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3 Money Growth and Interest Rates

Seok-Kyun Hur

3.1 Introduction

The primary purpose of our chapter is to investigate the roles of monetary policy in shaping the term-structure of interest rates. Monetary policy governing the stock of money influences the relative prices of money delivered at different times and different states. In turn, the current relative prices of money to deliver at different points of time in the future, which are, in other words, collectively called the term-structure of interest rates, influence economic decisions of private agents.

Intuitively speaking, the term-structure of interest rates is much more informative than any set of economic variables and thus will be useful as a reference for monetary policy. So far there have been continuous debates over what should be optimal targets of monetary policies. Mostly a combination of inflation and gross domestic product (GDP) gap is cited as a candidate for the target of monetary policy (Taylor 1993). Further developed models would allow autoregressive formations in inflation and GDP gap (Clarida, Gali, and Gertler 2000). Based on such criteria, a certain level of short-term interest rate (e.g., call rate in Korea, federal fund rate in the United States) is prescribed that a central bank should maintain. Though such concentration on the determination of the short-term interest rate is relatively easy to implement in practice, it only sequentially cross-checks the level of inflation and GDP gap with the current short-term interest rate. It neglects how the term-structure of interest rates as a whole reacts to the adjustment of the short-term interest rates, which might ex-

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plain why the same level of the short-term interest rate brings about different economic performances at different time and states.

Frequently we read numerous articles about predicting the future path of federal fund rate from newspapers. All of them are written on the implicit belief that monetary policy has influence on major aggregate economic activities, such as consumption, investment, and production, though its influence on these economic activities may differ in terms of directions, magnitudes, and timing. Unfortunately, a true transmission mechanism of monetary policy has not yet been thoroughly explored. A true description for the economy would be that the transmission mechanism works through multichannels, only a small number of which so far have been highlighted. To our knowledge, only a few economic models have emphasized the lagging effects of monetary policy in the context of analyzing the movements of the whole nominal bond-market equilibrium.[1]

Apart from the tradition, our chapter is based on the implicit belief that an effective monetary policy should consider the whole term-structure of interest rates rather than a yield rate of a bond with specific maturity. Furthermore, though control over the short-term interest rate has influence on the yields of bonds with longer maturities, it has not yet been clearly verified in which direction a change in the short-term interest rate shifts the whole term-structure of the interest rates. Provided that different yield curves lead to different performances of an economy, the monetary authority should perceive at least the impact of its current short-term interest rate policy on the term-structure of interest rates. However, an answer to this question would require thorough understanding of the whole economy as well as the bond market itself.

Most economic activities are determined by the anticipation of the future, which is well embedded in the term-structure of interest rates. Furthermore, the shape of the yield curve controlled by the money growth rates or the short-term interest rates plays a crucial role in determining the levels of the economic activities. Thus, we are interested in exploring how money growth rate or short-term interest rate policy shifts the term-structure of interest rates.

From the literature on durable consumption and investment[2], we under-

1. Most of the literature assumes that the shape of the term-structure curve depends on the anticipation for the future, the formation of which is hard to define or requires a somewhat arbitrary mechanism. For example, Ellingsen and Söderström (2004) explain how the yield curve responds to monetary policy. In their work, monetary policy is determined by the central bank's preference parameters over the volatilities of inflation, output, and the short-term interest rate. They claim variations in the preferences result in another yield curve by affecting people's expectation for the future. In contrast, our chapter focuses on verifying the relationship between the yield curve and the past money growth rates (or the past history of the short-term rate).

2. Refer to Hong (1996 and 1997) for durable good consumption and Breitung, Chrinko, and Kalckreuth (2003) for business investment.

stand that both of them are quite sensitive to economic fluctuations in comparison with consumption on nondurable goods and services. Intuitively speaking, since the flows of benefit from durable goods and capital continue for a certain period of time, durable goods consumption and investment entail the feature of irreversibility or indivisibility of purchase, which reduces durable goods consumption and investment decisions to optimal stopping problems. Hence, it is absurd to expect that the monetary authority can raise aggregate demands for durable goods and physical capital by merely changing the short-term interest rate. It is because in reality the falling short-term interest rate is often accompanied by an increase in the long-term interest rate, which discourages an agent from purchasing durable goods and physical capital. Thus, the monetary authority may need to find a certain pattern of a yield curve in order to reset the current yield curve to the pattern, which will boost the aggregate demand in times of depression.

On the other hand, the supply side may also depend on the term-structure of interest rates. Production requires a multiperiod binding planning horizon in addition to a time-to-build capital driven technology, in which the adjustments of production inputs are not completely flexible across time. Thus, the assignment or the employment of production inputs, not only capital but also labor, is perceived to be a function of the term-structure of interest rates.

The contents of the chapter are organized as follows: section 3.2 discusses a transmission channel of monetary policy in the economy, which relies on the lagged adjustment processes of various interest rates in the bond market. The feature of lagged adjustments resulting from delayed responses to monetary shocks is critical in that it relates the dynamics of interest rates to the past history of money growth rates or the past history of the short-term interest rates. Section 3.3 tests the models introduced in section 3.2 using the U.S. data, both monthly and quarterly. The relationship between the term-structure of interest rates and the money growth rates is estimated in consideration of endogenous money demand and velocity. Section 3.4 deduces the policy implications by discussing the time lags of monetary policy in implementing a certain yield curve as well as considering the impact of the current short-term interest rate targeting policy on the yield curve. Finally, section 3.5 concludes.

3.2 Theoretical Framework

From a survey of the current literature on the optimal monetary policy, we identify two common approaches from two distinctive traditions of thoughts—new classical and new Keynesian. The new classical approach[3]

3. Refer to Alvarez, Lucas, and Weber (2001) and Monnet and Weber (2001).

admits that market incompleteness, such as market segmentation, may cause the differential effects of monetary policy across time and across agents in the short run, whereas the new Keynesian approach[4] introduces sticky prices and wages to refute the neutrality of money. Regardless of different appearances, these two approaches have in common that they assume private agents respond to shocks in heterogeneous ways.

This section is purposed to provide a logical explanation about the delayed responses of aggregate macrovariables to monetary shocks and reveal the consequences of the delayed responses on the dynamics of the term-structure of interest rates induced by monetary policy. From the perspective of the new classical approach, we build a model, which allows a path-dependent dynamics of the interest rates governed by the past money growth rates.

To begin with, we investigate a limited bond-market participation model and show that the higher order moments of money supply can influence the term-structure of interest rates. Extended from a traditional Cash-in-Advance (CIA) model of Lucas and Stokey (1987), a general m-period-ahead CIA condition is imposed. The adoption of the CIA feature is critical because it, combined with the assumption of limited bond-market participation, brings about the more persistent redistribution effects of monetary policy on the economy. Based on these assumptions, the term-structure of interest rates is approximated by a system of linear equations of the lagged money growth rates. As is generally understood (Clarida, Gali, and Gertler 2000; Ellingsen and Söderström 2004), the expectation of the future money growth rates (or the future monetary policy) has effect on the current term-structure of interest rates. However, we emphasize the importance of the past path of monetary expansion in a sense that money shock would be realized in differential manners across heterogeneous agents in the economy.

Second, we explore the implications the nonnegativity restriction of nominal bond yield rates holds in the financial market, while showing that the linear approximation of the term-structure of interest rates by the past money growth path does not necessarily satisfy the nonnegative condition. The nonnegativity restriction of nominal bond rate is a critical barrier for the central bank to consider when it exercises open market operation policy. Especially, in a very low inflation regime, the possibility of reaching zero short-term interest rate often casts worries because zero rate is regarded as a natural lower boundary of a so called liquidity trap. It is commonly believed that the monetary policy without coordination with the expansionary fiscal policy would be ineffective in such a situation. However, the ineffectiveness of monetary expansion in case of falling into the zero nominal interest rate trap may be supported when only one type of bond is

4. For more details, refer to Clarida, Gali, and Gertler (1999) and Yun (1996).

available in the financial market other than money. Such an extreme absence of variety in the bond market is not realistic at all, and the plunge of the whole term-structure into zero has not been observed in the history, either. Hence, after complementing our term-structure model with nonnegativity restrictions, we discuss the effectiveness of monetary policy near zero short-term interest rate and explore a transitional path on which the bond-market equilibrium retrieves the positive interest rates.

3.2.1 Lagged Transmission Channel of Monetary Shocks

In this section we derive an equation linking the term-structure of interest rates with the past history of money growth rates. We introduce an economy with limited bond-market participation in order to induce a situation in which a monetary shock has differential impacts on heterogeneous agents across time (mainly redistribution effects). The impact differentials are caused by the unsynchronous timing of money shock transmitted to or perceived by the agents or by their different speed of reactions to the shock, and they lead to a nontrivial change in the term-structure of interest rates. On the other hand, in absence of such impact differentials, the yield curve would shift up or down in parallel according to the change of the present and the past money growth rates. A swing of the yield curve would be possible only by the coordinated variations of the expectation for the future monetary growth path and other real macrovariables.

Our model is an adapted version of Alvarez, Lucas, and Weber (2001). Our model assumes the following. First, there are two types of assets in the market—money and bond. Considering that the assets are a means of storing or growing values along the passage of time, the nominal return on money is always zero by construction, whereas the nominal return on bond is positive nominal interest rate. Due to the yield difference in these two types of assets, we need a mechanism guaranteeing the positive holding of money. Thus, we assign a CIA restriction, which is modified from the original one in Lucas and Stokey (1987).

Second, we assume limited bond-market participation, under which not every consumer can purchase bonds in the financial market due to transaction costs or information costs or regulation. There are two groups of consumers in the market—bond-market participants and nonparticipants, whose shares in the total population are λ and $1 - \lambda$, respectively.[5] These two groups are homogeneous in all the other aspects than the bond-market participation.

Third, the CIA condition to be introduced is defined on a multiperiod

5. It is assumed that all the bond-market participants hold all kinds of bonds with various maturities. A more realistic setup would allow that the bond-market participants should be classified into several groups by the maturities of bonds they hold (for example, short-term, medium-term, and long-term investors). Then, the equilibrium yield rate would display more dynamism.

time horizon as follows. At the current period, nominal consumption is afforded by a certain portion from the current nominal income, another certain portion from nominal income of the previous period, another certain portion from income earned two periods ago, and so on. A more intuitive interpretation of the multiperiod ahead CIA condition is that at the beginning of period t the current income (y_t) would be cashed instantly (p_t, y_t) and it would be spent for the next m periods by certain fractions of $v_{t,t+j}$, $j = 0, 1, 2, \ldots, m-1$, ($\Sigma_{j=0}^{m-1} v_{t,t+j} = 1$).

These assumptions are essential in inducing the redistributional effect of money injection across heterogeneous consumers and lowering interest rates for a certain period. In absence of heterogeneity or limited bond-market participation, there would be no redistribution of income among private agents and the interest rates would increase exactly at the speed of inflation.

Based on this story line, we derive a system of equations for our concern as follows:[6]

$$\mathbf{\Gamma}_t = \mathbf{\Phi\Delta}_t + \mathbf{R}(v^t, g^t) + \varepsilon_t, \tag{1}$$

$$\mathbf{\Gamma}_t \equiv \begin{bmatrix} r_{t,t+1} \\ r_{t,t+2} \\ \cdots \\ r_{t,t+n-1} \\ r_{t,t+n} \end{bmatrix}, \mathbf{\Delta}_t \equiv \begin{bmatrix} \mu_t \\ \mu_{t-1} \\ \cdots \\ \mu_{t-m+2} \\ \mu_{t-m+1} \end{bmatrix}, \mathbf{\Phi} \equiv \begin{bmatrix} \phi_{1,1} & \phi_{1,2} & \phi_{1,3} & \cdots & \phi_{1,m-1} & \phi_{1,m} \\ \phi_{2,1} & \phi_{2,2} & \cdots & \cdots & \cdots & \phi_{2,m} \\ \phi_{3,1} & \cdots & \cdots & \phi_{i,j} & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \phi_{n-1,m} \\ \phi_{n,1} & \phi_{n,2} & \cdots & \cdots & \phi_{n,m-1} & \phi_{n,m} \end{bmatrix},$$

where $\mathbf{\Gamma}_t$ is an $n \times 1$ vector of yield rates with different maturities, $\mathbf{\Delta}_t$ an $m \times 1$ vector of money growth rates up to date for the last $m-1$ periods, $\mathbf{R}$ an $n \times 1$ vector, and $\mathbf{\Phi}$ an $n \times m$ matrix. $\mathbf{R}(v^t, g^t)$ is the term evaluating the effects of other variables on the term structure of interest rates, such as a vector of the current and the past GDP growth rates (g^t) and is closely related to the current and the past velocities of money circulation (v^t).[7] The importance of $\mathbf{R}(v^t, g^t)$ is highlighted later in empirical analysis.

The model used for the derivation of equation (1) considers neither production nor money-market interactions. In this sense equation (1) does not represent all the equilibrium conditions. However, such a partial-equilibrium approach is worthy of trying because it can disentangle the direct effect of money growth, whereas a general equilibrium approach (including a vector autoregression [VAR] setup) evaluates both the direct and the indirect effects of money growth jointly. In addition, it is also notable

6. For more details on the derivation of the equations, see the appendix. In the appendix, we derive the system of equations with additional simplifying assumptions, such as zero GDP growth rate ($g_t = 0$ for all t) and the absence of taxation ($\tau_t = 0$ for all t). In contrast, equation (1) covers more general cases.

7. For formal definitions of g^t and v^t, see appendix.

that all yield rates other, than the federal fund rate can be converted to the functions of the federal fund rate and its lags because no-arbitrage conditions are levied in the determination of the yield rates.

Equation (1) shows path dependency in that the present term-structure of interest rates is affected not only by the money growth rate of the current period but also by those of the past ($m - 1$) periods.[8] Theoretically, path dependency is a common phenomenon and may arise from various sources. First, it can come from the learning process. All the economic decisions in a dynamic context should involve the formation of expectation for the future, which is in turn based on the learning processes from the past experience. This is also an excuse for not including the expectation for the future in the model. Second, path dependency can arise from some sorts of market frictions, which prevent economic agents from responding to shocks in a uniform manner and with simultaneous timing. Such inevitably heterogeneous responses of the agents may lead to persistent and lagging effects of monetary policy. There are many other sources of path dependency, but here we are particularly interested in these two sources.

Another notable point from equation (1) is that the lagged adjustments of interest rates in response to monetary policy vary across different types of bonds in terms of directions as well as magnitudes of changes. This implies that the monetary authority can adjust the shape of the term structure by using the dynamic or path-dependent relation of the term structure with monetary policy.

3.2.2 Zero Lower Boundary and Liquidity Trap

The term-structure of interest rates described in equation (1) provides static information evaluated at a point of time on the dynamics of various interest rates. Considering that equation (1) is obtained from the first order log-linear approximation of equation (A2), the interest rate dynamics may violate the nonnegativity of nominal interest rates and the nonnegativity restrictions should be additionally levied on the yields of all maturities.

A nominal interest rate is the rate of return on holding nominal bonds. Due to the definition and the existence of money, zero is a natural lower boundary for the nominal interest. So far, the probability of hitting zero interest rate has been evaluated extremely low and the consideration of nonnegativity yields has not been strongly enforced. However, the recent low interest rate regime in a few economies, including the United States and Japan, has caused worries that the nominal interest rate might hit zero and the economy might fall into the natural lower bound of the liquidity trap.

In this section, we analyze the propagation mechanism of the monetary policy in case of hitting the zero short-term interest rate by levying the nonnegativity restriction on equation (1). In addition, we distinguish the liq-

8. Money growth rates for the past $m - 1$ periods can be replaced by the higher-order moments of the money growth rate (μ_t) up to m –1th order.

uidity trap from the state of zero nominal interest rate and discuss an escape strategy from each of them using monetary policy.

There may be various ways of assigning the nonnegative condition to equation (1). Among them, the most intuitive one is to introduce shadow processes, which are equivalent with the yield rates when they are positive and diverge (become negative) when the yield rates are zero. In consideration of the nonnegativity condition as above, equation (1) should be modified to

$$(2)\quad \begin{bmatrix} r_{t,t+1} \\ r_{t,t+2} \\ \vdots \\ r_{t,t+n-1} \\ r_{t,t+n} \end{bmatrix} \equiv \begin{Bmatrix} \max\left[\sum_{j=1}^{m} \phi_{1,j}\mu_j^E + R_1(v^t, g^t) + \varepsilon_{1t}, 0\right] \\ \max\left[\sum_{j=1}^{m} \phi_{2,j}\mu_{t-j}^E + R_2(v^t, g^t) + \varepsilon_{2t}, 0\right] \\ \vdots \\ \max\left[\sum_{j=1}^{m} \phi_{n-1,j}\mu_{t-j}^E + R_{n-1}(v^t, g^t) + \varepsilon_{n-1t}, 0\right] \\ \max\left[\sum_{j=1}^{m} \phi_{n,j}\mu_{t-j}^E + R_n(v^t, g^t) + \varepsilon_{nt}, 0\right] \end{Bmatrix}$$

$$\boldsymbol{R}(v^t, g^t) \equiv \begin{bmatrix} R_1(v^t, g^t) \\ R_2(v^t, g^t) \\ \ldots \\ R_{n-1}(v^t, g^t) \\ R_n(v^t, g^t) \end{bmatrix} \text{ and } \varepsilon_t \equiv \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \ldots \\ \varepsilon_{n-1t} \\ \varepsilon_{nt} \end{bmatrix}.$$

Looking at equation (2), we may wonder what difference it makes from equation (1), except the addition of an operator max $[x, 0]$ to each row. A more critical difference could be found in the movement of a newly defined money growth rate μ_t^E, which is the effective money growth rate and is equal to the predefined money growth rate μ_t in absence of a zero rate bond. The divergence of μ_t^E from μ_t arises when the yield rate of a bond hits, stays at, or escapes from the zero boundary. It is because a bond, once its yield rate hits zero, would be treated as an equal for money. Accordingly, the money growth rate should be modified to account for a sudden change in the categories of money stock. Likewise, when the bond yield escapes from the zero rate, the exact opposite movement in the money growth rate as well as in the money stock would be observed.

So far we haven't clarified how the zero short-term interest rate is different from the liquidity trap. The liquidity trap is a state in which monetary expansion through open market operations or helicopter money drops cannot encourage economic agents to increase bond holdings and lower the interest rate further. In other words, the liquidity trap is a mental phenomenon, in which the substitution between money and bonds is extremely sensitive to the interest rate change. Accordingly, the level of the short-term interest rate, at which the liquidity trap arises, doesn't have to be zero.

On the other hand, the zero short-term interest rate does not necessarily imply the advent of the liquidity trap. There has never been a period in which the whole term-structure collapsed into the zero line, though there were some cases in which a point on the term-structure curve hit zero. Hence, even in the (near) zero short-term interest rate environment, the monetary authority can carry out expansionary monetary policy through open market operation by using other bonds with positive yield.[9]

Comprehension of the differences between the liquidity trap and the zero interest rate gives a clue to finding escape strategies from the liquidity trap. One of them is to use the increment of money stock neither for tax reduction, nor for the purchase of bonds, but for the purchase of goods. This can be regarded as a fiscal policy in that it increases the government expenditure. On the other hand, it still holds a feature of a monetary policy in that there is no additional fiscal burden in the government account. The inflationary effect of the government expenditure expansion funded by printing money would induce private agents to consume more and faster. In other words, the inflationary policy raises the velocity of money, $1/(1 - v_{t,t})$. The faster velocity is exactly opposite to the common belief that monetary expansion through the open market operation may reduce the velocity of money in a liquidity trap.

3.3 Empirical Analysis

This section verifies the validity of the claims deduced in the previous section. Equation (1) implies that the term-structure of interest rates is governed by the past money growth rates. In this section, mainly we use several modifications of equation (1) for empirical analysis.

There is a vast empirical literature on how monetary policy influences economic variables, including interest rates, most of which adopts VAR models with varying shock-identifying conditions. As is reviewed in Christiano, Eichenbaum, and Evans (1999), these models confirm the existence of short-run liquidity effect when the monetary shocks are given to M2, NBR (nonborrowed reserves), and the federal fund rate. However, when the M1 or monetary base is used for a policy variable, the liquidity effect is statistically insignificant.

9. Orphanides appreciates the usefulness of the open market operation policy, which is to "implement additional monetary expansion by shifting the targeted interest rates to that on successively longer-term instruments, when additional monetary policy easing is warranted at near-zero interest rates" (Orphanides 2003, 23–24).

In implementing an estimation strategy for equation (1), we do not use its Vector Error Correction (VEC) version for the following reasons: first, the variables in the right-hand side of equation (1) consist of the money growth rate, the GDP growth rate, and money velocity, and their lagged variables. Due to the inclusion of the lagged variables, the equation cannot represent the cointegration relations among the variables. Second, even if the VEC model was taken, it could not explain more than the traditional Expectation Hypothesis of interest rates.

Instead of giving up a VAR or a VEC setup, we have to verify the endogeneity of regressors. To handle with the endogeneity issue, we check a few exogeneity criteria including the Durbin-Wu-Hausman test and the Granger causality test. In case those tests support the exogeneity of the regressors, we justify the exclusion of omitted equations for money-supply and aggregate-supply functions.[10] Otherwise, we compare simple ordinary least squares (OLS) estimation of equation (1) with simultaneous estimation of equation (1), money supply and aggregate supply in order to check the robustness of the single-equation estimation.

Another notable point here is that empirical results from the estimation of equation (1) should be interpreted cautiously in that they reflect partial or direct effect from money growth. In contrast, results from a VAR or a VEC setup would measure the sum of both direct and indirect effects from money growth.

3.3.1 Data

Our analysis is based on the U.S. data from July 1959 to February 2000. We use the U.S. data because the U.S. government bond market is the most developed, and the maturities as well as the volume of the bonds traded in the market are diverse and huge enough to plot a reliable yield curve.

The variables of our concern are money stock, price, and income variables in addition to five key interest rates.[11] For the key interest rates, we select federal fund rate, 3-month Treasury bill, 6-month Treasury bill, 1-year Treasury bill, and a composite of long-term U.S. government securities.[12] For the macrovariables, we use M1 for an index of money stock, GDP deflator for price index, and real and potential GDP[13] for income measures.

The data frequencies differ from one category to another. For example, all the interest rates and M1 are recorded monthly whereas GDP deflator

10. Engle and Richard (1983) show that inference concerning the parameters from a conditional probability density is equivalent with that from a joint probability density when regressors are weakly exogenous. For a test method for weak exogeneity, refer to Beyer (1998) or Hendry and Ericsson (1991).

11. Interest rates are measured in annum whereas M1, GDP deflator, and GDP measures are on a quarterly basis.

12. The composite of the long-term treasury bonds is specifically defined to be an unweighted average on all outstanding bonds neither due nor callable in less than 10 years.

13. H-P filtered real GDP is used for potential real GDP.

and GDP[14] are recorded quarterly. To reconcile the conflicts of the data frequencies while at the same time exploiting the benefit of using monthly data, we run models separately with monthly and quarterly data.

As a variable for money stock, we use seasonally adjusted M1 for a couple of reasons. First, M1 is a money aggregate closest to high-powered money. Other money-stock indicators, such as M2 and M3, are under less direct control of the monetary authority and are more likely affected by money-demand fluctuations. M1, like other money-stock variables, are still susceptible to money-demand fluctuations. Admittedly, it is hard to distinguish money-demand shock from supply shocks, but we still maintain the use of M1 because M1 fits much better than the high-powered money with the real data.

Second, the time series of M1 is seasonally adjusted, considering that the asset prices tend to have no seasonality due to the prevalence of no-arbitrage condition. Accordingly, in order to couple the interest rates with the money growth rates, it is recommendable to use the seasonally adjusted M1.

3.3.2 Test Strategies and Stationarity of Variables

Before running regressions on equation (1), we test the stationarity of each variable included in the equations by Dickey-Fuller Generalized Least Squares (DF-GLS) method. The result shows that real GDP growth rate, potential GDP growth rate, and M1 growth rate are stationary with the significance of 1–10 percent for varying lags from one to ten. On the other hand, the velocity of money circulation ($v_{t,t}$), the inflation rate (π_t, measured by GDP deflator), and the yield rates ($\mathbf{\Gamma}_t$) turn out to be nonstationary.

The stationarity test results indicate that equation (1) is not testable with the yield rates and the money growth rate only. The remainder $\mathbf{R}(v^t, g^t)$ should be a nonstationary process by construction. Hence a test strategy for equation (1) is either to take the difference for the elimination of nonstationarity or to use $\mathbf{R}(v^t, g^t)$ in the estimation procedure by representing it in a linear function of (v^t, g^t).

Given that the GDP data is not available monthly, only the first strategy is applicable to the monthly data, whereas the quarterly data can implement the second one. Thus, depending on the frequency of the data, we adopt different testable equations. For the monthly data, we use the difference method as below

$$
\begin{aligned}
(3)\quad \mathbf{\Gamma}_t - \mathbf{\Gamma}_{t-1} &= \mathbf{\Phi\Delta}_t - \mathbf{\Phi\Delta}_{t-1} + \mathbf{R}(v^t, g^t) - \mathbf{R}(v^{t-1}, g^{t-1}) + \varepsilon_t - \varepsilon_{t-1} \\
&= \mathbf{\Phi}(\mathbf{\Delta}_t - \mathbf{\Delta}_{t-1}) + \mathbf{R}(v^t, g^t) - \mathbf{R}(v^{t-1}, g^{t-1}) + \varepsilon_t - \varepsilon_{t-1} \\
&= \mathbf{\Phi}^*\mathbf{\Delta}_t^* + \mathbf{R}(v^t, g^t) - \mathbf{R}(v^{t-1}, g^{t-1}) + \varepsilon_t - \varepsilon_{t-1} \\
&= \mathbf{\Phi}^*\mathbf{\Delta}_t^* + \boldsymbol{\eta}_t,
\end{aligned}
$$

14. As for the monthly data, an index of industrial production may be used as a proxy for nominal GDP. In that case, since the monthly GDP deflator is unavailable, Consumer Price Index or Producer Price Index can be substituted for the GDP deflator.

where

$$\mathbf{\Phi}^* \equiv \begin{bmatrix} \phi_{1,1} & \phi_{1,2}-\phi_{1,1} & \phi_{1,3}-\phi_{1,2} & \cdots & \phi_{1,m}-\phi_{1,m-1} & -\phi_{1,m} \\ \phi_{2,1} & \phi_{2,2}-\phi_{2,1} & \cdots & \cdots & \cdots & -\phi_{2,m} \\ \phi_{3,1} & \cdots & \cdots & \phi_{i,j}-\phi_{i,j-1} & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & -\phi_{n-1,m} \\ \phi_{n,1} & \phi_{n,2}-\phi_{n,1} & \cdots & \cdots & \phi_{n,m}-\phi_{n,m-1} & -\phi_{n,m} \end{bmatrix},$$

$$\mathbf{\Delta}_t^* \equiv \begin{bmatrix} \mu_t \\ \mu_{t-1} \\ \cdots \\ \mu_{t-m+1} \\ \mu_{t-m} \end{bmatrix}$$

$\boldsymbol{\eta}_t \equiv \mathbf{R}(v^t, g^t) - \mathbf{R}(v^{t-1}, g^{t-1}) + \varepsilon_t - \varepsilon_{t-1}$.

On the other hand, for the quarterly data, we use a fully linearized version of equation (1) as below:

$$\mathbf{\Gamma}_t = \mathbf{\Phi}\mathbf{\Delta}_t + \mathbf{\Psi}_v v^t + \mathbf{\Psi}_g g^t + \varepsilon_t, \tag{4}$$

where $\mathbf{\Psi}_v$ and $\mathbf{\Psi}_g$ are vectors of the same dimension with v^t and g^t respectively.

3.3.3 Results

Equations (3) and (4) consist of several equations and they are to be estimated by seemingly unrelated regression (SUR) in principle. However, in practice SUR usually underestimates the standard errors of estimates. Hence, we run regressions equation by equation with Newey-West estimates of standard deviations instead of SUR.

Equations (3) and (4) are tested with the monthly and the quarterly U.S. data, respectively. Especially with the quarterly data, we include real GDP growth rate, the velocity of money circulation (v^t) for the estimation of equation (4). In addition, inflation rate is used as one of the instrumental variables for v_t.

Figure 3.1 displays the historical patterns of the yield rates of our concern. Overall the five key interest rates commove, but with apparent idiosyncratic fluctuations. Our chapter distinguishes itself from other literature in that it represents such term-structure dynamics by a common factor of

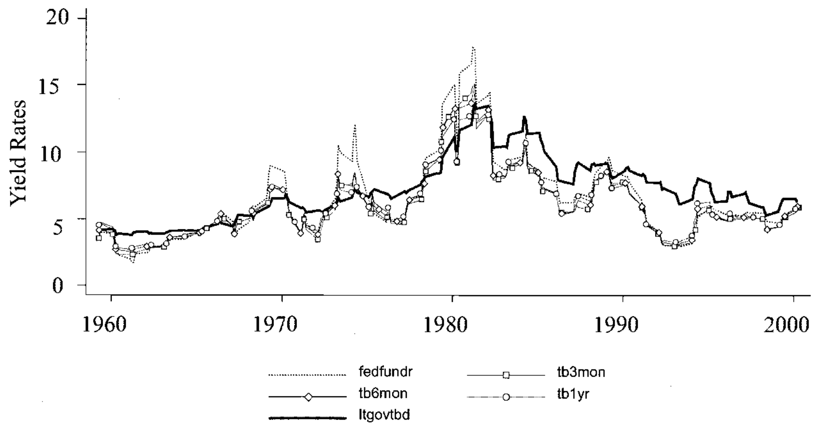

Fig. 3.1 The movements of yield rates in the United States during 1960–2000 (quarterly)

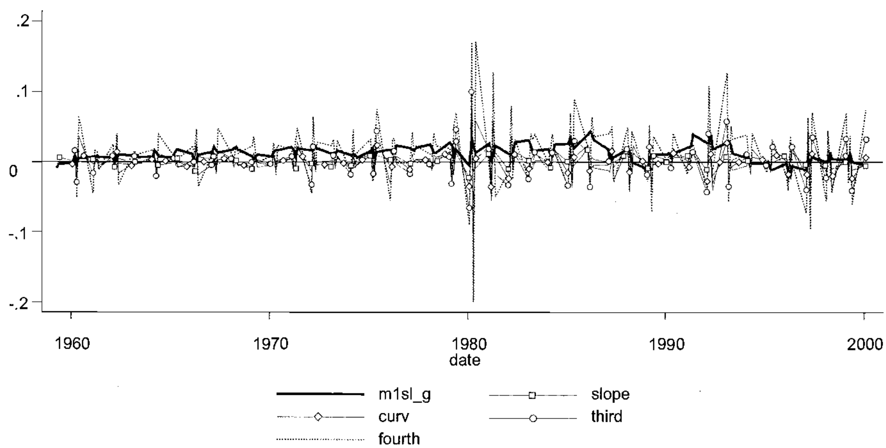

Fig. 3.2 The movements in the higher-order moments of M1 growth rate (quarterly)

the current and the past money growth rates, whose historical pattern is in turn graphically decomposed into different-ordered moments of money growth rates in figure 3.2.

Tests with Monthly Data

We test equation (3) with a little modification of $\mathbf{\Phi}^*\mathbf{\Delta}_t^*$. Since the lagged money growth rates in $\mathbf{\Delta}_t^*$ are hard to interpret intuitively, they are replaced by a vector $\boldsymbol{\theta}_t$, which contains the information on the current money growth rate and its higher-order differences.[15,16]

$$\text{(5)} \qquad \boldsymbol{\theta}_t \equiv \begin{bmatrix} \mu_t \\ \mu_t - \mu_{t-1} \\ \mu_t - 2\mu_{t-1} + \mu_{t-2} \\ \mu_t - 3\mu_{t-1} + 3\mu_{t-2} - \mu_{t-3} \\ \mu_t - 4\mu_{t-1} + 6\mu_{t-2} - 4\mu_{t-3} + \mu_{t-4} \\ \cdots \end{bmatrix}$$

The adoption of $\boldsymbol{\theta}_t$ changes equation (3) to

$$\boldsymbol{\Gamma}_t - \boldsymbol{\Gamma}_{t-1} = \boldsymbol{\Phi}^{**}\boldsymbol{\theta}_t + \boldsymbol{\eta}_t,$$

where $\boldsymbol{\Phi}^{**}$ is modified from $\boldsymbol{\Phi}^{*}$ so that it can match with $\boldsymbol{\theta}_t$.[17] We estimate equation (5) by running regressions equation by equation. The variances of the coefficient estimates are estimated by the Newey-West method.

Monetary aggregates like M1 reflect shocks not only to the behavior of the central bank, but also to money demand and the behavior of the banking sector as a whole (Christiano, Eichenbaum, and Evans 1999). Accordingly, in order to avoid the endogeneity of $\boldsymbol{\theta}_t$, we run the Wu-Hausman F-test and the Durbin-Wu-Hausman Chi-sq test by using the growth rate of monetary base as well as its higher-ordered differences for instrumental variables, but cannot reject a null hypothesis that $\boldsymbol{\theta}_t$ is exogenous in equation (5).[18]

Results from equation (5) are displayed in table 3.1. Money growth rate (μ_t) is excluded from the list of explanatory variables due to very low significance. Instead, the next three higher-order moments, slope, curvature, and the third-order moment of money growth rate, are used in the estimation of equation (5). Our findings include a couple of notable patterns. First, the signs of coefficients change alternatively from negative to positive and positive to negative. Second, the longer the maturity is, the less likely

15. The first-order moment of the money growth rate is to be called "slope" and the second one is "curvature." Higher-order moments other than the second one are to be denoted as their matching ordinal numbers.

16. The information contents in θ_t are equalized to those of Δ_t by including higher-order moments of money growth up to m.

17. On a quarterly basis, figure 3.2 shows how different order moments of money growth rate move in a heterogeneous way, which is also observable on a monthly basis. Another notable point is that the volatilities of the n-th order moments tend to increase with n as is shown in (table 3.5).

18. In principle, these exogeneity tests are consistent with another exogeneity test, which is based on cointegrated relations (Engle, Hendry, and Richard 1983; Hendry and Ericsson 1991; Beyer 1998).

it is to be influenced by the changes in the higher-order differences of money growth.

Reminded that table 3.1 summarizes the linear relations between the first-order differences of yield rates and the higher-order differences of money growth rate, we need to convert the results of equation (5) and evaluate directly the impact of money growth rate on the yield rates. Table 3.2 shows the liquidity effect is prevalent in the beginning and the Fisher effect shows up at later periods for all of the five key interest rates. Especially, the presence of the liquidity effect at period zero (in the first month) is meaningful in that this is the first case of confirming the liquidity effect using M1 (Christiano, Eichenbaum, and Evans 1999). On the other hand, the positive effects of money growth rate increase on the yield rates at period one

Table 3.1 Regression results of equation (5) (monthly)

	d_fedfundr	d_tb3mon	d_tb6mon	D_tb1yr	d_longbd
Slope	–127.9254***	–94.39297***	–85.78889***	–73.42162***	–30.08043***
(μ_t)	(27.96452)	(20.4626)	(18.60477)	(15.1847)	(8.06099)
Curvature	110.9467***	63.6107***	53.95926***	44.23584***	12.22965
($D.\mu_t$)	(24.56312)	(19.44036)	(17.83941)	(15.38967)	(9.06536)
Third	–29.04991***	–9.744747	–7.625036	–5.851174	–0.8182089
($D2.\mu_t$)	(7.56772)	(6.55566)	(6.007119)	(5.438865)	(3.474307)
R-square	0.1701	0.1994	0.1947	0.1795	0.1091

Note: All the numbers in parentheses are estimated standard deviation of corresponding coefficients.
***Significant at the 1 percent level.

Table 3.2 Cross-sectional variations in yield rates in response to 1 percent increase in money growth rate (monthly)

	fedfundr	tb3mon	tb6mon	tb1yr	ltgovbd
Estimates					
0	–46.03221	–40.52965	–39.45682	–35.0387	–18.67197
1	39.21423	36.9357	40.20249	37.54232	26.74801
2	–15.41497	–2.557601	–9.116989	–10.85891	–16.97112
3	44.46591	12.30309	16.74264	16.71058	17.79017
Lower (95%)					
0	–67.92918	–56.96087	–54.48401	–47.66546	–25.90708
1	10.73138	11.99402	18.2286	17.48822	13.71678
2	–52.29439	–35.40421	–35.8992	–34.92724	–32.03533
3	1.04308	–25.93205	–14.62933	–11.42724	–0.1755653
Upper (95%)					
0	–24.13525	–24.09842	–24.42963	–22.41193	–11.43686
1	67.69709	61.87738	62.17639	57.59642	39.77923
2	21.46445	30.28901	17.66523	13.20942	–1.90691
3	87.88873	50.53823	48.1146	44.84839	35.75591

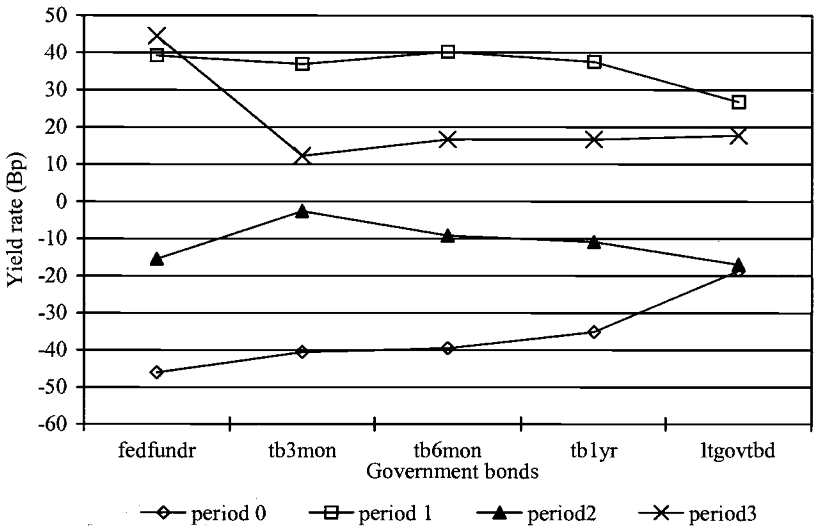

Fig. 3.3 Cross-sectional variations in the term-structure of interest rates in response to 1 percent increase in the money growth rate (monthly)

(in the second month) tend to almost absorb the previous negative liquidity effects and setting the yield rates back to the starting points, which indicates the emergence of the Fisher effect.

Additionally, figure 3.3, a graphical exposition of table 3.2, discovers a couple of interesting points. First, the longer the maturity is, the less responsive the yield rate is to the changes in money growth rate. Second, the liquidity effect prevails significantly across all the types of bonds at period zero and soon disappears, while the Fisher effect shows up at period one and stays afterwards. Third, the bonds with different maturities move generally in the same direction but with different magnitudes.

Test with Quarterly Data

As in the case of the monthly data, we modify equation (4) to

$$\Gamma_t = \overline{\boldsymbol{\Phi}}\boldsymbol{\theta}_t + \boldsymbol{\Psi}_v v^t + \boldsymbol{\Psi}_g g^t + \varepsilon_t, \tag{6}$$

where $\overline{\boldsymbol{\Phi}}$ is modified from $\boldsymbol{\Phi}$ so that it can match with $\boldsymbol{\theta}_t$. All the components in v^t except the current velocity of money ($v_{t-j,t-j}, j = 0, 1, 2, \ldots$) are omitted due to unobservability. From the money equation of $(m_t)(1/[1 - v_{t,t}]) = p_t y_t$, we identify $v_{t,t}$ as a function of money stock, price level, and real GDP.

In order to avoid the endogeneity of $\boldsymbol{\theta}_t$, we run the Wu-Hausman F-test and the Durbin-Wu-Hausman Chi-sq test by using the higher-ordered differences of monetary base as instrumental variables and reject a null hypothesis that $\boldsymbol{\theta}_t$ is (weakly) exogenous in equation (6). In addition, the Granger causality tests on (v^t, g^t) cannot support their (strong) exogeneity in equation (6). Hence, in estimating equation (6) we jointly estimate a money-supply function (measured in growth rate), an aggregate-supply function (also measured in growth rate), and a Taylor-rule type short-term interest rate rule, which in turn are functions of various yields, GDP gaps, and inflation rates. However, by comparing the results from the joint estimation with those from the single estimation of equation (6), we could not detect any qualitative differences between the two. Furthermore, the money-supply and the aggregate-supply function are not directly derived from our model and are just imposed to eliminate the endogeneity bias. Thus, we report the results from estimating equation (6) only.

Results from running equation (6) are displayed in table 3.3. As in the case of the monthly data, we run regressions equation by equation with Newey-West estimates of standard errors. However, equation (6) differs from equation (5) in that money velocity ($v_{t,t}$) is included[19] and the yield rates, not their first-order differences, are used as dependent variables. Compared with equation (5), equation (6) has greater explanatory power.

In table 3.3, most of the first- and the second-order differences of money growth rate (μ_t) are significant at a 5 percent significance level. The negative signs of the first- and the third-order differences in money growth rate explain the presence of the short-term liquidity effect.

Converting the higher-order moments of money growth into the lagged money growth rates as in table 3.4, we find that the signs of the estimated effects of money growth along the passage of time exactly coincide with our theoretical predictions and support the short-term liquidity effect and the long-term Fisher effect. However, the signs are not supported at 95 percent confidence intervals.

Such insignificance of the liquidity effect in table 3.4 can be better understood when it is compared with the results from the monthly data set (table 3.2), which confirms the significant negative effect at period zero as well as the significant positive effect at period one. Summing up the cross-sectional variations in yield rates for the first three months in table 3.2, it is easy to understand why the signs of the first quarter variations are not statistically significant. This interpretation also indicates indirectly that the length of lag (m) is about a month or so.

Figure 3.4 graphically exposes the cross-sectional variations in the term-structure of interest rates along the passage of time in response to a 1 percent increase in money growth rates.[20] It shows that the yield rates of the bonds with different maturities move in the same direction but with vary-

19. In order to avoid endogeneity, the money velocity is instrumented by the inflation rate as well as the other explanatory variables in equation (6), including its own higher-order differences.

20. A graph of cross-sectional variation differs from an impulse-response function of a VAR setup in that it does not consider the interactions of all the endogenous variables following a shock. However, for simplicity, the cross-sectional variations are interchangeably used with the impulse responses in the chapter.

Table 3.3 Regression results of equation (6) (quarterly)

Independent	Difference	fedfundr	tb3mon	tb6mon	tb1yr	ltgovbd
		Dependent				
μ_t	D0	298.13***	237.24***	238.58***	223.96***	136.63***
		(39.09)	(32.18)	(29.90)	(26.73)	(22.94)
	D1	–762.7388	–630.98***	–653.48***	–632.83***	–446.12***
		(182.60)	(153.39)	(148.83)	(137.28)	(120.12)
	D2	707.91**	610.81**	659.82**	666.85**	558.08**
		(304.41)	(259.07)	(256.40)	(241.84)	(214.52)
	D3	–343.76	–310.45	–346.95	–360.63**	–321.70**
		(222.42)	(191.95)	(190.36)	(181.26)	(9161.96)
	D4	70.71	65.82	74.78	78.55	70.84
		(61.65)	(53.54)	(53.05)	(50.70)	(45.27)
g_t	D0	–332.07***	–248.27***	–243.46***	–221.34***	–123.54***
		(56.57)	(46.14)	(43.93)	(40.41)	(36.00)
	D1	336.26	297.87**	304.13**	294.84**	259.71**
		(189.76)	(147.81)	(140.08)	(126.57)	(103.39)
	D2	–193.66	–191.88	–199.54	–201.73	–212.86
		(214.71)	(169.66)	(157.39)	(141.42)	(116.67)
	D3	38.66	42.97	41.81	42.61	65.93
		(109.73)	(87.95)	(81.30)	(73.28)	(62.87)
	D4	4.34	4.46	6.28	6.35	–3.06
		(24.70)	(20.65)	(19.73)	(18.37)	(16.61)
$v_{t,t}$	D0	54.40***	44.50***	44.09***	42.55***	41.16***
		(7.77)	(6.43)	(6.15)	(5.64)	(4.81)
	D1	2031.07***	1612.88***	1609.21***	1489.50***	535.41***
		(283.53)	(233.48)	(216.50)	(193.11)	(154.17)
	D2	–2486.19***	–2195.61***	–2268.09***	–2179.18***	–1182.56**
		(908.18)	(747.98)	(730.03)	(675.73)	(550.75)
	D3	1600.43	1522.96	1628.05**	1605.00**	977.80
		(913.03)	(768.84)	(757.91)	(713.18)	(605.03)
	D4	–400.25	–408.53	–445.34	–442.67	–278.71
		(337.63)	(286.99)	(283.99)	(269.58)	(229.38)
Constant		–41.35***	–33.29***	–32.85***	–31.42***	–28.06***
		(6.72)	(5.58)	(5.32)	(4.87)	(4.15)
R-square		0.6136	0.5978	0.6041	0.6086	0.6516

Note: All the numbers in parentheses are estimated standard deviation of corresponding coefficients.
***Significant at the 1 percent level.
**Significant at the 5 percent level.

ing magnitudes. As seen in the monthly data, the longer the maturity is, the less responsive the yield change is.

3.4 Policy Implications

From the previous sections, it is demonstrated theoretically and empirically that the impulse-response functions of the yield rates with respect to

Table 3.4 **Cross-sectional variations in yield rates in response to 1 percent increase in money growth rate (quarterly)**

Estimates	fedfundr	tb3mon	tb6mon	tb1yr	ltgovbd
Mean					
0	–29.7439	–27.5555	–27.259	–24.1077	–2.27344
1	95.35971	77.42151	75.59565	66.85081	11.72344
2	100.8781	74.39764	67.62069	56.22627	17.99554
3	60.93011	47.15575	47.84272	46.44869	38.35082
4	70.70663	65.82379	74.77775	78.54582	70.83833
Lower (95%)					
0	–72.449	–64.1373	–61.4791	–55.3686	–31.8303
1	–21.7694	–17.9108	–17.6397	–20.025	–57.6306
2	–35.0299	–40.515	–44.4904	–48.9846	–71.6344
3	–69.2319	–64.8058	–60.3734	–54.9368	–53.129
4	–51.1602	–40.0069	–30.1012	–21.6747	–18.6497
Upper (95%)					
0	12.96119	9.026414	6.96116	7.153189	27.28343
1	212.4888	172.7538	168.831	153.7266	81.07749
2	236.7862	189.3103	179.7318	161.4371	107.6254
3	191.0921	159.1173	156.0588	147.8342	129.8306
4	192.5734	171.6545	179.6567	178.7664	160.3264

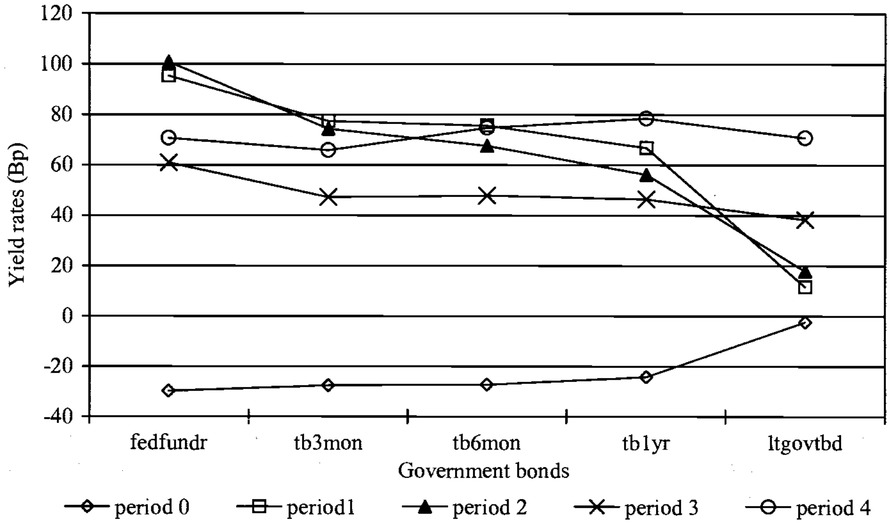

Fig. 3.4 Cross-sectional variations in the term-structure of interest rates in response to 1 percent increase in the money growth rate (quarterly)

money shocks determine the shape of the term-structure of interest rates. Using this property, the monetary authority can implement a certain shape of the term-structure of interest rates when there is no exogenous shock other than changes in money growth rate. Then, the monetary authority has to be concerned about the representability of a certain term-structure of interest rates as well as the time lags to take for the implementation.[21]

3.4.1 Implementability and Time Lags

In a type of equation (4), the dimension of the $n \times m$ matrix $\mathbf{\Phi}$ determines the representability of the term structure.[22] If dim $\mathbf{\Phi}$ is no less than the number of bond types available in the market (n), then a certain money growth rate path can lead to an arbitrary term-structure of interest rates within m periods. Otherwise, complete representability is not achievable.[23]

An easier criterion for the representability and the time lags of the implementation process is to check an impulse-response matrix, which is defined to be a stack of impulse-response-function values with respect to maturities and time horizon. Define the impulse-response matrix Ξ to be an $n \times T$ matrix, where T is an arbitrarily set time horizon (before all the impulse responses completely phase out) and n is the types of bond maturities available in the market. If $n > T$, then the representability of the system is limited to dim $(\Xi) < n$. If $n \leq T$ and dim $(\Xi) > n$, then the composite effect of the money growth rates during the last n quarters can represent any arbitrary term-structure of interest rates. Thus, we see that at least the horizons of impulse-response functions should be longer than the kinds of assets available in the market in order to guarantee the representability. The time lags of implementation is not easy to answer due to the presence of multiple solutions. However, the higher dimension of Ξ is more likely to raise the likelihood of attaining at a certain term-structure of interest rates within a shorter time horizon.

3.4.2 Determination of the Short-Term Interest Rate

In reality, it is more often the case that monetary authorities use the short-term interest rate rather than the money stock M1 for a control variable of monetary policy. Especially in the United States, the Federal Reserve is known to set the short-term interest rate based on the deviations of

21. Table 3.5 shows that the higher-ordered moments of money growth rate have been more volatile to the United States compared with the lower ones.

22. Representing a certain term-structure of interest rates doesn't necessarily guarantee the system would stay at the level continuously. Stability is another issue to tackle, but will be not be dealt with further in the chapter.

23. In that case, the Gaussian least square method would provide a minimum Δ_t^* from solving $\min_{\Delta_t} \varepsilon_t \varepsilon_t = (\overline{\mathbf{\Gamma}}_t - \mathbf{\Phi}\mathbf{\Delta}_t - \mathbf{\Psi}_v v^t - \mathbf{\Psi}_g g^t)(\overline{\mathbf{\Gamma}}_t - \mathbf{\Phi}\mathbf{\Delta}_t - \mathbf{\Psi}_v v^t - \mathbf{\Psi}_g g^t)$, where $\overline{r}_t$ is a targeted level of the yield curve.

Table 3.5 **Covariances of different-ordered moments of money growth**

	μ_t	slope	curvature	third	fourth
		Monthly, 487 observations			
μ_t	0.000025				
slope	0.000011	0.000022			
curvature	6.3e–06	0.000028	0.000057		
third	1.3e–06	0.00003	0.000087	0.000173	
fourth	–6.2e–06	0.000031	0.000089	0.00018	–0.000212
		Quarterly, 159 observations			
μ_t	0.00012				
slope	0.000039	0.000076			
curvature	0.000025	0.000101	0.000202		
third	0.000018	0.000119	0.000332	0.000645	
fourth	0.000068	0.000123	0.000461	0.001081	0.002076

inflation and GDP from certain levels.[24] Though this is the case, the relationship between money and interest rates does not change when the Federal Reserve uses the interest rate rule rather than money-aggregate targeting (Monnet and Weber 2001):

$$r_{t,t+1} = \bar{r} + \phi_\pi(\pi_t - \bar{\pi}) + \phi_x(y_t - y_t^p)$$

The effect of such a monetary policy of the short-term interest rate determination on the yield curve can be analyzed as a brief extension of our model.

Suppose that the short-term interest rate is prescribed by the Federal Reserve at period t as in the above Taylor-type rule. Then, by combining it with the first row of equation (6), we obtain an autoregressive equation of money growth rate μ_t as follows:

$$(7)\quad \mu_t = \frac{1}{\phi_{1,1}}\left[\sum_{i=1}^{m} \phi_{1,i+1}\mu_{1-i} + \boldsymbol{\Psi}_{1v}v^t + \boldsymbol{\Psi}_{1g}g^t - \phi_\pi(\pi_t - \bar{\pi}) - \phi_x(y_t - y_t^p) - \bar{r} + \varepsilon\right]$$

The impulse-response functions of the yield rates in regard to such federal fund rate policy can be obtained by plugging equation (7) back to equation (6) and representing it with the federal fund rate and its lags.

Table 3.6 provides the results from equation (7), showing that the Taylor-type short-term interest rate rule causes μ_t to move in an autoregressive way. Both the first and the second lags of μ_t are positive (the positivity of the second lag is valid at the 1 percent significance level) while the log GDP gap and the inflation rate hold negative signs in support of the Taylor rule.

24. Taylor (1993) estimates $r_{t,t+1} = 0.04 + 1.5\,(\pi_t - 0.02) + 0.5\,(y_t - y_t^p)$ using the U.S. data of the 1980s.

Table 3.6 **Autoregressive movements of money growth rate induced by a Taylor type short-term interest rate policy function**

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
A. Lag length selection order criteria (quarterly, 159 observations)								
0	539.221				0.0000718	–6.70345	–6.60067	–6.45038
1	541.121	3.801	1	0.051	0.0000710	–6.71492	–6.60423	–6.44239
2	544.495	6.747	1	0.009	0.0000689	–6.74516	–6.62657**	–6.45316**
3	544.842	0.694	1	0.405	0.0000695	–6.73684	–6.61034	–6.42537
4	545.035	0.387	1	0.534	0.0000702	–6.72656	–6.59216	–6.39563
5	547.654	5.237**	1	0.022	.0000688**	–6.74718	–6.60487	–6.39678
6	548.655	2.002	1	0.157	0.0000688	–6.74719**	–6.59698	–6.37733

		Dependent
Independent	Lag	μ_t
B. Estimation results (no. of observations = 158)		
μ_t	L1	0.45 (0.24)
	L2	0.47*** (0.18)
$y_t - y_t^p$		–0.04 (0.03)
π_t		–0.16 (0.29)
$v_{t,t}$	D0	0.00 (0.02)
	D1	1.13 (1.78)
	D2	–1.96 (1.61)
	D3	0.74 (1.22)
	D4	–0.51 (0.45)
g_t	D0	–0.25 (0.33)
	D1	0.11 (0.42)
	D2	0.13 (0.50)
	D3	0.01 (0.31)
	D4	0.00 (0.07)
Constant		0.00 (0.02)
R-square		0.5243

Note: All the numbers in parentheses are estimated standard deviation of corresponding coefficients.
***Significant at the 1 percent level.

The number of lags is chosen from applying the Bayesian Information Criterion (BIC).

So far we have implicitly assumed that M1 is under the tight control of monetary authority. However, in reality, M1 is not directly controlled by the monetary authority because variations in the demand side are hardly predictable and the magnitude of the demand side effect is greater than our anticipation. Despite such a problem, we do not use monetary base instead of M1 because the money equation does not hold for the monetary base. Another solution to this is to represent equation (6) with various moments of the federal fund rate in substitution for the moments of the money growth rate as follows:

$$\Gamma_t' = \overline{\mathbf{\Phi}}'\theta_t' + \mathbf{\Psi}_v' v^t + \mathbf{\Psi}_g' g^t + \varepsilon_t, \tag{8}$$

where $\mathbf{\Gamma}_t'$ is a vector of the yield rates except the federal fund rate (r_t) and

$$\boldsymbol{\theta}_t' \equiv \begin{bmatrix} r_t \\ r_t - r_{t-1} \\ r_t - 2r_{t-1} + r_{t-2} \\ r_t - 3r_{t-1} + 3r_{t-2} - r_{t-3} \\ r_t - 4r_{t-1} + 6r_{t-2} - 4r_{t-3} + r_{t-4} \\ \cdots \end{bmatrix}.$$

The substitution of equation (8) for equation (6) can explain the propagation process of changes in the short-term interest rate policy through the bond market. The estimation results of equation (8) are summarized in tables 3.7–3.8 and figure 3.5,[25] in which the presence of liquidity effect is significantly identified at least for period zero (for the first quarter).

3.4.3 Escape from Zero Short-Term Interest Rate

Suppose that the yield rate of n-period bond, $r_{t,t+n}$, hits (or escapes from) zero at period t. Then the effective money growth rate and money stock would be $\mu_t^E \equiv \mu_t + (B_{t,t+n}/M_t)$ and $M_t^E \equiv M_t + B_{t,t+n}$ (or $\mu_t^E \equiv \mu_t - [B_{t,t+n}/M_t]$ and $M_t^E \equiv M_t$), where $B_{t,t+n}$ is the amount of n-period bond available in the market and μ_t is the ordinary money growth rate. It is noticeable that μ_t^E would jump (drop) in a more volatile way when a yield of a certain bond hits (escapes from) the zero level.

Given that the effect of increased μ_t is negative in the short-run (the liquidity effect) and positive in the long-run (the Fisher effect), then a monetary system itself has an automatic mechanism of returning to a positive interest rate as follows: once a type of bond hits zero, then the total nominal value of the bond issue is added to the effective money stock, which in turn gives downward pressure on the interest rates of bonds with near maturities. Such a tendency of the yield curve approaching the zero line would continue until the short-run negative liquidity effect coming from new entrants to the category of the effective money stock (M_1^E) dominates the long-run Fisher effect arising from the accumulation of M_1^E. So far we have assumed that the monetary authority keeps the money growth rate μ_t constant. Considering that the monetary authority is able to speed up the money growth rate μ_t, then the time required to return to the positive yield curve will be shorter.

25. The money velocity is instrumented as in equation (6).

Table 3.7 Regression results of equation (8) (quarterly)

		Dependent			
Independent	Difference	tb3mon	tb6mon	tb1yr	ltgovbd
fedfundr	D0	0.79***	0.86***	0.84***	0.37**
		(0.06)	(0.06)	(0.07)	(0.18)
	D1	–0.22	–0.58***	–0.85***	–0.79
		(0.16)	(0.18)	(0.22)	(0.50)
	D2	0.34	0.79***	1.14***	0.85
		(0.25)	(0.27)	(0.31)	(0.69)
	D3	–0.18	–0.44**	–0.63***	–0.41
		(0.18)	(0.20)	(0.22)	(0.48)
	D4	0.04	0.10	0.14**	0.08
		(0.05)	(0.05)	(0.06)	(0.13)
g_t	D0	25.03**	47.25***	63.88***	50.94
		(11.57)	(11.22)	(14.90)	(42.33)
	D1	–22.29	–79.22***	–123.79***	–94.11
		(28.32)	(26.06)	(32.41)	(92.45)
	D2	17.76	68.72**	106.57***	69.81
		(31.22)	(28.60)	(35.05)	(102.14)
	D3	–9.22	–27.69	–40.72**	–20.38
		(16.72)	(15.71)	(19.26)	(55.76)
	D4	3.12	5.08	5.99	0.02
		(3.92)	(3.73)	(4.58)	(12.73)
$v_{t,t}$	D0	6.97	–2.18	–4.19	48.64**
		(7.67)	(7.72)	(8.99)	(20.84)
	D1	43.14	8.21	–9.02	–153.45
		(38.53)	(35.26)	(44.19)	(131.68)
	D2	–125.45	23.17	147.98	419.76
		(91.03)	(83.08)	(99.99)	(311.95)
	D3	115.80	–24.16	–152.72	–332.50
		(88.79)	(80.45)	(97.63)	(326.31)
	D4	–43.93	–1.27	41.25	93.82
		(30.29)	(27.40)	(34.60)	(118.70)
Constant		–5.26	1.90	3.60	–35.82**
		(5.93)	(5.98)	(6.93)	(15.86)
R-square		0.3771	0.9771	0.9619	0.7011

Note: All the numbers in parentheses are estimated standard deviation of corresponding coefficients.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

3.5 Concluding Remarks

Our chapter explores a transmission mechanism of monetary policy through bond market. Based on the assumption of delayed responses of economic agents to monetary shocks, we derive a system of equations relating the term-structure of interest rates with the past history of money

Table 3.8 **Cross-sectional variations in yield rates in response to 1 percent increase in federal fund rate (quarterly)**

Estimates	tb3mon	tb6mon	tb1yr	ltgovbd
Mean				
0	0.7750026	0.7304612	0.6318231	0.1020515
1	–0.0955232	–0.0884209	–0.0826153	0.0104195
2	0.0634101	0.0781971	0.0777503	0.0807758
3	0.0033343	0.0370159	0.0739016	0.1008343
4	0.0448813	0.1002093	0.1400108	0.0780675
Lower (95%)				
0	0.6850988	0.6360089	0.5231302	–0.0711424
1	–0.2279744	–0.2121276	–0.2454524	–0.3135994
2	–0.0725128	–0.0436097	–0.0861536	–0.2218558
3	–0.1220846	–0.0879021	–0.0916794	–0.2422914
4	–0.0551716	–0.0072723	0.0164971	–0.1867573
Upper (95%)				
0	0.8649064	0.8249136	0.7405161	0.2752455
1	0.0369279	0.0352859	0.0802217	0.3344384
2	0.1993331	0.2000039	0.2416543	0.3834075
3	0.1287531	0.1619338	0.2394827	0.4439601
4	0.1449343	0.207691	0.2635245	0.3428923

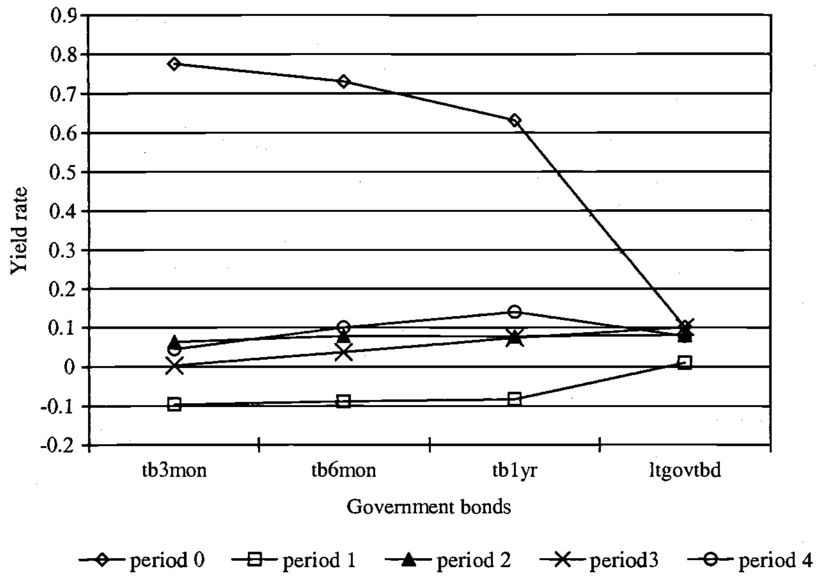

Fig. 3.5 Cross-sectional variations in the term-structure of interest rates in response to 1 percent increase in the federal fund rate (quarterly)

growth. The equations are empirically tested with the U.S. data after some modifications. Impulse-response functions of various yield rates with respect to monetary shocks as well as to the short-term interest rate (such as federal fund rate in the United States) reveal that the reactions of the yield rates may vary across the bonds with different maturities in terms of directions as well as in terms of magnitudes. Such path-dependency of monetary policy induces that monetary policy targeting a certain shape of the term-structure of interest rates could be implemented with certain time lags.

More specifically, our results for both the monthly and the quarterly data sets demonstrate that the interest rates of various maturities are significantly influenced by M1 growth rate and its higher-order differences up to the third order. The directions of influence are the same for all the bonds regardless of their maturities, but the relative magnitudes vary, which implies that the yield curve can be differently shaped depending on the past history of M1 growth rates.

When properly converted, our results confirm the sequential emergence of a liquidity effect and a Fisher effect across all the types of U.S. government bonds with different maturities using the monthly data. While the analysis into the quarterly data set fails in identifying the existence of liquidity effect and/or Fisher effect, these two observations may be reconciled by the inference that liquidity effect persists for about a month or so.

However, our results should be interpreted cautiously because they evaluate the direct effect of money shock on the interest rates and do not consider its indirect effect through other economic variables. In the same context, our chapter assumes that some endogenous variables, such as the velocity of money circulation and the bond-market participation rate, are exogenous. Furthermore, no production function is introduced. Such simplification would reduce the number of testable equations to derive and have them underidentified. Several exogeneity tests and instrumental variable regressions, which have already been adopted, are partial solutions to the symptom. Accordingly, a more complete solution including the further extension of the current model is to be sought in the future works.

Appendix

An m-*Period Extension of Alvarez, Lucas, and Weber (2001)*

Our model is an adapted version of Alvarez, Lucas, and Weber (2001). Consider an economy in which there exists two types of agents—bond-market participant and nonparticipant. Regardless of the type, both groups have the same intertemporal utility function:

$$\sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^t U(C_t), \text{ where } U(C_t) = \frac{C_t^{1-\gamma}}{1-\gamma}.$$

Whereby the λ portion of the population participates in bond trading and the (1 – λ) portion does not. The aggregate production of this economy is y_t.

$$y_t = \lambda C_t^T + (1-\lambda)C_t^N + \frac{T_t}{P_t},$$

where C_t^T and C_t^N are consumption of the trader and the nontrader each and T_t is the nominal value for lump-sum tax payment. The budget constraint for the nontrader is

$$P_t C_t^N = \sum_{j=0}^{m} v_{t-j,t} P_{t-j} y_t, \text{ where } \sum_{j=0}^{m} v_{t,t+j} = 1.$$

At each period the nontrader sells his or her product in the market and receives cash in return ($P_t y$). He or she allocates these proceeds across m + 1 periods on consumption with the proportion of $v_{t,t+j}, j = 0, 1, \ldots, m$. Another more realistic interpretation of this m-period-ahead CIA feature is that $v_{t,t+j}, j = 0, 1, \ldots, m$ is the proportion of consumers who need j period time lag in responding to monetary shocks.

On the other hand, the trader spends his or her money not only on consumption but also on bond trading.

$$\begin{aligned} P_t C_t^T &= \sum_{j=1}^{m} v_{t-j,t} P_{t-j} y_t + \frac{1}{\lambda}\left[B_t - \left(\frac{1}{1+r_t}\right)B_{t+1} - T_t\right] \\ &= \sum_{j=0}^{m} v_{t-j,t} P_{t-j} y_t + \frac{M_t - M_{t-1}}{\lambda}. \end{aligned}$$

Bond and money supplies satisfy

$$B_t - \left(\frac{1}{1+r_t}\right)B_{t+1} - T_t = M_t - M_{t-1},$$

where the government levies the lump-sum tax T_t on the trader only. The effect of money stock increment would be used either in purchasing bonds or in reducing tax burden. The goods market equilibrium is attained when the next equation holds:

$$P_t C_t = (1-\lambda)P_t C_t^N + \lambda P_t C_t^T = P_t y_t.$$

Combining the above equations, we obtain

$$\begin{aligned} P_t y_t &= \sum_{j=0}^{m} v_{t-j,t}(P_{t-j} y_{t-j}) + M_t - M_{t-1} \\ &= M_{t-1} + v_{t,t} P_t y_t + M_t - M_{t-1} \\ &= V_{t,t} P_t y_t + M_t. \end{aligned}$$

Accordingly, the equation of exchange is written as

$$M_t \frac{1}{1 - v_{t,t}} = P_t y_t.$$

Thus, $v_{t,t}$ can be understood as the money velocity.

From the above equations, we represent the consumption of the trader in the function of money growth rates. Here it is noteworthy that we are interested in the consumption of the trader because in the bond market only the marginal utility of the trader matters for the determination of a yield curve.

$$C_t^T = \frac{1}{\lambda} y_t - \frac{(1-\lambda)}{\lambda} C_t^N = \frac{1}{\lambda} y_t - \frac{(1-\lambda)}{\lambda P_t} \sum_{j=0}^{m} v_{t-j,t} P_{t-j} y_{t-j},$$

where $\mu^t = (\mu_t, \ldots, \mu_{t-m})$, and $v^t = (v_{t,t} \ldots, v_{t-m,t})$. Then, the equilibrium nominal interest rate must satisfy the following marginal condition:

$$\left[\frac{\frac{1}{1+r_{t,t+k}}}{\frac{1}{1+\rho}}\right]^k = E_t\left[\frac{U'(C_{t+k}^T \cdot \frac{(1-v_{t,t})}{(1-v_{t+k,t+k})}}{U'(C_t^T)\prod_{i=0}^{k}(1+\mu_{t+i})}\right].$$

Notably, the consumption plugged in the above equation is the consumption of the trader's, neither that of the nontrader's nor the aggregate consumption. This is a way of inducing the distributional effect between the trader and the nontrader groups, which in turn leads to the short-term liquidity effect.

For simplicity, we assume $y_t = y$ and $\tau_t = 0$ for all t. Then,

$$\begin{aligned}
C_t^T &= \frac{1}{\lambda} y\left\{1 - (1-\lambda)\sum_{j=0}^{m} v_{t-j,t}\frac{P_{t-j}}{P_t}\right\} \\
&= \frac{1}{\lambda} y\left\{1 - (1-\lambda)\sum_{j=1}^{m-1} v_{t-j+1,t}\frac{1}{\prod_{i=1}^{j}(1+\mu_{t-i+1})} \cdot \frac{(1-v_{t,t})}{(1-v_{t-j,t-j})}\right\} \\
&\equiv c(\mu_t, \ldots, \mu_{t-m}, v_{t,t}, \ldots, v_{t-m,t})y \equiv c(\mu^t, v^t)y,
\end{aligned}$$

$$\begin{aligned}
\left[\frac{\frac{1}{1+r_{t,t+k}}}{\frac{1}{1+\rho}}\right]^k &= E_t\left\{\frac{U'[c(\mu^{t+k}, v^{t+k})y]}{U'[c(\mu^t, v^t)\, y]} \cdot \frac{1}{\prod_{i=0}^{k}(1+\mu_{t+i})} \cdot \frac{(1-v_{t,t})}{(1-v_{t+k,\,t+k})}\right\} \\
&= E_t\left\{\left[\frac{c(\mu^{t+k}, v^{t+k})y}{c(\mu^t, v^t)y}\right]^{-y} \cdot \frac{1}{\prod_{i=0}^{k}(1+\mu_{t+i})} \cdot \frac{(1-v_{t,t})}{(1-v_{t+k,t+k})}\right\}.
\end{aligned}$$

We assume that the velocity of money ($v_{t,t}$) is constant or exogenously given and the money increase is directed towards the purchase of bonds in the financial market. On the other hand, the last line of equation (A1) enables us to briefly analyze the effect of a change in $v_{t,t}$ on the term-structure of interest rates.

Consider the liquidity trap as an extreme case, in which any interest rates would not be affected by an increase in money stock. This phenomenon can arise in the economy of equation (A1) exactly when the increase of μ_t is cancelled out by the decrease of $v_{t,t}$. Under a situation like this, the only policy option the government can take is to increase expenditure by speeding up the money growth rate. Then, the market interest rates would go higher following the money increase. It is notable that such a way of monetary expansion transmits a stimulus not through the bond market but through the goods market. The shift of the term-structure of interest rates following the monetary expansion is attributed to a new equilibrium in the goods market, which works in an opposite direction to the usual propagation mechanism of open market operation. Anyway, this suggests a way of escaping from the liquidity trap with monetary policy.[26]

Taking the first-order approximation of log $c(\mu^t, v^t)$ around the point $(0, \bar{v})$, we obtain

$$\text{(A2)} \qquad \log c(\mu^t, v^t) \cong \left(\frac{1-\lambda}{\lambda}\right)\left[\sum_{j=0}^{m} \bar{v}\left(\sum_{i=0}^{j} \mu_{t-i}\right) + f(v^t)\right]$$

$$U'[c(\mu^t, v^t)y] = \exp\left\{-y\left(\frac{1-\lambda}{\lambda}\right)\left[\sum_{j=0}^{m} \bar{v}\left(\sum_{i=0}^{j} \mu_{t-i}\right) + f(v^t)\right]\right\}y^{-y}.$$

Substituting equation (A2) into equation (A1) and taking log by both sides, then we obtain

$$\text{(A3)} \quad \begin{bmatrix} r_{t,t+1} \\ r_{t,t+2} \\ \cdots \\ r_{t,t+n-1} \\ r_{t,t+n} \end{bmatrix} \equiv \begin{bmatrix} \phi_{1,1} & \phi_{1,2} & \phi_{1,3} & \cdots & \phi_{1,m-1} & \phi_{1,m} \\ \phi_{2,1} & \phi_{2,2} & \cdots & \cdots & \cdots & \phi_{2,m} \\ \phi_{3,1} & \cdots & \cdots & \phi_{i,j} & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \phi_{n-1,m} \\ \phi_{n,1} & \phi_{n,2} & \cdots & \cdots & \phi_{n,m-1} & \phi_{n,m} \end{bmatrix} \begin{bmatrix} \mu_t \\ \mu_{t-1} \\ \cdots \\ \mu_{t-m+2} \\ \mu_{t-m+1} \end{bmatrix} + \mathbf{R}(v^t),$$

or simply

$$\mathbf{\Gamma}_t = \mathbf{\Phi}_t \mathbf{\Delta}_t + \mathbf{R}(v^t),$$

where $\mathbf{R}_t$ is an $n \times 1$ vector, and $\mathbf{\Delta}_t$ an $m \times 1$ vector, and $\mathbf{\Phi}_t$ an $n \times m$ matrix. The coefficients of the matrix in equation (A3) are derived from equations (A1) and (A2). For $1 \leq j < m - i + 1$,

26. Though the arguments in this paragraph consider neither Ricardian equivalence nor the crowding-out effect explicitly, the equations from our model can test their validity.

$$\phi_{i,j} = -\gamma\left(\frac{1-\lambda}{\lambda}\right)\bar{v}.$$

For m: $m \geq j \geq m - i + 1 \geq 1$,

$$\phi_{i,j} = \gamma\left(\frac{1-\lambda}{\lambda}\right)\bar{v}\left(\frac{m-j+1}{i}\right) > 0.$$

Neglecting that the expectation for the future monetary policies does not change, then the coefficients of $\mathbf{\Phi}$ indicate that cross-sectionally an increase in μ_t lowers the yield rates of bonds with shorter maturities than $m + 1$ periods, while the yield rates of the bonds with maturities longer than m are raised. Combining these two, we can deduce that there is a slope change in the yield curve between m and $m + 1$. Accordingly, the liquidity effect view is supported for bonds with maturities shorter than m and the Fisher's view is valid for bonds with maturities longer than $m + 1$. In addition, the cross-time effect of μ_t changes signs from negative to positive, which also confirms that in the long run the Fisher effect prevails.

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Comment R. Anton Braun

Seok-Kyun Hur's analysis challenges many current views about how monetary policy affects the yield curve, in particular, and economic activity more generally. In a world where leading central banks have long since abandoned monetary-aggregate targeting and now follow interest rate targeting rules and where academics typically model monetary policy using Taylor rules, Hur explores the link between monetary aggregates and the yield curve. Against the background of a large and growing academic literature that models money under the assumptions of monopolistic competition and costly price adjustment, Hur derives empirical restrictions from a flexible price model. Finally, rather than following the large empir-

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ical structural vector-autoregression (SVAR) literature that seeks to isolate the effects of surprises to money supply by looking at narrow aggregates such as the composition of nonborrowed reserves in total reserves, Hur instead infers monetary policy directly from movements in M1. It is refreshing to see someone challenge so many orthodox views and as I read this chapter I had the hope that this novel approach to one of the principal questions in monetary economics would provide some new insights.

The chapter starts by positing an extension to the segmented-markets model of Alvarez, Lucas, and Weber (2001). Alvarez, Lucas, and Weber (2001) consider an economy with traders and nontraders. Nontraders can't visit the bonds market and are thus subject to a cash-in-advance constraint that requires that current consumption expenditures equal a variable fraction of current period receipts plus last period's unspent receipts. Traders, participate in both the goods market and a bonds market with centralized trade where they receive government transfers of money and adjust their holdings of money and bonds. This model delivers a liquidity effect in the short run but the Fisher effect dominates in the long run.

Hur extends Alvarez, Lucas, and Weber (2001) by imposing the restriction that nontraders are required to fund today's consumption using a distributed lag of previous period receipts. Households must store receipts received in each date in one of m separate cookie jars. This is because in any given period m cookie-jar-specific liquidity shocks arrive. At the start of each period the shopper goes to the oldest cookie jar, empties it, and goes shopping. Then the seller starts placing current period receipts in that cookie jar. Part way through the period the shopper returns home and goes to the second-oldest cookie jar and takes some fraction of the remaining receipts from it. The shopper returns once again later and proceeds to the next cookie jar and takes out some random fraction of the receipts from it. Things continue in this fashion until the shopper has removed a random fraction of the receipts from each cookie jar, including the cookie jar with current period receipts. This assumption creates what Hur refers to as path dependence: today's aggregate state depends on the vector of money growth rates over the past m periods. After some algebra a log-linear representation (equation 1) is derived that links the term-structure of interest rates to a distributed lag of previous money growth rates.

The fact that the demand for cookie jars will be very large in this economy raises a serious issue about the entire formulation. Why would nontrading households ever choose to allocate receipts to more than one cookie jar? This distinction matters. If instead nontraders are allowed to keep all of their receipts in a single cookie jar then, regardless of whether they experience a single liquidity shock or even m distinct liquidity shocks in a given period, the path dependence disappears.

Given these problems with the model formulation it is perhaps most useful to treat the empirical work in this chapter as documenting some new data facts. The principal result from the empirical work is that one can uncover liquidity effects at short horizons of one month or one quarter and a dominant Fisher effect at longer horizons by simply regressing first differences of yield rates on higher-order differences of M1. This is a potentially interesting finding. However, it flies in the face of a large body of previous results that find that M1 is highly endogenous. Unfortunately, it is impossible to tell whether the results in the chapter are a statistical artifact due to the peculiar way in which M1 is chosen to enter[1] or a substantive new contribution. Given the previous results in the literature (see, e.g., Christiano, Eichenbaum, and Evans 1999 for a nice survey) I think one must be concerned about whether the results reported in the chapter are confounding money-supply and money-demand shocks. The SVAR literature provides some simple criteria for assessing whether this is the case. According to this literature, an easing in monetary policy in addition to lowering short-term rates on impact also increases output and increases prices. If Hur's empirical work has indeed successfully identified monetary policy in higher-ordered differences of M1 growth rates, then positive shocks to monetary policy should also increase output and prices.

Finally, the chapter touches on issues related to the conduct of monetary policy when interest rates are close to zero. This is a fascinating and still largely unexplored question. The perspective taken in this chapter that growth rate of money is a relevant indicator or perhaps even *the* relevant indicator of monetary policy is compelling when nominal interest rates are zero. Hur argues that the combination of a transient liquidity effect and persistent Fisher effect creates an automatic stabilizer that keeps nominal interest rates positive and that this mechanism is enhanced when money growth rates are increased. Although this is a provocative conjecture, Japan's experience casts considerable doubt on either its veracity or quantitative importance. Japan has experienced a near-zero call rate for about seven years. Over the same period of time M1 has nearly doubled.

I enjoyed reading this chapter and was both impressed and very sympathetic to some of its unorthodox assumptions. Unfortunately, the logic of the model and the haphazard nature of the empirical analysis make it is impossible to tell what, if any, new insights this chapter sheds on our understanding about the effects of monetary policy on the term-structure of interest rates.

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1. For instance, the level of M1 growth is omitted from the monthly specification.

Comment Yuzo Honda

Summary of the Paper

Making use of the recent model by Alvarez, Lucas, and Weber (2001), as well as the consumption-based capital asset pricing model (consumption-based CAP-M), Dr. Seok-Kyun Hur derives the term-structure of interest rates as a function of past growth rates of money and of velocity variables. Then he applies this theory to U.S. data from the period July 1959 to February 2000 to test the theory's validity. Based on theoretical and empirical considerations, the author suggests using the term-structure of interest rates as a target of monetary policy.

Picking out one short-term interest rate as an operating target is the standard practice among central banks in most advanced countries. It is true that changes in the short-term interest rate are transmitted to the longer-term market interest rates through imperfect substitutions among bonds with various maturities. But the longer-term interest rates are also endogenously affected by changes in other exogenous variables in the real sector of the economy.

Despite of this fact, Hur challenges the standard practice for central banks to target one short term interest rate, and suggests that central banks might want to target the whole term-structure of interest rates, using his proposed model.

The Gap between Theory and Empirical Studies

Hur's chapter is challenging at least in the following two respects. First, he proposes an interesting microeconomic model for empirical studies. Secondly, the idea of targeting the whole term-structure of interest rates is totally new. The proposed economic model is interesting in itself. The idea of examining the responses of the whole term-structure to an exogenous shock is also interesting in the empirical part.

However, there is a gap between his theoretical model and empirical works. It seems to me that Hur needs to work more to fill in the gap. The relevant question that Hur should address is what are exogenous variables and what are endogenous variables in his theoretical model and empirical studies, respectively. In the theoretical part, money growth rates μ_t are exogenous variables. However, in reality, or in the empirical part, money growth rates are endogenous, to a first approximation.

Hur implicitly assumes the situation in figure 3C.1, in which money supply shifts exogenously with the given money demand. Money in this section is understood as M1 as in his chapter. In such a case, an exogenous increase in money supply leads to a lower interest rate, which is called the

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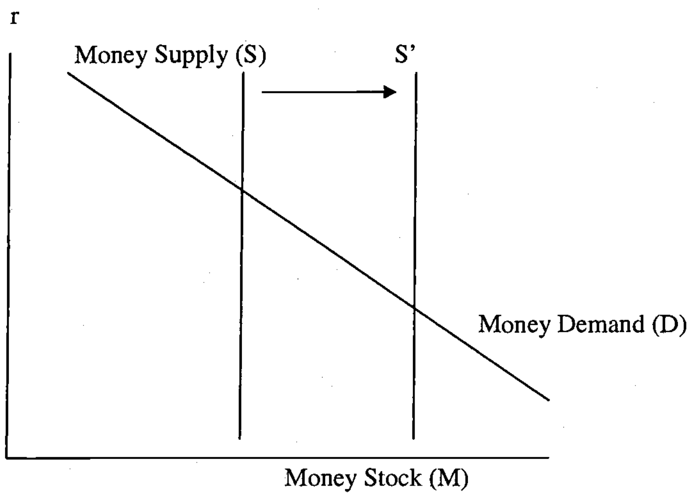

Fig. 3C.1 Money supply shifts with given money demand

"liquidity effect" in the chapter. In this model, money supply is exogenously determined by the central bank, while the short-term interest rate is endogenously determined.

Instead of figure 3C.1, consider the situation in figure 3C.2, in which the central bank changes its target interest rate with a given money-demand curve. In this model, the short-term interest rate r is exogenously determined by the central bank, while the amount of money stock M is endogenously determined.

Which is closer to the real world, figure 3C.1 or 3C.2? Although the author's theoretical model postulates the situation where money supply is exogenously given, as in figure 3C.1, money supply in reality is endogenous as in figure 3C.2 for most of the sample period. It is well known that the Federal Reserve has been using the federal fund rate as the operating target to steer monetary policy for most of the sample period (Bernanke and Blinder 1992; Bernanke and Mihov 1998).

There are, however, exceptional periods. For the period October 1979 through October 1982, the Federal Reserve used nonborrowed reserves as its primary operating target. In addition, they used monetary aggregates like M1 or M2 as intermediate targets in the 1970s, although they started to de-emphasize monetary aggregates as intermediate targets from October 1982 onwards. During these exceptional periods, there might be reasons to believe that money stock is exogenous. However, except for these relatively short periods, there seems to be little reason to believe that money supply is exogenous.

In order to fend off the above criticism, Hur adopts "Wu-Hausman

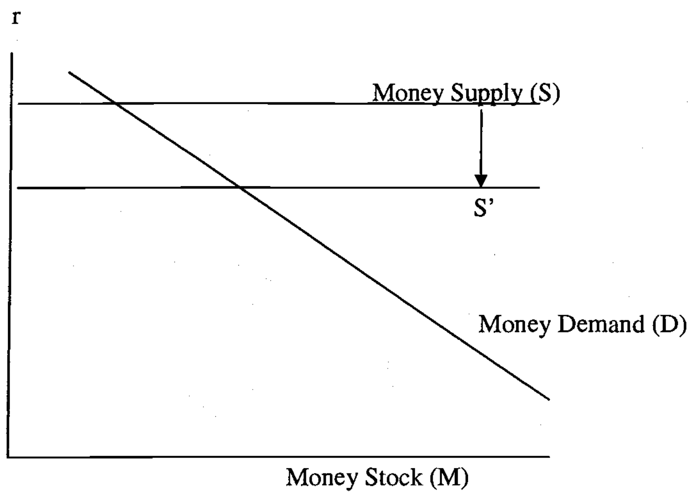

Fig. 3C.2 The central bank changes the target interest rate

F-test and Durbin-Wu-Hausman Chi-sq test" (see, for example, the subsection 3.3.3) and tests the exogeneity of money growth rates μ_t. Do these tests help? My answer is "Not Quite." These tests certainly help us to infer whether or not money growth rates μ_t are exogenous with respect to the term-structure of interest rates (or the left-hand side variables). In this sense these tests are useful. However, even if the above tests indicate that money growth rates are exogenous with respect to the term-structure of interest rates, money growth rates μ_t are still the results of the interaction between monetary-policy shocks and the activity in the real sector of the economy. Money growth rates of M1 are the mixture of policy shocks and the economic activity in the real sector. It is misleading to interpret money growth rates of M1 as monetary-policy shocks.

Alternative Approaches

There might be many approaches to overcome this gap between his theoretical model and empirical studies. One approach would be choosing only those sample periods for which the central bank actually used monetary aggregates like M1 or M2 as an intermediate target. Then exogenous money growth rates may be justified for such sample periods. It might also be worth investigating whether or not the author's theory might be justified in other countries like Germany, where monetary aggregates were used as an intermediate target for the longer period.

An alternative approach would be extending his theory and constructing a new model, into which we introduce a central bank explicitly. In this new model, we also interpret money as high-powered money (HPM) rather

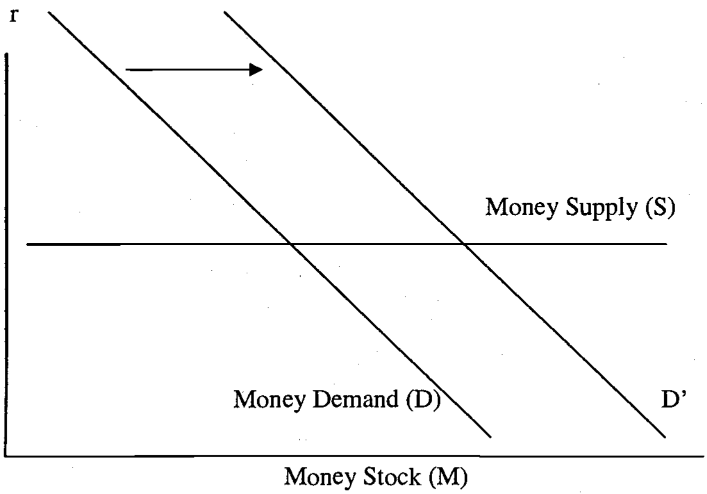

Fig. 3C.3 The central bank accommodates money supply in accordance with a money-demand shift

than M1. The central bank exogenously determines the level of the short-term interest rate as in figure 3C.3. As some exogenous shock shifts money demand out from D to D′ as in figure 3C.3, the central bank accommodates money supply in accordance with a shift in money demand. In this new model, the control variable that the central bank manipulates is the short-term interest rate. When the central bank lowers the short-term rate as in figure 3C.2, then the stock of HPM increases endogenously along the money-demand curve. I believe that a model that incorporates such features is appealing as a first approximation to real financial markets in the United States.

In short, Hur might want to explore for a new theoretical model in which one single short-term rate is exogenously determined by the central bank, while the stock of HPM as well as the whole term-structure of interest rates are jointly and endogenously determined by the interaction between the short-term interest rate and real economic activity.

Term Structure as a Target of Monetary Policy?

Hur makes a bold proposal to use the term-structure of interest rates as a target of monetary policy. I believe his suggestion is perhaps too bold, and I am not convinced by the chapter that it is a good idea to adopt the term-structure as a target of monetary policy.

There are several reasons. First, it is well known that controlling the longer end of the term-structure is more difficult (and costly). The influence of exogenous shocks from the real economy is expected to be larger at the longer end. See, for example, Cook and Hahn (1989), and Kuttner

(2001) for the case of the U.S. financial markets in which the effects of monetary-policy shocks are found to be smaller at the longer end of the term structure.

Secondly, the empirical relationship obtained is based on the history of the conduct of monetary policy by the Federal Reserve. As explained above, the Federal Reserve largely controlled the federal funds rate to steer the economy for most of this period, and the M1 was largely determined endogenously in interaction with the real economy. If the Federal Reserve adopts the growth of M1 as a policy instrument, as the author proposes, the past relationship that the author wishes to exploit might change.

Thirdly, most central banks in advanced countries have found the link between GDP and monetary aggregates less stable and less reliable in the recent years. Mainly due to this reason, most central banks gave up controlling monetary aggregates in the 1980s. Given this past history, I doubt if it is a good alternative strategy to target M1, the term-structure of interest rates, and ultimately GDP.

Finally, controlling M1 will take some time in collecting data on deposits, and we cannot use M1 as an operating target on a daily basis. If there should be any role for M1, it might be used only as an intermediate target.

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