(0.05)			
4	0.24	0.83	-0.80	1.38		
	(0.38)	(0.50)	(0.45)	(0.30)		
5	-0.01	0.30	-0.01	-0.08	0.45	
	(0.13)	(0.16)	(0.14)	(0.12)	(0.07)	
6	0.05	0.11	-0.06	-0.04	0.10	0.38
	(0.12)	(0.17)	(0.14)	(0.11)	(0.12)	(0.06)
	b_1	b_2	b_3	c_1	c_2	c_3
	0.96	1.00	1.03	0.56	0.41	0.27
	(0.05)	(0.05)	(0.05)	(0.14)	(0.14)	(0.14)
	σ_1	σ_2	σ_3	σ_4	σ_5	
	0.32	0.27	0.26	0.27	0.29	
	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	

Note: Standard errors in parentheses.

Table 2: **Variance Decompositions**

		Origin of shocks					
	Periods	i_t	p_t	o_t	m_t	l_t	s_t
i_t	0	100.0	0.0	0.0	0.0	0.0	0.0
	4	49.6	16.4	17.1	6.6	8.2	2.2
	20	40.8	17.6	17.7	6.5	15.0	2.3
p_t	0	20.8	79.2	0.0	0.0	0.0	0.0
	4	21.5	58.1	8.5	3.9	7.5	0.6
	20	19.2	51.2	11.1	3.9	13.1	1.4
o_t	0	4.8	24.0	71.1	0.0	0.0	0.0
	4	19.4	51.2	20.6	2.5	5.9	0.4
	20	16.8	48.0	18.2	3.1	13.0	0.9
m_t	0	6.6	13.5	26.3	53.6	0.0	0.0
	4	11.6	20.7	19.8	21.7	10.6	15.6
	20	20.5	15.2	26.8	16.0	10.6	10.9
l_t	0	0.2	18.4	5.5	7.9	68.0	0.0
	4	8.4	18.4	29.1	5.0	33.9	5.2
	20	17.2	15.5	28.8	5.5	26.4	6.6
s_t	0	1.3	15.3	5.2	7.4	0.1	70.8
	4	33.0	13.3	18.1	6.8	2.5	26.4
	20	28.5	14.6	20.9	6.9	9.6	19.4

Note: Variance decomposition for each of the six variables. The first column shows the dependent variable and the second column gives the number of periods from the initial shock. The prediction horizons are zero quarters, four quarters, and twenty quarters, respectively. The numbers show the proportion of the variance of prediction error of the variable in the left-side column attributed to the variables in the top row.

Figure 1: One- to Five-Year Market Rates (in Percentages)

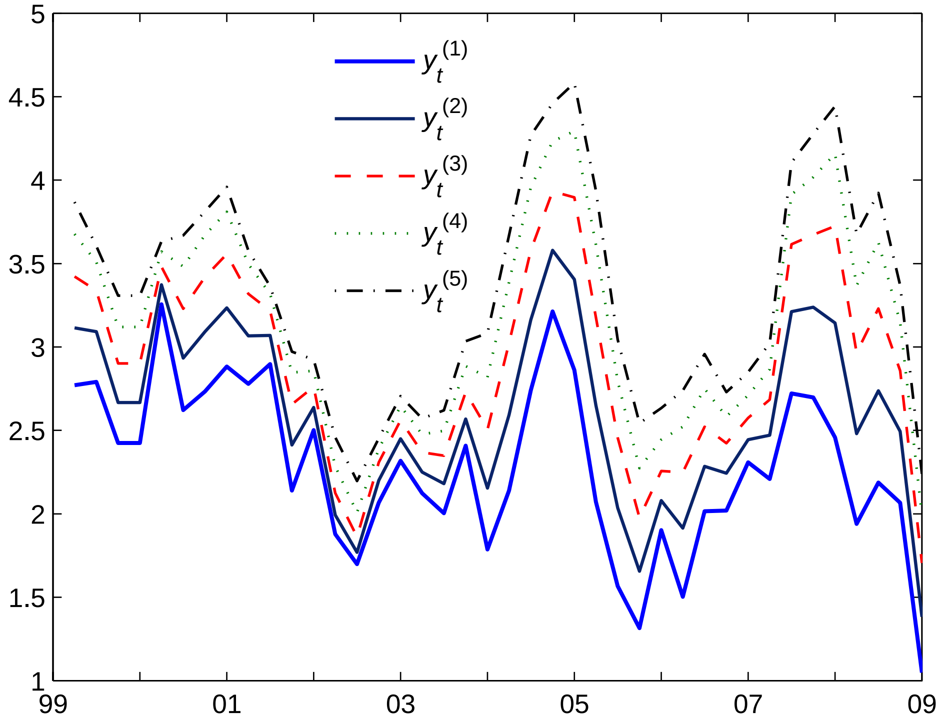
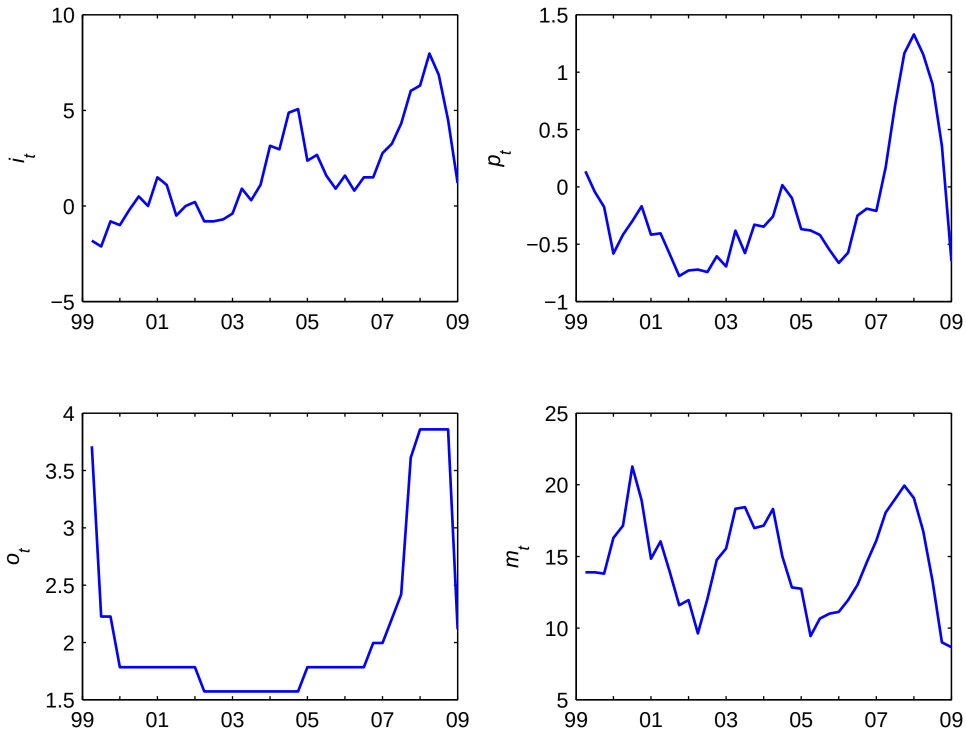
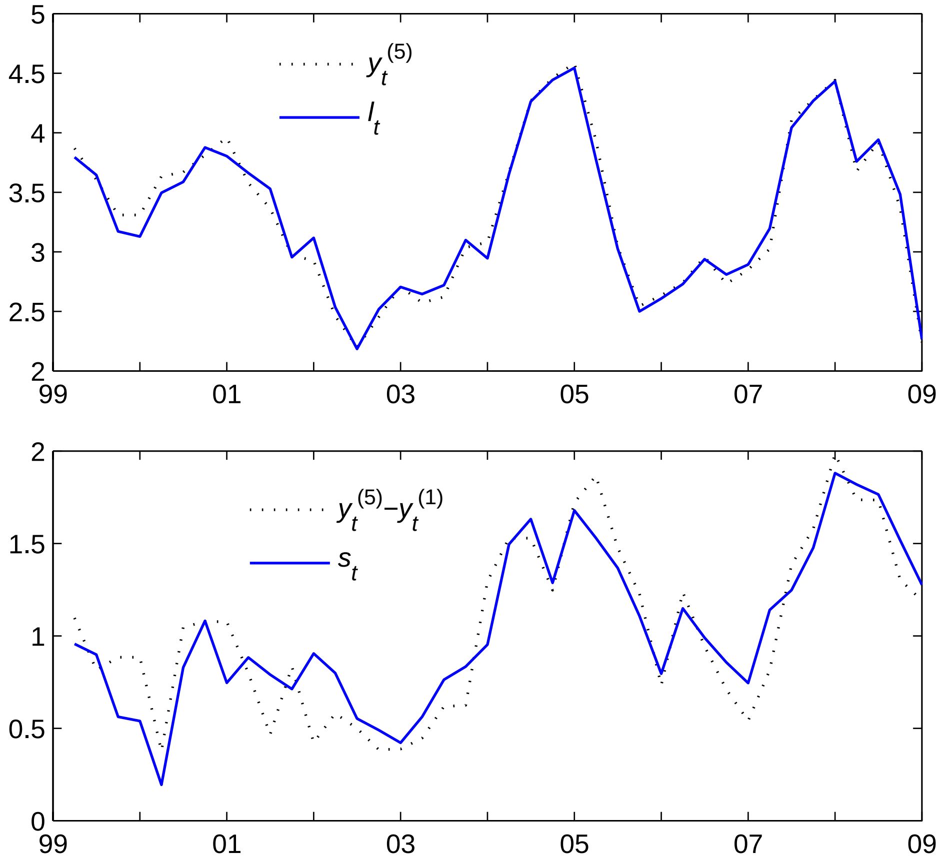


Figure 2: Macroeconomic and Monetary Variables



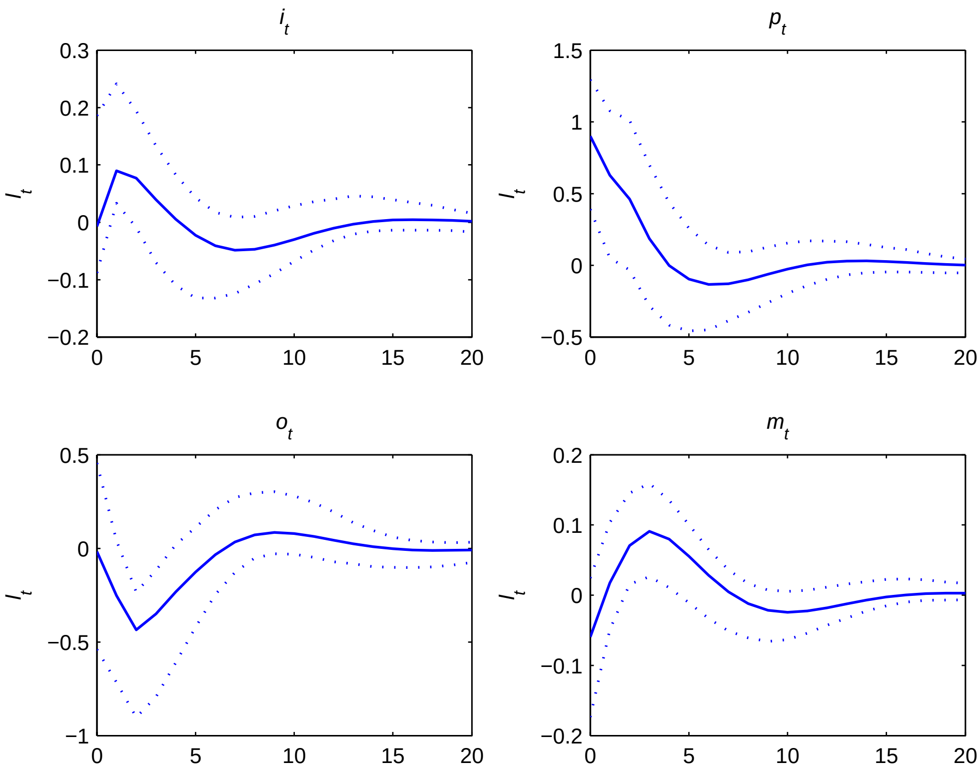
Note: Starting from the upper left corner, the figure shows the annual inflation rate (i_t), the output gap (p_t), the one-year deposit rate (o_t), and the annual growth of money supply (m_t), respectively. All variables are in percentages.

Figure 3: The Estimated Level and Slope



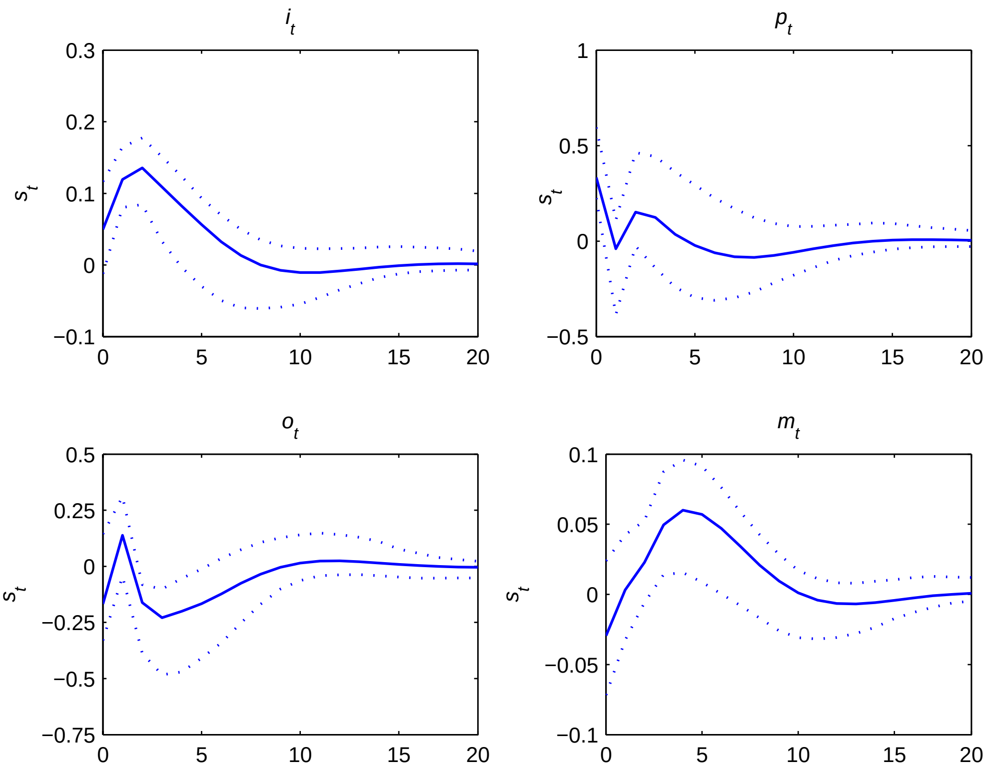
Note: The upper graph presents the actual five-year market rate ($y_t^{(5)}$) and the estimated level factor (l_t). The lower graph presents the actual spread between the long- and short-term market rates ($y_t^{(5)} - y_t^{(1)}$) and the estimated slope factor (s_t). All variables are in percentages.

Figure 4: Impulse Responses for the Level of the Yield Curve



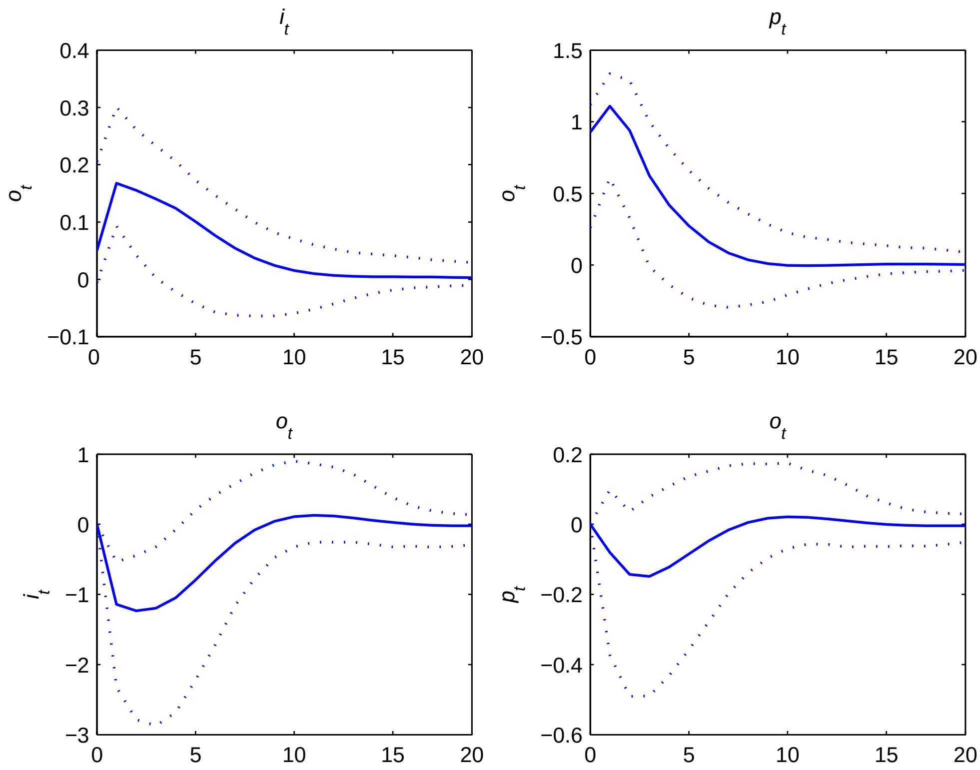
Note: Starting from the upper left corner, the figure shows the impulse responses of the level of the yield curve (l_t) following a one-percent shock in the inflation (i_t), the output gap (p_t), the official rate (o_t), and the money supply (m_t), respectively. The solid lines are the impulse responses, while the dashed lines are confidence intervals based on bootstrapping.

Figure 5: Impulse Responses for the Slope of the Yield Curve



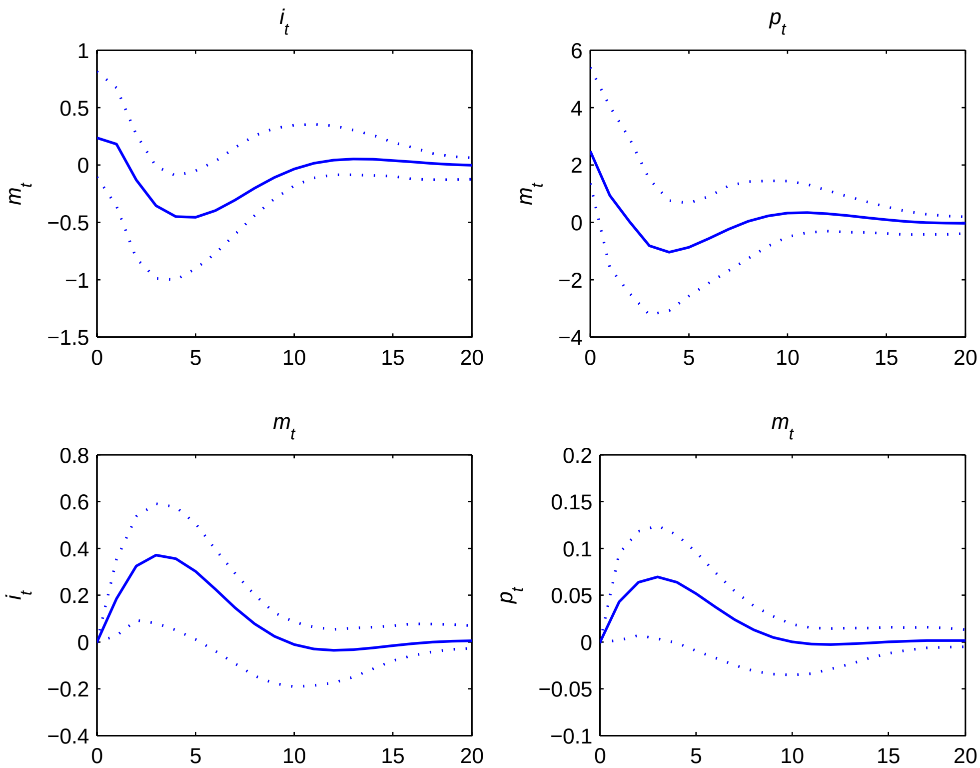
Note: Starting from the upper left corner, the figure shows the impulse responses of the difference between the slope of the yield curve (s_t) following a one-percent shock in the inflation (i_t), the output gap (p_t), the official rate (o_t), and the money supply (m_t), respectively. The solid lines are the impulse responses, while the dashed lines are confidence intervals based on bootstrapping.

Figure 6: Impulse Responses of the Official Rate to Economic factors and Vice Versa



Note: The two upper graphs show the impulse responses of the official rate (o_t) following a one-percent shock in the inflation (i_t) and the output gap (p_t), respectively. The two lower graphs show the impulse responses of inflation and output gap following a one-percent shock in the official rate. The solid lines are the impulse responses, while the dashed lines are confidence intervals based on bootstrapping.

Figure 7: Impulse Responses of Money Supply to Economic factors and Vice Versa



Note: The two upper graphs show the impulse responses of the money supply (m_t) following a one-percent shock in the inflation (i_t) and output gap (p_t), respectively. The two lower graphs show the impulse responses of the inflation and output gap following a one-percent shock in money supply. The solid lines are the impulse responses, while the dashed lines are confidence intervals based on bootstrapping.