Rational Expectations, Long-run Taylor Rule, and Forecasting Inflation

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<Contents>

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The rational expectations model implies that nominal interest rates reflect expectations of inflation, and thus the term structure of interest rates provides information on the future change in inflation. However, the monetary authority manipulates the short-term interest rate in response to the change in the price level, and accordingly the prediction of inflation cannot be separated from the monetary policy. This paper explores the linkage between the monetary policy rules and the prediction of inflation. The prediction of inflation can be influenced by the monetary policy rules if the Fed reacts strongly to inflation. Using the long-run Taylor rule, an assessment of the prediction performance regarding future change in inflation is provided. The empirical results indicate that the long-run Taylor rule improves forecasting accuracy.

Key words: Fisher Equation; Monetary Policy Rules; Predictability
JEL classification: E37; E43

Ⅰ. Introduction

The rational expectations model implies that asset prices reflect forward-looking behavior in the financial market, and therefore they have been used as predictors of economic growth, business cycles, and future changes in inflation. In particular, the term structure of interest rates provides potential information on the prediction of interest rates and inflation according to the expectations hypothesis and the Fisher equation. However, the monetary authority manipulates the short-term interest rate in response to macro fundamentals such as the changes in the price level and real economic activity, and accordingly the prediction of inflation hinges on the monetary policy rules. This paper investigates the linkage between the monetary policy rules and the prediction of inflation, and provides an assessment of the predictive performance of the term structure and the monetary policy rules regarding future changes in inflation.

The predictive information contained in the yield curve has been analyzed in many empirical studies. The empirical results show that the prediction performance of the term structure model varies depending on the maturities of the yield curve and the sample period. Mishkin (1990a) has shown that the term structure provides almost no information about the future change in inflation for maturities of six months or less. Fama (1990) has pointed out the variation in the real term structure, which affects the prediction performance of the term structure model. Mishkin (1991) also provided empirical results showing that the term structure provides information of predicting inflation in two or three countries out of the 10 OECD countries examined.

It is natural to ask what affects the prediction performance of the term structure model. It is noteworthy that the term structure of interest rates reveals the stylized facts of temporal persistence as discussed in Seo (2003) compared to the variation of the change in inflation. The stylized facts indicate imbalance in regression.

Many studies have shown that the persistence of the term spread is related to the monetary policy. Mankiw and Miron (1986) provided empirical results that the predictive information of the term structure began to disappear after the founding of the Federal Reserve and its manipulation of interest rates. Woodford (1999) and Rudebusch (2002) suggested that the central bank tends to adjust the target interest rate gradually, and thus such inertial monetary policy also implies the slow adjustment of the term spread. Clarida et al. (2000) have shown that the macroeconomic stability is closely related to the monetary policy rules, which involve the manipulation of the short-term interest rate as instrument to achieve the target inflation and the desirable output level. Necessarily, the variation in inflation is associated with the Fed's reaction to inflation.

Although there exists a vast literature on the monetary policy rules, there have been no attempts to relate the monetary policy rules to the prediction of inflation. This paper is to provide an empirical assessment of the linkage between the monetary policy rules and the prediction of inflation. As the rational expectations model does not consider the effect of the monetary policy rules, this study resolves the mismatch between economic theory and empirical findings.

Another important issue in forecasting inflation is associated with parameter instability. The Phillips curve relates the unemployment rate to a measure of inflation. Thus, the Phillips-curve-based inflation forecasts have been used widely in monetary policymaking. However, these forecasts have been found to be sensitive to instability, particularly in the 1970s and early 1980s. Consequently, Atkeson and Ohanian (2001) argue that the likelihood of drawing an accurate prediction of a change in inflation is no better than a coin flipping. In this paper, we consider the inflation forecasts using the monetary policy rules. As the monetary policy rules may differ between the monetary policy regimes, we examine the parameter stability by using the statistical methods.

In the paper, we undertake an empirical analysis of this linkage using the U.S. monthly data for the period January 1960-December 2004. First, we estimate the long-run Taylor rule, which is composed of the federal funds rate and the 12-month inflation rate. The coefficient of reaction to inflation varies depending on the sample period and across the monetary policy regimes. Second, the prediction of inflation is found to be associated with the Fed's reaction to inflation. The coefficient of the term structure is significant for the sample period when the coefficient of reaction to inflation is close to unity. As the parameter of reaction to inflation increases, the predictive information contained in the term structure becomes weaker. This result explains the previous empirical findings that the predictive information of the term structure varies depending on the sample period. Third, an assessment of the prediction performance regarding future change in inflation is provided using the long-run Taylor rule. The empirical results indicate that the long-run Taylor rule improves forecasting accuracy.

The paper is organized as follows. Section 2 deals with the term structure model and the influence of the monetary policy rules on the prediction of inflation. Section 3 discusses the econometric methods to assess the information contained in the term structure and the long-run Taylor rule. The main results are provided in Section 4.

Ⅱ. The Model

The Fisher equation implies that the nominal interest rates reflect expectations of inflation, and therefore the term structure provides potential and useful information about the future path of inflation. Fama (1990) and Mishkin (1990a) assessed the predictive information contained in the term structure based on the following model.

$$\pi_{t,t+m} - \pi_{t,t+l} = \mu + \alpha(R_t^m - R_t^l) + u_{t+m}, \tag{1}$$

where $\pi_{t,t+h}$ is the *h*-step ahead inflation, and R_t^h is the nominal yield on a security with a maturity of *h* for *h=m, l* and *m>l* .

The term structure model (1) implies that the change in inflation depends on the term structure of interest rates. From the Fisher equation, the nominal interest rate (R_t^h) is composed of the real interest rate (κ_t^h) and the expected inflation as follows:

$$R_t^h = \kappa_t^h + E_t(\pi_{t,t+h}), \tag{2}$$

where $E_t(\cdot)$ is the conditional expectation based on the information available at time *t*.

By taking a difference of *l*-step ahead inflation from *m*-step ahead inflation, we get the term structure model (1) and the following conditions.

$$\mu = -E(\kappa_t^m - \kappa_t^l)$$

$$\alpha = 1$$

$$u_{t+m} = [\pi_{t,t+m} - E_t(\pi_{t,t+m})] - [\pi_{t,t+l} - E_t(\pi_{t,t+l})] - [(\kappa_t^m - \kappa_t^l) - E_t(\kappa_t^m - \kappa_t^l)].$$

If we assume rational expectations and the constancy of the real term structure, $E_t(u_{t+m}) = 0$ holds in equation (1) and the error u_{t+m} is exogenous to the variables in the current information set. As a result, the future change in inflation has a linear relationship with the term structure with a unit slope. Therefore, the term structure provides systematic information about the future path of inflation.

The prediction performance of the term structure model has been examined in many empirical studies. The results show that the predictability of inflation varies depending on the maturities of the yield curve and the sample period. Mishkin (1990a) has shown that the term structure of interest rates provides almost no information about the future change in inflation for maturities of six months or less. Fama (1990) has pointed out the variation in the real term structure, which brings in less-successful performance of the term structure model. Mishkin (1991) also provided empirical results showing that the term structure provides information of predicting inflation in two or three countries out of the 10 OECD countries examined.

It is natural to ask what affects the prediction of inflation based on the rational expectations model. One plausible explanation, suggested in previous studies, is related to the non-spherical errors, which may affect the prediction performance of the term structure model. The term structure model involves the overlapping data, which generates serial correlation in the error term inevitably. However, the problem of overlapping data becomes more severe for long-period ahead inflation forecasting while the empirical evidences are less favorable in forecasting inflation for maturities of six months or less.

The term structure of interest rates reveals the stylized facts of temporal persistence and nonlinear mean reversion as shown by Seo (2003). On the other hand, the change in inflation is relatively less persistent, and thus the stylized facts indicate imbalance between the term structure and the change in inflation.

It has been shown in many studies that the persistence of the term spread is related to the monetary policy. Mankiw and Miron (1986) provided empirical results that the predictability of the term structure began to disappear after the founding of the Federal Reserve and its manipulation of interest rates. Rudebusch (1995) and Balduzzi et al. (1997) also found that the changes in the interest rate were due to the Fed's unexpected changes in its target interest rate. As Woodford (1999) suggests, the central bank tends to adjust interest rates gradually, and thus such inertial monetary policy also implies the slow adjustment of the term spread.

According to the expectations hypothesis, the long-term interest rate is the average of the current and future short-term interest rates.

$$R_t^m = \frac{1}{m}\sum_{i=1}^{m} E_t(R_{t+i-1}) + q_t \, , \qquad (3)$$

where R_t^m is the yield on a security with a maturity of *m*, R_t is the yield on the unit-maturity security, and q_t is the liquidity premium.

The expectations hypothesis (3) can be written as follows:

$$R_t^m - R_t = \frac{1}{m}\sum_{i=1}^{m-1}\sum_{j=i}^{m-1} E_t(\Delta R_{t+m-j}) + q_t .$$

If the liquidity premium is constant, the expectations hypothesis implies that the term structure or the yield curve provides information on the future change in the short-term interest rate. Thus, the expectations hypothesis implies that the change in the short-term interest rate depends on the term structure. However, the empirical findings suggest that the persistence of the term structure is closely related to the Fed's control of interest rates. In particular, Taylor (1993) suggested the monetary policy rules. The monetary authority regulates the target interest rate (r_t^*) in response to the macro fundamentals: one-year inflation rate (π_t) and output gap (y_t) as follows.

$$r_t^* = r^* + \beta(\pi_t - \pi^*) + \theta y_t\,, \tag{4}$$

where r^* is the desired nominal rate, which is compatible with the inflation target π^*.

The Fed's reaction function has been estimated by assuming the partial adjustment process in Clarida et al. (2000) and Rudebusch (2002).

$$\begin{aligned} r_t &= (1-\rho) r_t^* + \rho r_{t-1} \\ &= (1-\rho)(\beta\pi_t + \theta y_t + v) + \rho r_{t-1}\,, \end{aligned}$$

where r_t is the actual federal funds rate and $v = r^* - \beta\pi^*$.

Rudebusch (2002) estimated the reaction function and found that the partial adjustment coefficient ρ is large and significant, which supports the monetary policy inertia. Judd and Rudebusch (1998) used the error correction specification because the unit root hypotheses of the interest rates cannot be rejected.

$$\begin{aligned} \Delta r_{t+1} &= \phi(r_t - r_t^*) + C(L)\Delta r_t \\ &= \phi(r_t - \beta\pi_t - \theta y_t - v) + C(L)\Delta r_t \end{aligned}$$

If ϕ<0, the federal funds rate adjusts to the equilibrium error between the actual funds rate and the optimal target rate. The equilibrium error disappears eventually, which implies a long-run equilibrium relationship. The long-run relationship is governed by two highly persistent variables: the federal funds rate and the inflation rate.

$$w_t = r_t - \beta\pi_t. \tag{5}$$

The long-run coefficient β is the parameter of reaction to inflation. If w_t is stationary, the long-run monetary policy rules form a long-run relationship based on the definition of Engle and Granger (1987). The output gap is stationary, and it affects the long-run relationship temporarily. This specification makes our empirical analysis simple and tractable. However, our analysis can be extended to the monetary policy rules that include real economic activity. If we include the output gap, the influence of the monetary policy rules on the prediction of inflation can be explained by the variation in the output gap.

The rational expectations model does not consider the Fed's control of interest rates in response to inflation. The expectations hypothesis implies the long-run relationship between the short rate and the long rate. However, if the monetary policy rules are effective, the short rate converges to the target rate, which can be different from the long rate. Thus, the relationship between the term structure and the change in inflation becomes weaker.

The long-run relationship w_t can be written as follows:

$$w_t = (r_t - R_t) + (R_t - \beta E_t \pi_{t+m}) + \beta(E_t \pi_{t+m} - \pi_t).$$

The long-run Taylor rule w_t is composed of the term spread, the relationship between the long-term rate and the expected inflation, and the expected change in inflation. Accordingly, the long-run monetary policy rules imply a relationship between the term structure and the change in inflation.

$$\pi_{t+m} - \pi_t = \frac{1}{\beta}(R_t - r_t) + \eta_{t+m}, \tag{6}$$

where

$$\eta_{t+m} = \frac{1}{\beta}[(r_t - \beta\pi_t) - (R_t - \beta E_t \pi_{t+m})] + (\pi_{t+m} - E_t \pi_{t+m}).$$

If the long-run parameter β equals one, the long-run Taylor rule reduces to the short-term realized real interest rate. Also, the relationship between the long-term rate and the expected inflation becomes the long-term real interest rate. If we assume the constancy of the real term structure, the implied term structure model becomes close to the rational expectations model. In that case, the long-run monetary policy rules are consistent with the rational expectations model.

However, this is a special case. If β is different from one, the slope and the error in (6) depend on the parameter β. First, an increase in the long-run reaction parameter leads to a decrease in the slope, which lowers the effect of the term structure in predicting inflation. Second, if β is different from one, the term structure model is valid under the constancy of the long-run monetary policy rules. In general, the change in inflation depends on the long-run monetary policy rules as well as the term structure. Third, the discrepancy between the Fisher equation and the long-run monetary policy rules increases as β increases. The discrepancy generates uncertainty in forecasting inflation, and as a result the variance of the error increases and the relevancy of the forecasts may diminish. Finally, the prediction performance of the term structure model can be affected by parameter uncertainty in the reaction parameter β.

The parameter uncertainty cannot be overlooked because it affects the prediction of inflation severely. Clarida et al. (2000) related the monetary policy rules to macroeconomic stability. The reaction parameter may change across the monetary policy regimes, which generates parameter uncertainty in forecasting inflation. Furthermore, the Fed's reaction may vary over the business cycle. The monetary authority is likely to focus on the prevention of inflation in the boom while high unemployment becomes the main concern in the recession. The central bank's regimedependent preferences have been suggested in Ruge-Murcia (2003), which also produces parameter uncertainty in forecasting inflation.

When the long-run monetary policy rules include other macro fundamentals, uncertainty in forecasting inflation inevitably increases. In addition, the term structure is associated with real economic activity as shown by Estrella and Hardouvelis (1991), and the measurement of output gap accompanies informational limitation as discussed in Orphanides (2003). These factors increase uncertainty and reduce the relevancy of the inflation forecasts.

The predictability of the term structure model has been measured in many studies. However, the assessment of the term structure information has been based on the rational expectations model, and the long-run aspects of the monetary policy rules have not been considered. In this study, we examine the prediction of inflation using the long-run information contained in the monetary policy rules.

Ⅲ. Methodology

1. Forecasting Models

Denote π_t as the 12-month inflation rate, r_t as the federal funds rate, and R_t as the yield on the one-year Treasury note. Our model of forecasting inflation is based on the following:

$$\pi_{t+m} - \pi_t = \mu + \alpha(R_t - r_t) + \lambda(r_t - \beta\pi_t) + \sum_{i=1}^{k} \gamma_i \Delta\pi_{t-i} + \eta_{t+m}. \qquad (7)$$

Our model (7) is very close to the forecasting model used by Stock and Watson (1999), which explains the change in inflation using the term structure information. Our forecasting model incorporates the information of the long-run monetary policy rules. The long-run Taylor rule accompanies the parameter β, which signifies the Fed's reaction to inflation. In the paper, we estimate the long-run parameter β by using reduced rank regression on the vector error correction model. The lagged values of the differenced inflation are added to reduce serial correlation in the error. If $\lambda = 0$, our model becomes the term structure model as follows:

$$\pi_{t+m} - \pi_t = \mu + \alpha(R_t - r_t) + \sum_{i=1}^{k} \gamma_i \Delta\pi_{t-i} + \eta_{t+m} . \qquad (8)$$

Thus, if the long-run information of the monetary policy rules does not help explain the change in inflation, our model reduces to the forecasting model using the term structure information, which has been proposed by Stock and Watson (1999).

The Martingale property of inflation has been suggested in several studies such as Atkeson and Ohanian (2001). The Martingale property implies that the future change in inflation is unpredictable. We treat the random walk model as the reference model to evaluate the inflation forecasting models.

$$\pi_{t+m} - \pi_t = \mu + \eta_{t+m} . \qquad (9)$$

We compare the predictive performance of the inflation forecasting models-Model A: the random walk model; Model B: the forecasting model that uses the term structure; and Model C: the forecasting model that uses the term structure and the long-run monetary policy rules.

2. Parameter Stability

When we evaluate the forecasting models, we need to consider parameter uncertainty because it affects the prediction accuracy severely. As discussed in Clarida et al. (2000), the monetary policy rules may differ between the monetary policy regimes. To examine the parameter stability, we implement the tests for structural change in the reaction parameter of the Taylor rule.

$$r_t = \beta_1 \pi_t 1(t \le t^*) + \beta_2 \pi_t 1(t > t^*) + \omega_{2t}, \tag{10}$$

where 1( ) is the indicator function, and t^* is the date of the break point.

In policy regime 1, the Fed reacts to inflation by adjusting the target rate with the coefficient β_1. In policy regime 2, the magnitude of reaction may change depending on the coefficient β_2. If the magnitude of reaction to inflation does not vary across regimes, the linear error correction model is valid. Therefore, the tests for structural change in the long-run Taylor rule can be based on the following hypotheses:

$$H_0 : \beta_1 = \beta_2 \text{ against } H_1 : \beta_1 \ne \beta_2.$$

We assume that the date of structural change is unknown. Although the dates of the monetary policy regimes are known, it is the general case that the true date of break may differ from the historical date. Thus, the testing for structural change entails the nuisance parameter t^*, which cannot be identified under the null hypothesis as discussed in Andrews (1993). We use the optimal test statistics defined in Seo (1998).

$$AveLM_n = \frac{1}{t_U - t_L + 1} \sum_{t^* = t_L}^{t_U} LM_n(t^*)$$

$$ExpLM_n = \log[\frac{1}{t_U - t_L + 1} \sum_{t^* = t_L}^{t_U} \exp(LM_n(t^*)/2)]$$

$$SupLM_n = Max_{t^* \in [t_L, t_U]} LM_n(t^*)$$

The algorithm to compute the test statistics is as follows. First, we estimate the linear error correction model. Second, we calculate the LM statistics using the null model and parameter estimates for each break point $t^* \in [t_L, t_U]$. The trimming values can be chosen symmetrically with the trimming probability P, for example, .10 or .15. Third, we find the average, the weighted average, and the maximum of the LM statistics. As the test statistics follow nonstandard distributions, we use the critical values suggested in Seo (1998). If the test statistic is greater than the critical value, we reject the null hypothesis of no structural change.

Ⅳ. Main Results

In the empirical analysis, we use the monthly data of the federal funds rate ($= r_t$) and the yield on the one-year U.S. Treasury note ($= R_t$). The 12-month inflation rate is calculated using the consumer price index (CPI). That is, $\pi_t = (\log P_t - \log P_{t-12}) \times 100$, where P_t is the CPI.

The data set is obtained from the Federal Reserve Economic Data[1] for the sample period January 1960-December 2004 (1960:1-2004:12). The estimation of the model and the in-sample forecasts are based on the sample period 1960:1-1999:12. The out-of-sample forecasts are obtained for the period 2000:1-2004:12.

Figure 1 shows the change in inflation of 12-month horizon, which is $\pi_{t+12} - \pi_t$. The time plot of the term spread is provided in Figure 2. The term spread, defined as $R_t - r_t$, varies slowly compared to the variation of the change in inflation.

Because the term structure predictability may depend on the monetary policy rules, we investigate this linkage statistically. Our empirical analysis involves the estimation

[1] Http://research.stlouisfed.org/fred2

of the long-run Taylor rule, and so we examine the time series behavior of the variables to estimate the long-run Taylor rule. Table 1 shows the augmented Dickey-Fuller (ADF) unit root tests. The unit root hypothesis of the 12-month inflation rate cannot be rejected for each AR lag length from 1 to 7. The federal funds rate shows mixed results. At the AR lag length 2, the ADF test rejects the unit root hypothesis while the unit root hypothesis maintains at other lag lengths. At the AR lag length 3, which is chosen by the Bayesian information criterion (BIC), the ADF test cannot reject the null hypothesis of unit root in the federal funds rate. The yield on the one-year Treasury note is persistent and the unit root hypotheses cannot be rejected.

<Table 1> Unit Root Tests

Variables	AR Lag Length						
	1	2	3	4	5	6	7
π_t	-1.470	-1.895	-2.160	-2.046	-2.165	-2.463	-2.507
r_t	-2.315	-3.290	-2.811	-2.727	-2.501	-2.484	-2.367
R_t	-2.169	-2.984	-2.362	-2.371	-2.279	-2.523	-1.996

*: The critical value at the 5% significance level is -2.867.

Table 2 shows the cointegration tests for the term structure and the long-run Taylor rule, which is composed of the federal funds rate and the 12-month inflation rate. The long-run Taylor rule implies that these two variables have a long-run relationship. At the VAR lag order 2, the Johansen cointegration test rejects the null hypothesis of no cointegration at the 5% significance level. However, at the VAR lag order 3, which is chosen by the BIC, the trace statistic for cointegration is slightly less than the 5% critical value.

<Table 2> Cointegration Tests

Variables	VAR Lag Length					
	1	2	3	4	5	6
(r_t, π_t)	13.252	23.114	19.223	17.736	16.435	17.977
(r_t, R_t)	53.737	57.543	39.293	34.019	24.414	24.786

*: 5% critical value = 20.262
**: The VAR lag length selected by the BIC is 3 for each model.

The cointegration tests support the long-run relationship of the term structure between the federal funds rate and the long-term interest rate at each VAR lag length. Therefore, the term structure contains the long-run information of predicting the short-term interest rate.

Using the bivariate error correction model, the long-run Taylor rule is estimated at the VAR lag length 3, which is chosen by the BIC. For the sample period 1960:1-1999:12, the long-run coefficient is close to one, which is compatible with the rational expectations model. However, the reaction coefficient varies widely across the monetary policy regimes. The magnitude of reaction to inflation increased in the Greenspan monetary policy regime (1987:8-1999:12) compared to the entire in-sample period. The reaction coefficient is large, and its standard error is also huge, which reflects the variation in the Fed's reaction to inflation.

<Table 3> Long-run Taylor Rule

$$r_t = \nu + \beta\pi_t + \omega_t$$

Sample Period	β		ν	
1960:01-1999:12	0.900	(0.191)	2.701	(0.997)
1987:08-1999:12	2.629	(0.861)	-2.464	(2.934)

*: The standard errors are in the parentheses.

Our model implies that the term structure information loses its predictability of inflation as the magnitude of reaction to inflation increases. At the same time, the parameter uncertainty is likely to lower the relevancy of the inflation forecasts based on the term structure information.

Table 4 shows the results of testing for parameter stability of the long-run Taylor rule. The test statistics are based on the bivariate error correction model of the federal funds rate and the 12-month inflation rate for the sample period 1960:1-1999:12. The 5% critical values are obtained from Seo (1998) for the stability of the long-run cointegrating vector and from Andrews (1993) for the stability of the adjustment vector.

The parameter stability of the long-run reaction parameter can be rejected based on the Exp-LM and Sup-LM statistics. Although the Ave-LM statistic does not support parameter instability, Figure 3 shows that parameter instability increased in the mid 1970s and reached the peak in the early 1980s. This result coincides with the period of the change in the operating system for which the volatility of the interest rate and inflation increased. After the mid 1980s, the LM statistics of the long-run reaction parameter became stabilized. Also, the parameter stability of the short-run adjustment vector can be rejected. We find parameter instability in the Fed's reaction to inflation. Parameter uncertainty may affect the relevancy of the inflation forecasts.

<Table 4> Parameter Stability of the Long-run Taylor Rule

	Ave-LM	5% c.v.	Exp-LM	5% c.v.	Sup-LM	5% c.v.
β	1.086	2.71	3.46	2.02	17.283	9.09
$adj.\ vector$	7.343	4.61	10.824	3.22	28.761	11.79
$(\beta, adj.\ vector)$	8.429	6.08	13.524	4.25	36.247	14.23

*: The 5% critical values are in the parentheses

Next, we compare the prediction accuracy of inflation forecasting models: random walk; forecasting with the term structure; and forecasting with the long-run Taylor rule and the term structure.

Table 5 reports estimation results of the forecasting models. First, we estimate the forecasting model using the term structure. An intercept and four lagged values (*k=4*) of differenced inflation are augmented to estimate the forecasting model. For the sample period 1960:1-1999:12, the response of inflation to the term structure is significant although the term spread has the limited predictability of the change of inflation as the adjusted *R*-squared coefficient shows. However, for the period 1987:8-1999:12, the response of inflation to the term structure became negative and insignificant. Figure 4 depicts the relationship between inflation change and term spread, which supports the estimation results. As Figure 4 shows, the change in inflation is weakly related to the term spread for the entire in-sample period. However, this relationship disappeared in the Greenspan monetary policy regime.

<Table 5> Inflation Forecasting Model

	$R_t - r_t$		$r_t - \beta\pi_t$		$\bar{R}^2$
1960:1-1999:12	0.393	(0.183)			0.078
	0.426	(0.226)	0.035	(0.117)	0.077
1987:8-1999:12	-0.187	(0.253)			0.009
	-0.075	(0.233)	0.255	(0.071)	0.343

*: The standard errors are in the parentheses.

For the sample period 1960:1-1999:12, the long-run information of the Taylor rule is not significant as shown in Table 5. However, for the sample period 1987:8-1999:12, the predictability of the model with the long-run Taylor rule improves dramatically in terms of the adjusted *R*-squared coefficient compared to the forecasting model using the term spread only. The information of the long-run Taylor rule is calculated using the estimated reaction parameter. In addition, an intercept and four lagged values (*k=4*) of differenced inflation are augmented to estimate the model. While the term structure information is weak in the Greenspan monetary policy regime, the long-run Taylor rule exhibits a significant information effects. The change in inflation responds positively to the long-run Taylor rule. When the actual short-term rate is greater than the optimal target rate, the equilibrium process begins with an increase in inflation. Therefore, the long-run Taylor rule provides information to predict the future change in inflation. Figure 5 displays the relationship between the change in inflation and the long-run Taylor rule. This relationship becomes evident for the Greenspan monetary policy regime.

We examine the robustness of the predictive information in the long-run Taylor rule by using the different forms of inflation forecasting model. First, we consider the term structure of interest rates with different maturities. The term spread is defined as the difference of the yields between the 10-year Treasury bond and 3-month Treasury bill. As Table 6 shows, the coefficient of the term spread has the negative sign and it is insignificant for the period 1960:1-1999:12. However, the long-run Taylor rule has a significant information effect in predicting the change in inflation for the Greenspan monetary policy regime. The similar results, which are not reported in the paper, are obtained for several choices of the term structure with different maturities.

<Table 6> Inflation Forecasting Model with Different Term Structure

	$R_t - r_t$		$r_t - \beta\pi_t$		$\overline{R}^2$
1960:1-1999:12	-0.066	(0.142)			0.046
	-0.084	(0.139)	-0.044	(0.112)	0.046
1987:8-1999:12	-0.207	(0.095)			0.052
	0.113	(0.157)	0.286	(0.088)	0.353

*: The standard errors are in the parentheses.

We also consider several macroeconomic variables in inflation forecasting model with the long-run Taylor rule and the term structure. As Table 7 shows, the coefficients of term structure and the Taylor rule do not appear to be seriously affected by the inclusion of macroeconomic variables. For the sample period 1960:1-1999:12, the coefficients of the macroeconomic variables such as unemployment rate, the change in industrial production, M2 growth, and the oil price change are significant in explaining the change in inflation. However, these macroeconomic variables become insignificant for the sample period 1987:8-1999:12.

<Table 7> Inflation Forecasting Model with Other Macro Variables

Sample Period	1960:01-1999:12		1987:8-1999:12	
Term Structure	0.3646	(0.1686)	-0.1757	(0.2498)
Taylor Rule	0.0750	(0.0869)	0.3001	(0.0923)
Unemployment	-0.4118	(0.1003)	0.1389	(0.1629)
IP Change	0.0536	(0.0124)	0.0022	(0.0126)
M2 Growth	0.0745	(0.0315)	-0.0043	(0.0316)
S&P 500 Returns	0.0026	(0.0020)	-0.0014	(0.0015)
Oil Price Change	0.0021	(0.0008)	0.0013	(0.0009)
$\overline{R}^2$	0.270		0.347	

*: The standard errors are in the parentheses.

Table 8 summarizes the predictive accuracy of inflation forecasting models. The random walk model is treated as the reference model. The inflation forecasts using the long-run Taylor rule and the term structure achieve an improvement in the predictive accuracy by 4.55% in terms of the RMSE compared to the random walk model for the sample period 1960:1-1999:12. The MAE decreases by 2.02% for the same period. On the other hand, for the sample period 1987:8-1999:12, the inflation forecasts using the long-run Taylor rule show an improvement in the prediction accuracy by 20.62% in terms of the RMSE relative to the random walk model while the term structure information reveals 2.14% gain. Therefore, the inflation forecasts using long-run Taylor rule information show an improvement in the prediction accuracy relative to the forecasts using the term structure only.

<Table 8> Forecasting Accuracy

		Model 1 (=A)	Model 2 (=B)	Model 3 (=C)	B/A	C/A
In-Sample forecasting						
1960:1-1999:12	RMSE	1.8746	1.7906	1.7893	0.9552	0.9545
	MAE	1.3689	1.3430	1.3412	0.9811	0.9798
1987:8-1999:12	RMSE	0.9609	0.9403	0.7627	0.9786	0.7938
	MAE	0.7029	0.7034	0.6199	1.0007	0.8819
Out-of-Sample forecasting						
1960:1-1999:12	RMSE	1.2036	1.2704	1.2803	1.0554	1.0637
	MAE	1.0181	1.0977	1.1133	1.0782	1.0934
1987:8-1999:12	RMSE	1.1914	1.1295	1.0568	0.9481	0.8871
	MAE	1.0307	0.9640	0.9059	0.9353	0.8790

*: $\text{RMSE} = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(\pi_t - \hat{\pi}_t)^2}$; $\text{MAE} = \frac{1}{n}\sum_{t=1}^{n}|\pi_t - \hat{\pi}_t|$

Table 8 also shows the prediction accuracy of the out-of-sample forecasts for the period 2000:1-2004:12. The forecasts are calculated recursively with a start-up sample period of 1960:1-1999:12 and 1987:8-1999:12. Given the start-up sample period 1960:1-1999:12, the out-of-sample inflation forecasts do not show any improvement regardless of the information about the term structure and the long-run Taylor rule. However, given the start-up sample period 1987:8-1999:12, the out-of-sample inflation forecasts using the long-run Taylor rule and the term structure achieve a significant improvement in the predictive accuracy by 11.29% measured by the RMSE while the out-of-sample forecasts using the term structure only improves 5.19% compared to the random walk model. Considering parameter instability in the monetary policy rules, this evidence is quite noteworthy. As the parameter in the monetary policy rules becomes more stable, the inflation forecasts using the long-run Taylor rule are likely to generate more accurate prediction of inflation.

Ⅴ. Concluding Remarks

In this paper, we investigate the influence of the monetary policy rules on the prediction of inflation. Our analysis finds that the prediction performance of the term structure model hinges on the monetary policy rules, which involve the manipulation of the federal funds rate in response to the change in the price level. As the Fed's reaction to inflation becomes stronger, the predictive information contained in the term structure becomes weaker. Using the long-run Taylor rule, a new assessment of the prediction performance regarding future change in inflation is provided. The empirical results indicate that the long-run Taylor rule improves forecasting accuracy.

The rational expectations model cannot explain this linkage, and thus this study resolves the discordance between economic theory and empirical findings.

We extended our analysis to the model with other macroeconomic variables. The information of economic indicators tends to be less important as the central bank shows strong commitment to the inflation. However, the information of the monetary policy rules, if strong, can be used for predicting the future path of inflation.

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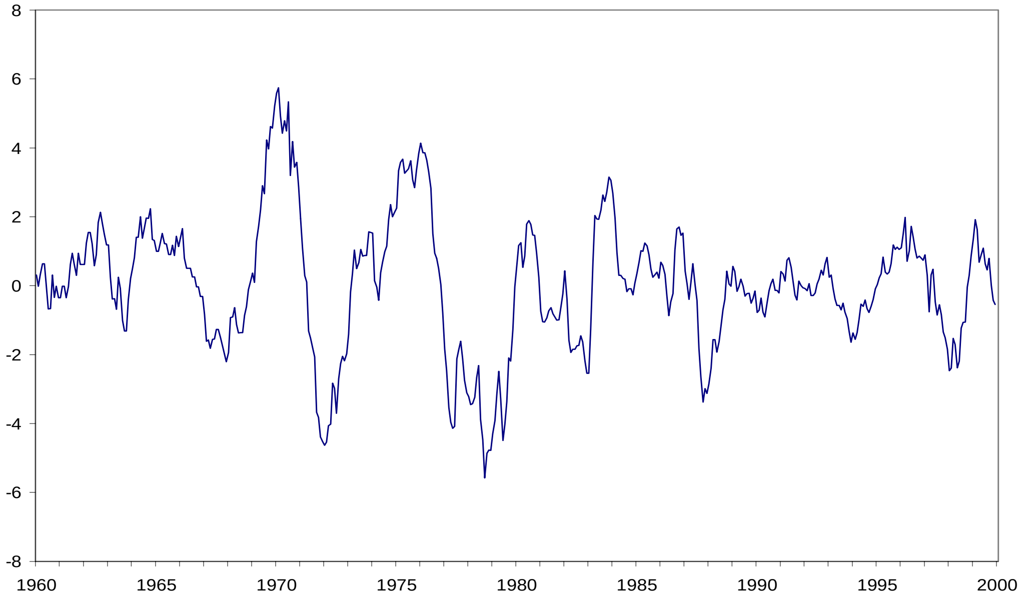
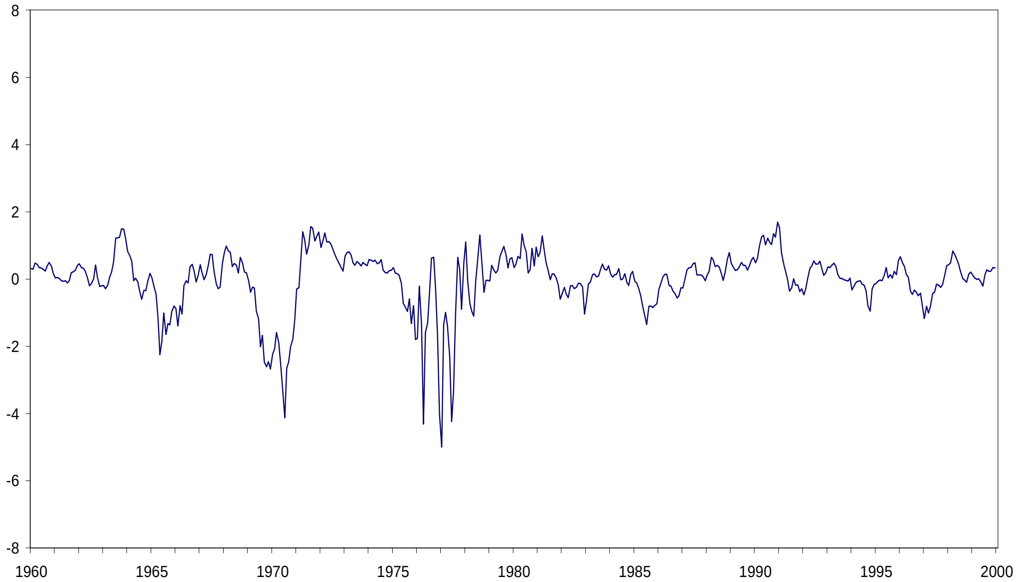
<Figure 1> <u>Change in Inflation</u>

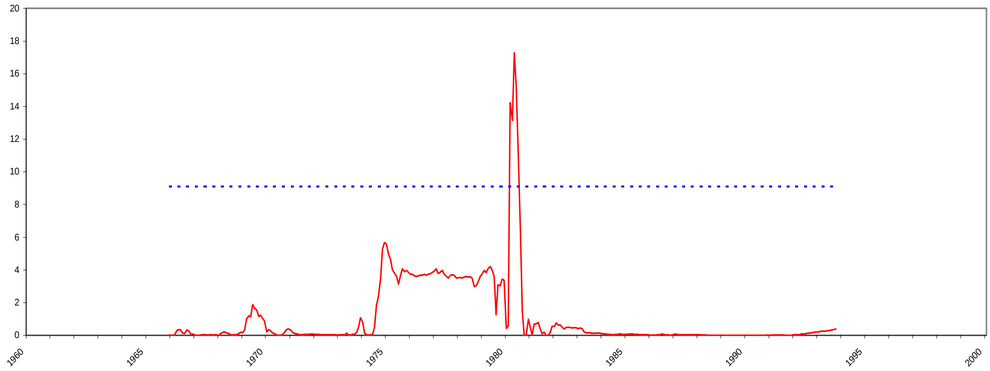


<Figure 2> <u>Term Spread</u>

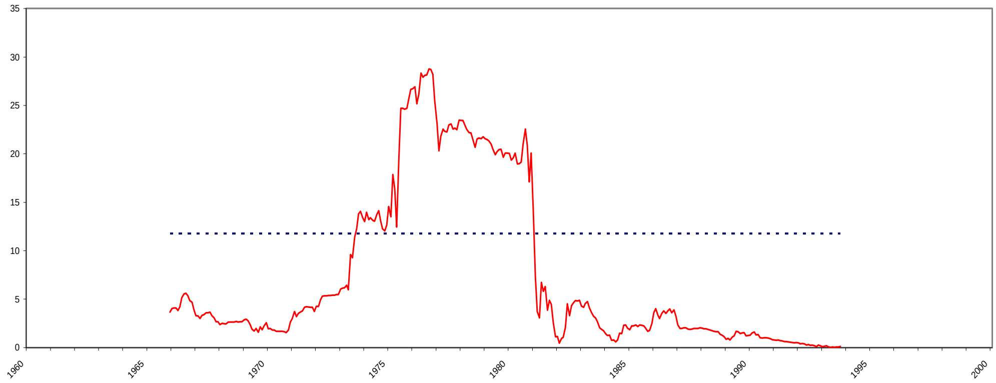


<Figure 3> Stability Tests of the Long-run Taylor Rule: 1960:1-1999:12

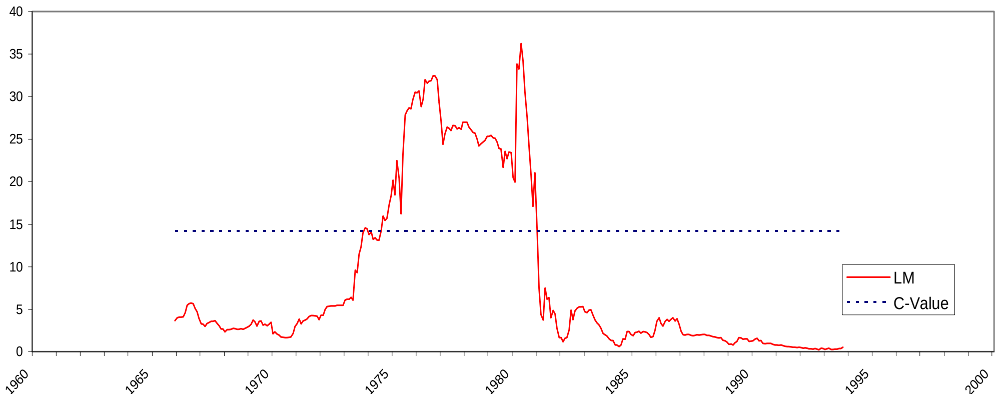
3.1 $LM^{\beta}(\tau)$



3.2 $LM^{adj.vector}(\tau)$

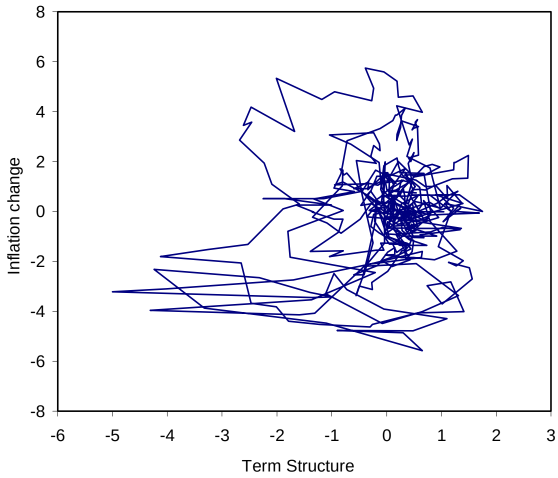


3.3 $LM^{\beta \cdot adj.vector}(\tau)$

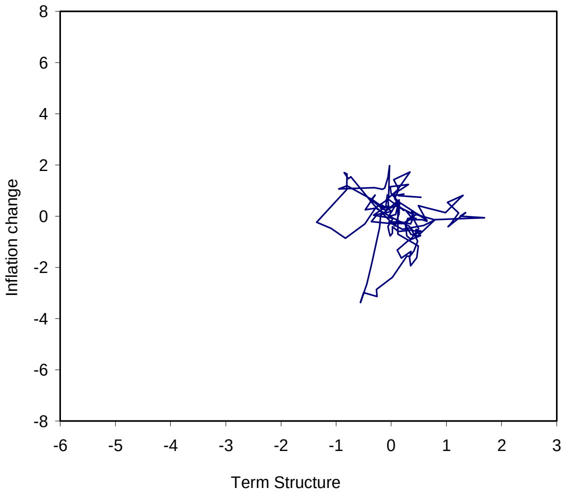


<Figure 4> Term Structure and Inflation Change

4.1 1960:1-1999:12

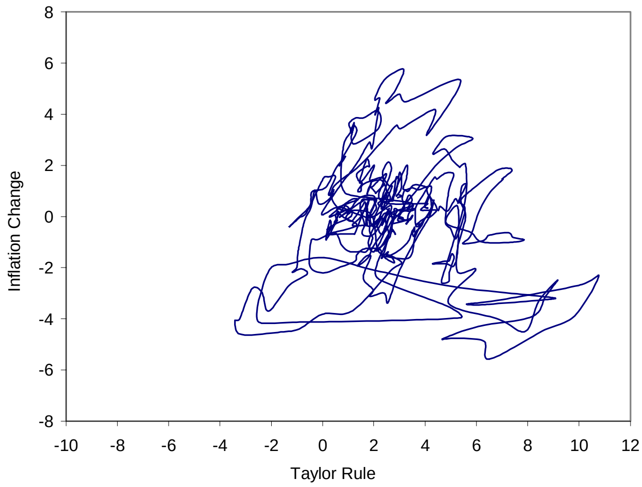


4.2 1987:8-1999:12



<Figure 5> Taylor Rule and Inflation Change

5.1 1960:1-1999:12



5.2 1987:8-1999:12