MONETARY POLICY RULES AND THE BOND MARKET IN THE U.S.

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Abstract

We show that the Federal Open Market Committee (FOMC) changes the target federal funds rate in reaction to information contained in the bond market. To this end we show that augmenting a simple Taylor rule with bond market information can significantly improve the model's fit, both in and out-of-sample. The improvement is enough to produce lower forecast errors than those of non-linear policy models. In addition, the inclusion of these bond market variables resolves the parameter instability of the Taylor rule documented in the literature, and implies that the lagged federal funds rate plays a much smaller role than that suggested in previous studies.

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Macroeconomic performance since the early 1980's is characterized by relatively moderate business cycle fluctuations. During this Great Moderation, inflation in the United States has trended downward and remained low, while the volatilities of both inflation and real output have tempered. This economic stability coincides with the end of the Federal Reserve's Monetarist Experiment and the start of a new Federal Reserve monetary policy regime where the Federal Reserve implements monetary policy via the federal funds rate.

Taylor (1993, 1997) notes that the Federal Reserve's target federal funds rate in the 1980s and 1990s closely resembles a policy rule that responds to changes in inflation and real Gross Domestic Product (GDP). Taylor's work has sparked general interest in modeling monetary policy via the manipulation of short-term interest rates. Much effort has been expended trying to formalize an optimal policy rule as well as to simply model policy behavior. One avenue of research, proposed by Taylor (2005), is how to "put asset prices directly into policy rules." This paper furthers that work by investigating whether augmenting the Taylor rule with bond market variables can better explain observed monetary policy.

Using previous literature as a guide, we construct a list of bond market variables that contain information about expectations of future macroeconomic performance. Taking historical yield data from the Federal Reserve, we construct several term and credit spreads, as well as measures of curvature. We orthogonalize this level, slope, and curvature data with respect to the current level of inflation and output, and then construct principal component analysis of the data. Using the first three principal components, we augment Taylor's (1993) policy rule and demonstrate a significant improvement in the goodness of fit, both in-sample and out-of sample. With these new bond market variables, we show that the policy rule can in fact outperform simple autoregressive models.

The paper proceeds as follows. In Section 1, we briefly review the theoretical analysis of the Taylor rule. We also describe the information provided by different measures in the bond market including the yield curve, slopes of the yield curve, and curvatures. In Section 2 we describe the data, methodology, and new bond market variables we build, and in Section 3 we examine augmented Taylor rule with the addition of new bond market variables built. We discuss the stability and forecasting ability of the model. Section 5 concludes.

1. The Taylor rule and the bond market

1.1 The Taylor rule

The short-term interest rate is a monetary policy instrument under the control of the central bank. In the United States, the Federal Reserve exercises monetary policy via control of the federal funds rate, the overnight rate at which banks lend to each other. In the context of a macroeconomic model, an appropriately specified reaction function can be used to evaluate the actions and policy stance of a central bank. By estimating such rules empirically, researchers have aimed to gain insight into how central bank behavior has varied both over time and across institutions. Much of the recent literature in this area is based on an augmented version of monetary policy rule introduced by Taylor (1993).

$$i_t = \gamma_0^* + \pi_t + \alpha(\pi_t - \pi^*) + \beta y_t \tag{1}$$

where i_t is the nominal federal funds rate, π_t is the inflation rate over the last four quarters, and π^* is the target inflation rate. The variable y_t is the output gap and is the percentage deviation of real GDP from its trend, and $(\pi_t - \pi^*)$ is called the inflation gap.

The intuition behind Equation (1) is that the Federal Reserve's target federal funds rate should rise and fall with both inflation and the output gap. The coefficients α and β represent the policy maker's responsiveness to deviations from the target output and inflation marks. In the original form of the Taylor rule, Taylor (1993) assigns 2% to both the equilibrium real interest rate, γ_0^*, and to the target inflation rate, π^*, while setting $\alpha = \beta = 0.5$. Taylor (1993) documents that this simple rule does a good job in tracking the federal funds rate between 1987 and 1992. Nevertheless, estimating α in Equation 1 is problematic unless the target inflation rate is known. As such, Equation (1) is most commonly simplified in empirical work as follows:

$$i_t = \gamma_0 + \alpha\pi_t + \beta y_t + \varepsilon_t \tag{1a}$$

Note that $\gamma_0 = \gamma_0^* - \alpha\pi^*$, so the implicit assumption of Equation (1a) is that the equilibrium real rate and the inflation target set by the Federal Reserve are constant over the sample. In addition to redefining the intercept and adding an error term, ε_t, empirical work typically includes lagged values of the federal funds rate, i_{t-1}.

$$i_t = \gamma_0 + \alpha\pi_t + \beta y_t + \gamma_1 i_{t-1} + \varepsilon_t \tag{1b}$$

Amato and Laubach (1999) note that lagged values of the federal funds rate, i_{t-1}, increase the rule's goodness of fit. As also discussed in Levin et al. (1999) and Rudebusch (2002) and Woodford (1999), lagged values create some inertia or partial adjustment in the system and represent the Federal Reserve's desire to smooth interest rate changes over time[1]. Rudebusch (2002, 2006) finds that the actual amount of policy inertia is quite low and the illusion of

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[1] As in Rudebusch (2002) and English et al. (2003), the monetary policy rules may be characterized by both partial adjustment (the smoothing effects denominated by lag one of the federal funds rate) and serially correlated omitted variables. We show below that the addition of the lag two value of the federal funds rate could be explained as a serially correlated omitted variable.

monetary policy inertia evident in the estimated policy rules likely reflects the persistent shocks that central banks face. Ősterholm (2005) finds that the lack of cointegration and its poor forecasting ability under some circumstances means that the Taylor rule in its simplest form generally is incompatible with the data, implying that central banks are doing something other than mechanically following such a simple instrument rule.

1.2 The augmented Taylor rule

Despite the improved fit lagged values provide, the Taylor rule in Equation (1b) falls short in certain dimensions. For instance, Qin and Enders (2008) document that the model fails to produce better forecasts of the federal funds rate than a second order autoregressive model. This has lead researchers to look for other variables that can help explain observed Federal Reserve target rates. To this end, the simple Taylor rule is augmented to include x_t, a vector of fundamental economic variables.

$$i_t = \gamma_0 + \alpha\pi_t + \beta y_t + \gamma_1 i_{t-1} + \kappa x_t + \varepsilon_t \qquad (2)$$

Clarida et al. (1998) examine the effectiveness of the Taylor rule augmented with different exchange rate mechanisms. They show that it is difficult to build credibility through fixed exchange rate mechanisms. Molodtsova and Papell (2009) include real exchange rates into the augmented Taylor rule with the implicit assumption that the central bank sets the target level of the exchange rate to make PPP (purchasing power parity) hold. The central bank increases (decreases) the nominal interest rate if the exchange rate depreciates (appreciates) from its PPP value. They find very strong evidence of exchange rate predictability with Taylor rule fundamentals.

Hayford and Malliaris (2004) include the simple S&P 500 P/E ratio (price/earnings) to measure the role overvaluation of the stock market plays in an augmented Taylor rule. They find no empirical evidence that the Federal Reserve attempted to moderate stock market valuations during the late 1990s, and their empirical evidence suggests that the Fed accommodated the high valuations of the stock market during that period. Mattesini and Becchetti (2006) construct an index of stock price misalignment by computing the fundamental value of stocks using a discounted cash flow approach. Adding their index into an augmented Taylor rule, they show that the Federal Reserve reacts to deviations from fundamental values on the stock exchange by raising the federal funds rate. Fuherer and Tootell (2008), on the other hand, find little evidence to support the proposition that the FOMC responds to stock values except as filtered through a forecast of accepted monetary policy goal variables. Drescher et al. (2010) estimate the augmented Taylor rule with real estate prices and yield two main findings. First, the Federal Reserve does implicitly respond to real estate prices. Second, these responses are pro-cyclical and their intensity changes over time.

1.3 Non-linear Taylor rules

Instead of searching for other macroeconomic variables to help explain the federal funds rate, recent research investigates the possibility that the policy rule may be nonlinear. Qin and Enders (2008) document that non-linear Taylor rules perform noticeably better during Alan Greenspan’s time as Chairman of the Federal Reserve. Nevertheless, these non-linear Taylor rules produce higher forecast errors than simple autoregressive models.

Bunzel and Enders (2010), however, find more encouraging results. They formulate the Taylor rule as a threshold process such that the Federal Reserve acts more aggressively when inflation is high than when inflation is low.

$$i_t = (\gamma_0 + \alpha\pi_t + \beta y_t + \gamma_1 i_{t-1} + \gamma_2 i_{t-2})I_t$$

$$+(1 - I_t)(\gamma_0^* + \alpha^*\pi_t + \beta^* y_t + \gamma_1^* i_{t-1} + \gamma_2^* i_{t-2}) + \varepsilon_t \tag{3}$$

Here x_{t-d} is the magnitude of the threshold variable in period $t-d$, and I_t is an indicator function where $I_t = 1$ if $x_{t-d} > \tau$ and $I_t = 0$ otherwise.[2] Bunzel and Enders (2010) report strong evidence for the existence of a threshold process. They document that such models are capable of producing lower mean forecast errors than an autoregressive model of the federal funds rate as well as the linear Taylor rule model in Equation (1b).

1.4 Macroeconomic expectations and information from the bond market

We use the augmented Taylor rule in Equation 2 to investigate the role bond market information plays in the Federal Reserve's choice of a target federal funds rate. We turn our attention to the bond market since yields and yield spreads reflect investor expectations about inflation and economic growth[3]. In addition, yields and yield spreads and have been shown to be related to future economic performance[4]. As such, the Federal Reserve may glean information

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[2] The dynamic adjustment process of monetary policy is a particularly interesting topic because of the lively debate about its nature whether lagged values of the interest rate is intrinsic (endogenous) or extrinsic (exogenous). Bunzel and Enders (2010) also include the second lagged value of interest rate i_{t-2} when it is significant based on their belief that i_t is an $I(1)$ variable (see also Phillips and Perron (1988); Elliott, Rothenberg, and Stock (1996)).

[3] As discussed in Adrian et al. (2010) "The traditional explanation offered for the forecasting power of the term spread rests on the informational value of the yield curve for future short rates. An inverted yield curve is seen as reflecting expectations of low future short rates which, in turn, are attributed to weakness in expected credit demand, diminished inflation expectations, and central bank policy in response to subdued economic conditions. In this sense, the mechanism is purely informational, rather than offering a causal mechanism."

[4] Note that the information in the bond market in part may reflect expectations about future Federal Reserve behavior. As mentioned in Diebold et al. (2005) , "From a macroeconomic perspective, the short-term interest rate is a policy instrument

about inflation and economic growth that might not be captured by the current level of inflation and output.

For instance, Mehra (2001) considers the additional influence of long-term inflationary expectations as reflected in the behavior of the long-term bond rate (the 10 year bond yield) and finds that the federal funds rate target responded to the bond rate in the post-1979 period. One conclusion from Mehra (2001) is that the good macroeconomic performance of the U.S. economy in the post-1979 period may in fact reflect the willingness of the Fed to act preemptively in response to movements in long-term inflationary expectations as reflected in the behavior of the bond rate.

Treasury yield spreads and corporate bond spreads are used as financial business-cycle indicators as part of macroeconomic indicators (for example, Piazzesi and Swanson (2008)). Estrella and Hardouvelis (1991) find that a positive slope of the yield curve is associated with a future increase in real economic activity and has extra predictive power over other economic variables. Stock and Watson (2003) conclude that the term spread in the bond market comes closest to achieving the goal as a reliable predictor of output growth across countries over multiple decades. As for inflation forecasts, they find that the term spread helped to predict inflation for the United States[5].

Adrian et al. (2010) point out that one of the most robust features of macroeconomics is the forecasting power of the term spread for future real activity, with an inverted yield curve being a harbinger of recessions within a 12 to 18 month period (see Estrella and Hardouvelis

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under the direct control of the central bank. From a finance perspective, long rates are risk-adjusted averages of expected future short rates."

[5] Individual asset prices provide improvements that are sometimes modest but rarely large. Their findings that term spread helped to predict inflation was not the case in other countries or in the second period in the United States.

(1989, 1991), and Stock and Watson (1989, 1993)). In addition, the yield curve has been demonstrated to predict recessions even prior to 1955 (Bordo and Haubrich (2004)), and across countries (Bernard and Gerlach (1996), and Estrella, Rodrigues, and Schich (2003)). Estrella (2004) constructs an analytical rational expectations model to investigate the reasons for the empirical results that the slope of the yield curve (measured as yield spreads) has been shown to be a significant predictor of inflation and real economic activity.

Confirming a variety of earlier studies, Haubrich and Dombrosky (1996) find that the 10-year to three-month spread has substantial predictive power and provides one of the best forecasts of real growth four quarters into the future. Piazzesi and Swanson (2008) point out that Treasury yield spreads and corporate bond spreads are financial business-cycle indicators. They document that simply ignoring those risk premia significantly biases forecasts of the future path of monetary policy. Yield spreads act as indices for future economy condition for central banks to take into account.

2. Data and methodology

2.1 Data and key variables

In order to estimate the Taylor rule, we need data on the federal funds rate, GDP, and inflation. To this end we collect monthly values of the federal funds rate and the chain weighted GDP deflator from the Federal Reserve Bank of St. Louis, as well as the real-time values of GDP available at the Philadelphia Federal Reserve Bank's website. We choose to follow the variable definitions used in Rudebusch (2002) and Bunzel and Enders (2010). Specifically, our interest rate (i_t) is the quarterly average of the monthly values of the federal funds rate. This nominal quarterly federal funds rate, i_t, is calculated as the simple average of the monthly nominal federal funds rate. The four-quarter inflation rate (π_t) is constructed as $\pi_t = 100 * (lnp_t - lnp_{t-4})$, where lnp_t is the natural log of the chain-weighted GDP deflator at time *t*.

To construct the output gap, we filter the real output data with a Hodrick-Prescott (HP) filter using the same RATs program as Bunzel and Enders (2010). Specifically, beginning with $\mathrm{t} = 1963{:}2$, we apply the HP filter to the real-time output series running from 1947:1 through *t*. The filtered series represents the trend values of real GDP where y_t^f is the last observation of the filtered series. We construct the output gap for time period *t* (y_t) as the percentage difference between real-time output at *t* and the filtered value y_t^f. We then increase *t* by one period and repeat the process as in Croushore and Stark (2001). Our aim is not to ascertain how real output evolves over the long run, but to obtain a reasonable measure on the pressure of the Federal Reserve to use monetary policy to affect the level of output.

In order to augment the Taylor rule with information from bond markets, we obtain bond market data from the Federal Reserve Bank of St. Louis. We collect quarterly data on Moody's seasoned Aaa corporate bond yields (AAA), quarterly Moody's seasoned Baa corporate bond yield (BAA), quarterly 30-year Treasury Constant Maturity Rate (GS30), quarterly 20-year Treasury Constant Maturity Rate (GS20), quarterly 10-year Treasury Constant Maturity Rate (GS10), quarterly 5-year Treasury Constant Maturity Rate (GS5), quarterly 2-year Treasury Constant Maturity Rate (GS2), quarterly 1-Year Treasury Constant Maturity Rate (GS1), quarterly 6-Month Treasury Constant Maturity Rate (GS6M), and quarterly 3-Month Treasury Constant Maturity Rate (GS3M).

Term spreads are calculated as the yield on the longer maturity bond minus the yield on the shorter maturity bond. We also construct two credit spreads. The first is the difference between the Moody’s seasoned Baa corporate bond yield and the Aaa corporate bond yield. The second credit spread is the difference between the Moody’s seasoned Baa corporate bond yield and the 10-year Treasury bond yield. We try to include all the bond yield information we have for our analysis. Note that 6-month and 3-month Treasury bond yield data started from 1982Q1. The available 30-year Treasury bond yield data are 1977Q2-2002Q1 and 2006Q1-2011Q2. The 20-year Treasury bond yield data are missing from 1987Q1 to 1993Q3. Consistent with previous literature, our final available data includes 3-month, 6-month, 1-year, 2-year, 3-year, 5-year, 7-year, and 10-year Treasury bond yields starting from 1983Q1 and ending at 2011Q2. Our Treasury term spreads include the 6- to 3-month, 1-year to 6-month, 2- to 1-year, 3- to 2-year, 5- to 3-year, 7- to 5-year, and 10- to 7-year Treasury term spread.

Finally, we define two measures for the curvature of the U.S. Treasury yield curve. The first curvature variable (curvature) is the 5 year government bond yield minus the average of the 6 month government bond yield and the 10 year government bond yield. The second curvature (curvature2) variable is defined as the 10 year government bond yield minus the average of the 6 month government bond yield and the 20 year government bond yield. We report summary statistics for all our variables in Table 1.

2.2 Methodology

Because of the array of (correlated) choices for bond market proxies of the level, slope, curvature, and credit spreads, we use principal component analysis (PCA) to combine the information in these bond market variables. Furthermore, we orthogonalize the bond market variables with respect to inflation and output. Results from these regressions are reported in Table 2. These results show that Treasury and corporate bond yields are closely related to inflation and output gap which explain around 60% of the yield variance. Treasury term spreads are also partially explained by inflation and output gap, though the relation is not as strong. Treasury yield curvatures, on the other hand, seem unrelated to inflation and the output gap.

We conduct PCA analysis of the orthogonalized variables (regression residuals from Table 2). Our PCA result for the clustering of the bond market information is reported in Table 3 Panel A. Our sample period starts from 1982Q1 when all the short-term and long-term variables were available. Our findings show that the first principal component of the bond market variables is a combination of Treasury and corporate bond yields with almost equal weights of around -0.3. This level component accounts for 56.3% of the total variance in the bond market data. The second principal component is a combination of different Treasury term spreads and curvature variables. The weights given vary, but are typically around 0.3 for these variables. The third principal component loads on the credit spread variables with weights of -0.62, including the BAA to AAA credit spread and the BAA to 10-year Treasury spread. These first three principal components account to 92.6% of the total variance. We find almost identical patterns in the factor loadings if we use the raw as opposed to orthogonalized data, reported in Table 3 Panel B. The weights on the level variables are roughly -0.28 for the first principal component, 0.31 for the spread and curvature variables in the second principal component, and -0.62 for the credit spread variables in the third principal component. In addition, the first three principal components account for 92.6% of the total variation in the raw data.

3. Linear model with bond market variables

3.1 General linear results

We divide the whole sample around 1979:Q3, corresponding to the appointment of Paul Volcker as the Federal Reserve Chairman, because it has been suggested in the previous literature that U.S. monetary policy was conducted in significantly different ways before 1979 and after 1979 (see Hakes, 1990; Judd and Rudebusch, 1998, and Pakko, 2005, for instance). The first subsample period is from 1965:Q3 to 1979:Q2, which was called the pre-Volcker period. The second subsample period is from 1979:Q3 till now, which was called the post-Volcker period. It is also of interest to examine the Greenspan era from 1987:Q4 till now since over that time period the Federal Reserve has not announced official targets for the M1 money supply, relying more heavily on federal funds rate targets[6].

Table 4 reports results for the Taylor rule given in Equation (1b), as well as the Taylor rule from Equation 2 that is augmented with the first five principal components of the bond market data. Our augmented Taylor rule is therefore:

$$\mathrm{i_t} = \gamma_0 + \alpha\pi_\mathrm{t} + \beta\mathrm{y_t} + \gamma_1\mathrm{i_{t-1}} + \kappa_1 R_{1t} + \kappa_2 R_{2t} + \kappa_3 R_{3t} + \kappa_4 R_{4t} + \kappa_5 R_{5t} + \varepsilon_\mathrm{t} \qquad (4)$$

where R_{it} is the value at time t of the i^{th} principal component. The models in Table 4 are estimated over different sub periods: the pre-Volker (1965:3-1979:2), post-Volker (1979:3-2011:2) and Greenspan (1987:4-2011:2) eras. Consistent with previous research, we can see that the Taylor rule performs best in describing the federal funds rate targets for the Greenspan period (1987Q4-2011Q2) with an adjusted R^2 value of 0.976. In contrast the Taylor rule for the pre-Volcker period has an adjusted R^2 value of 0.834. For both the post-Volcker period and the Greenspan period, a subsample of the post Volcker period, we find that the Fed became more focused on controlling inflation together with the output gap.

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[6] We include the time period following the retirement of Greenspan to show that fact that Bernanke declared that the Fed follows the Taylor rule.

Also evident in Table 4 is that the inclusion of the bond market factors significantly improves the Taylor rule's fit in the pre-Volker period. The adjusted R^2 values increase from 0.834 to 0.958 and the AIC values decrease from around 150 to 78. The improvement to the Taylor rule's performance in the Greenspan era is less striking. While the coefficient on the first three principal components are statistically significant, the adjusted R^2 falls from 0.976 to 0.966/ Nevertheless, the AIC for the Taylor rule in the Greenspan era improves from 94 to -79.9 with the addition of the bond market principal components.

Since of the Federal Reserve deemphasized the role of money supply targets in monetary policy in 1982, we now turn our attention to the 1982-2011 period. Similar to Bunzel and Enders (2010), we break the post-1982 period down into several periods of particular interest. First, Alan Greenspan became chairman of the Federal Reserve in 1987. In addition, in 1987 the Federal Reserve discontinued the practice of announcing growth targets for the M1 money supply. In addition, we introduce another break in 2007 which roughly marks the start of the financial crisis and the Great Deviation. Taylor (2010) defines the Great Deviation as the recent period during which macroeconomic policy became more interventionist, less rules-based, and less predictable. Eleven out of twelve Great Deviations happened during the 2007Q3-2011Q2 period. Results for the sub-periods defined by these dates are reported in Table 5.

Results in Table 5 indicate that the Taylor rule slope and intercept coefficients are fairly stable over the different time periods. Nevertheless, the augmented Taylor rule outperforms the simple Taylor rule in all sub-periods. In addition, the Taylor principal (Taylor, 1993) that the Fed should respond aggressively to inflation (coefficient on inflation is greater than 1.5) is strongly supported in the augmented Taylor rule. Similarly, the Federal Reserve's response to the output gap appears more aggressive in the augmented Taylor rule specification. Here β, the coefficient on the output gap, is uniformly greater than 0.41, whereas in the simple Taylor rule it is always less than 0.35. This result for the simple Taylor rule contrasts with Taylor's (1993) original specification for the coefficient of 0.5. Alternatively, the statistical and economic significance of the lagged federal funds rate is largely reduced by the inclusion of the orthogonalized bond market variables. While the coefficient for the simple Taylor rule is greater than 0.9 in all sub-samples, it is never greater than 0.32 in the Taylor rule augmented with the orthogonalized bond market principal components.

Coefficients on the first two bond market principal components are consistently significant all through the sub-samples. The third principal component is only significant when the financial crisis (2008-2011) is included. Recall that the first component loaded negatively on the level, while the second component loaded positively on the slopes. An increase in the level of the Treasury yield curve (which tends to decrease the first factor) can represent expectations of higher inflation, while an increase in the slope (which tends to increase the second factor) can represent increased fears of a future economic slowdown or overheating. Nevertheless the economic interpretation is not clear given the difficulty in plainly interpreting the economic meaning of the principal components as well as the movement in yields. We stress that our analysis is not aimed at arguing how the Federal Reserve interprets the forward-looking data embodied by the bond markets. Rather we simply argue that this data may contain information about future growth and inflation expectations that is not captured by the current level of inflation and productivity, and hence is utilized by the Federal Reserve in setting monetary policy.

3.2 Stability of the linear model

Bunzel and Enders (2010) argue that the optimal policy rule may be non-linear. They show that modeling the Taylor rule as a threshold process improves the in-sample and out-of-sample explanatory power of the model. In their analysis, they use three forms of non-linear models, TAR model, the opportunistic model, and the full "opportunistic model". TAR is the threshold autoregressive model with inflation rate as the threshold variant. The opportunistic model is a model in the form of Equation (3) such that the indicator function is a simple average of the inflation rate prevailing 1 and 2 years ago. The full "opportunistic model" is also a model in the form of Equation (3) with the indicator function as both a simple average of the inflation rate prevailing 1 and 2 years ago and positive or negative output gap. In this section we compare the augmented Taylor rule to their threshold process.

First, we follow Bunzel and Enders (2010) and use standard recursive estimation methods to ascertain if the parameters of the augmented Taylor rule are stable. For example, for each time period T in the interval 1990:1 to 2011:2, we estimate an equation in the form of:

$$\mathrm{i}_t = \gamma_0 + \alpha\pi_t + \beta y_t + \gamma_1 \mathrm{i}_{t-1} + \kappa_1 R_{1t} + \kappa_2 R_{2t} + \kappa_3 R_{3t} + \varepsilon_t \tag{5}$$

using observations 1983:1 through T. Hence, we obtain 86 regression equations each containing an estimate of γ_0, α, β, γ_1, κ_1, κ_2, and κ_3. The time paths of the resulting estimated coefficients are displayed in Panels A through D of Figure 1, respectively. Panels on the left reproduce the panels in Figure 2 of Bunzel and Enders (2010) where the simple Taylor rule is estimated. Panels on the right report the parameter estimates from the augmented Taylor rule. While Bunzel and Enders (2010) find instability in the inflation coefficient for the simple Taylor rule, we find the coefficient is stable. In addition, the intercept and coefficient for the output gap fall sharply and then seem to stabilize around 1995 for the simple Taylor rule. A similar, though not as pronounced, pattern is evident in the augmented Taylor rule. The coefficient for the first lagged value of federal funds rate in the simple Taylor rule rises from roughly 0.5 to 0.8 and then stabilizes around 1995. In contrast, the same coefficient is fairly constant in the augmented Taylor rule specification, ranging from roughly 0.25 to 0.3.

For instance, the inflation coefficient fell gradually from 1.80 to 1.70, the output gap coefficient increased abruptly from 0.40 to 0.45, implying that economic growth became more important for the Fed than inflation control for this special time period. The lagged value of federal funds rate coefficient increased gradually from 0.15 to 0.20. Our new finding is the significance of the residual credit spread coefficient since the beginning of 2009 and then the coefficient stayed stable thereafter. The monetary policy became stable after 2009.

3.3 Out-of-Sample Forecasting

While we find the augmented Taylor rule does not exhibit the parameter instability documented in Bunzel and Enders (2010), it is not clear that the augmented rule is superior to their threshold specification. We perform out-of-sample forecasting in order to validate the in-sample findings and to compare the augmented model to the threshold model. Following the empirical work of Bunzel and Enders (2010), we use the so called “backward-looking” variants of the Taylor rule. We replace contemporaneous independent variables in the Equation 5 with lagged values of those variables. Our linear augmented Taylor rule becomes:

$$\mathrm{i_t} = \gamma_0 + \alpha\pi_{t-1} + \beta y_{t-1} + \gamma_1 \mathrm{i}_{t-1} + \kappa_1 R_{1t-1} + \kappa_2 R_{2t-1} + \kappa_3 R_{3t-1} + \varepsilon_t \qquad (6)$$

Different from a normal linear Taylor rule, Equation (7) requires the determination of residual bond market variables ex ante. For example, at time t we first orthogonalize the first

$t-1$ bond market variable observations with respect to inflation and the output gap. We then use PC analysis and include the first three principal components to estimate Equation 7. Once the coefficients γ_0, α, β, γ_1, κ_1, κ_2, and κ_3 have been estimated, it is straightforward to update Equation (7) by one period and use the contemporaneous values of π_{t+1}, y_{t+1}, i_{t+1}, $R_{1,t+1}$, $R_{2,t+1}$, and $R_{3,t+1}$ to forecast i_{t+1}. Note that $R_{1,t+1}$, $R_{2,t+1}$, and $R_{3,t+1}$ are constructed using the bond market variables at t and the PCA weights estimated at $t-1$. We use the first 50 observations to form the first forecast , so our first out of sample observation is the forth quarter of 1987. Consistent with Bunzel and Enders (2010), we report forecast results extending until the end of 2005, as well as until the third quarter of 2007 (the start of quantitative easing)

In our Table 6 we report the mean out-of-sample forecast errors from Bunzel and Enders (2010) (located in their Table 6) for the simple Taylor rule, a threshold linear Taylor rule, as well as the opportunistic and fully opportunistic versions of their model. We also include in Table 6 the mean forecast errors for the augmented Taylor rule. As shown in the table, the out-of-sample forecasts provide corroborating evidence in support of the augmented linear Taylor rule. The forecast errors from the augmented Taylor rule are smaller than all other models. Compared with the Bunzel and Enders' (2010) full opportunistic threshold model, our model has almost 50% smaller forecast errors mean, though it must be noted that the variance of the forecast errors is greater.

Table 6 also reports the "Full-period estimation" results from Bunzel and Enders (2010) where the coefficients from the models are estimated using all observations. Here the forecasting is not truly out-of-sample, but no observations are lost in the analysis. Only the variances are shown since the mean of the regression residuals are necessarily zero. The results show that the linear augmented Taylor rule has larger forecast error variance than the opportunistic threshold model for the full sample, and roughly the same variance for the sample starting in 1987. This larger variance despite having a smaller mean error may reflect that the augmented Taylor rule could also be improved upon within the context of a threshold model, and we are currently investigating this possibility.

4. Conclusion

We continue the discussion of how to “put asset prices directly into policy rules” posed by Taylor (2005). We choose bond market variables as representatives for asset prices in the economy. Drawing on previous literature that demonstrates the information content of bond market variables with respect to future macroeconomic performance, we include in our analysis Treasury and corporate bond yields, Treasury term spreads, corporate credit spread, and measures of curvature. Our analysis is based on an augmented Taylor rule framework with inflation rate, output gap, and the one year lag value of the federal funds rate.

Due to the degree of multicolinearity in the bond market variables and the sheer number of candidate variables, we conduct principal component analysis to construct five linear combinations of the variables. As such, we do not claim to show how the Fed responds to the information in the bond market, only that it does. Nevertheless, the first principal component loads largely on the level of yields, the second component on the slopes and curvatures, while the third component loads on credit spreads.

We document that augmenting the Taylor rule with these bond market factors significantly improves the in-sample and out-of-sample fit of the model. This improvement in fit is true for both the pre-Volker and post-Volker eras. In addition, we show that the importance of lagged values of the federal funds rate is greatly diminished, though not completely removed. Our analysis also shows that inclusion of the variables reduces the parameter instability documented in Bunzel and Enders (2010).

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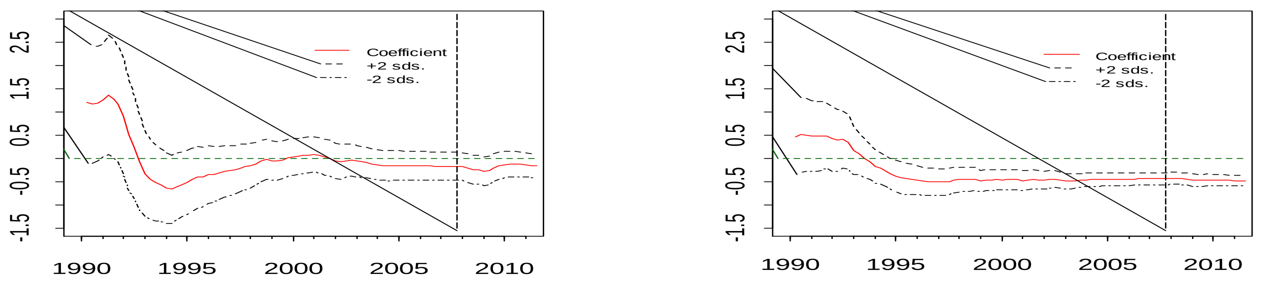
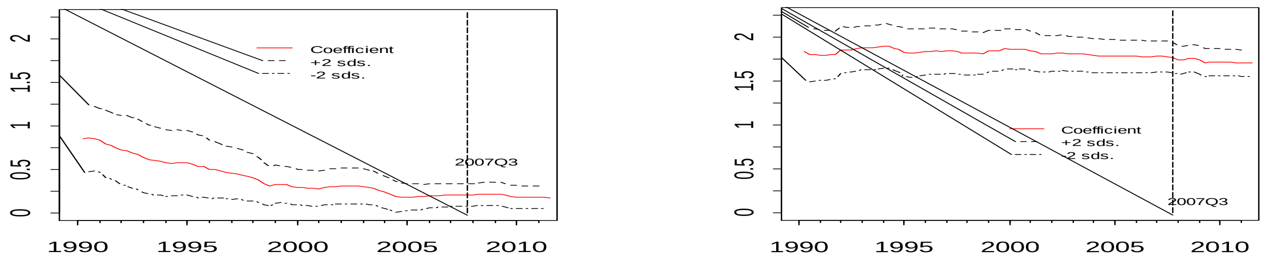
Figure1. Recursive estimation of the Taylor rule and augmented Taylor rule

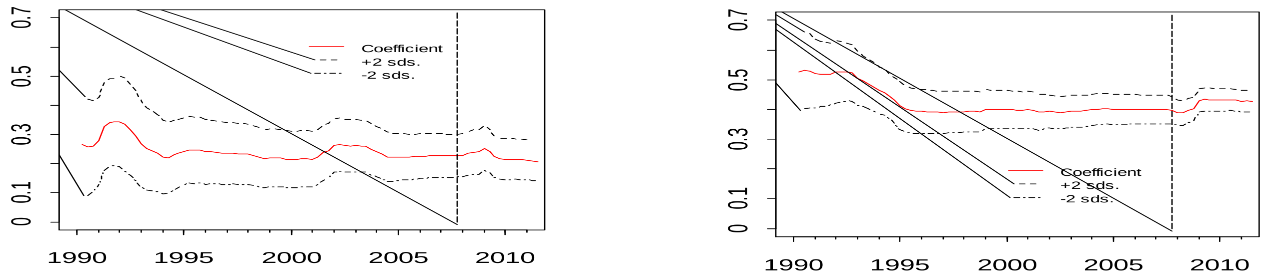
Note: Figure 1 provides the comparison of the stability of two different Taylor rule models. Type I recursive estimation is based on a simple linear Taylor rule with the equation $i_t = \gamma_0 + \alpha\pi_t + \beta y_t + \gamma_1 i_{t-1} + \varepsilon_t$, and Type II recursive estimation is based on an augmented Taylor rule $\mathrm{i_t} = \gamma_0 + \alpha\pi_t + \beta y_t + \gamma_1 \mathrm{i}_{t-1} + \kappa_1 R_{1t} + \kappa_2 R_{2t} + \kappa_3 R_{3t} + \varepsilon_t$, where R_{it} is principle component based on all the bond variables including bond yields, spreads, and curvatures. Each of our recursive estimations start in 1983Q1.


Panel I-A: Intercept

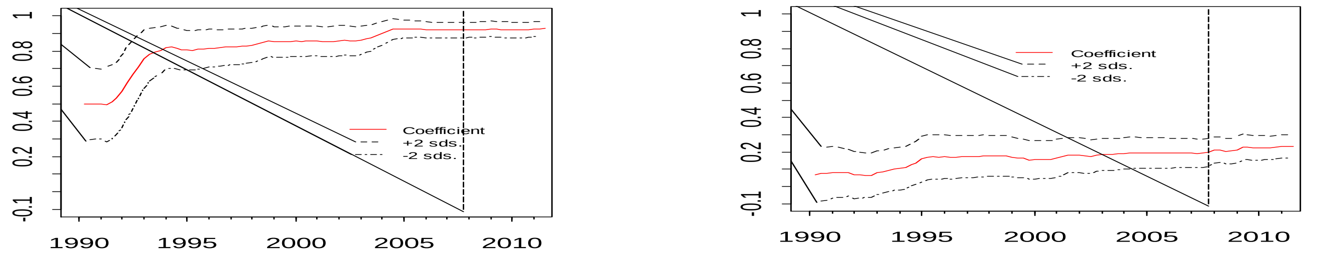
Panel II-A: Intercept


Panel I-B: Inflation Coefficient

Panel II-B: Inflation Coefficient


Panel I-C: Output Gap Coefficient

Panel II-C: Output Gap Coefficient


Panel I-D: Lagged Value Coefficient

Panel II-D: Lagged Value Coefficient

Table 1
Panel A: Descriptive statistics

The descriptive statistics is based on the sample period from 1982Q1 to 2011Q2. Federal funds rate refers to the nominal quarterly Federal funds rate; inflation rate is the four-quarter inflation rate; output gap is the percentage difference between real-time GDP values and the Hodrick-Prescott (HP) filtered GDP values; AAA is quarterly Moody's seasoned Aaa corporate bond yield; BAA is quarterly Moody's seasoned Baa corporate bond yield; GS10 is quarterly 10-year Treasury constant maturity rate; GS7 is quarterly 7-year Treasury constant maturity rate; GS5 is quarterly 5-year Treasury constant maturity rate; GS3 is quarterly 3-year Treasury constant maturity rate; GS2 is quarterly 2-year Treasury constant maturity rate; GS1 is quarterly 1-year Treasury constant maturity rate; GS6M is quarterly 6-month Treasury constant maturity rate; GS3M is quarterly 3-month Treasury constant maturity rate; btoa is the spread between AAA and BAA; bto10 is the spread between BAA and GS10; s10to7 is the spread between GS10 and GS7; s7to5 is the spread between GS7 and GS5; s5to3 is the spread between GS5 and GS3; s3to2 is the spread between GS3 and GS2; s2to1 is the spread between GS2 and GS1; s1to6m is the spread between GS1 and GS6M; s6mto3m is the spread between GS6M and GS3M; c5toa6m10 is the curvature calculated as "GS5 minus the average of GS6M and GS10"; c5toa3m10 is the curvature calculated as "GS5 minus the average of GS3M and GS10".

	Mean	Standard deviation	25th percentile	50th percentile	75th percentile
Federal funds rate	5.124	3.088	3.010	5.270	6.900
Inflation rate	2.583	1.063	1.950	2.250	3.260
Output gap	-0.037	1.387	-0.880	0.265	0.875
AAA	7.857	2.351	5.768	7.420	9.128
BAA	8.932	2.561	7.123	8.200	10.253
GS10	6.667	2.669	4.608	6.160	8.288
GS7	6.495	2.783	4.535	6.115	8.165
GS5	6.226	2.882	4.390	5.870	7.940
GS3	5.869	3.026	3.810	5.740	7.750
GS2	5.646	3.089	3.640	5.530	7.563
GS1	5.244	3.044	3.350	5.235	7.043
GS6M	5.051	2.996	3.180	5.155	6.490
GS3M	4.840	2.897	3.023	5.090	6.233
btoa	1.075	0.471	0.755	0.945	1.268
bto10	2.265	0.738	1.743	2.075	2.663
s10to7	0.173	0.207	0.040	0.125	0.328
s7to5	0.268	0.197	0.100	0.240	0.398
s5to3	0.358	0.317	0.090	0.300	0.598
s3to2	0.223	0.184	0.053	0.235	0.360
s2to1	0.402	0.286	0.220	0.400	0.618
s1to6m	0.193	0.190	0.080	0.190	0.290
s6mto3m	0.211	0.195	0.090	0.160	0.278
c5toa6m10	0.367	0.323	0.155	0.358	0.599
c5toa3m10	0.473	0.379	0.226	0.435	0.733

Table 2

Regression results between bond market variables and original Taylor rule variables, i.e. inflation and output gap

$$B_{it} = \theta_0 + \theta_1 \pi_t + \theta_2 y_t + \varepsilon_t$$

We regress our bond market variables belos, B_{it}, on both inflation, π_t, and the output gap, y_t. The regression results are based on the sample period from 1982Q1 to 2011Q2. AAA is quarterly Moody's seasoned Aaa corporate bond yield; BAA is quarterly Moody's seasoned Baa corporate bond yield; GS10 is quarterly 10-year Treasury constant maturity rate; GS7 is quarterly 7-year Treasury constant maturity rate; GS5 is quarterly 5-year Treasury constant maturity rate; GS3 is quarterly 3-year Treasury constant maturity rate; GS2 is quarterly 2-year Treasury constant maturity rate; GS1 is quarterly 1-year Treasury constant maturity rate; GS6M is quarterly 6-month Treasury constant maturity rate; GS3M is quarterly 3-month Treasury constant maturity rate; btoa is the spread between AAA and BAA; bto10 is the spread between BAA and GS10; s10to7 is the spread between GS10 and GS7; s7to5 is the spread between GS7 and GS5; s5to3 is the spread between GS5 and GS3; s3to2 is the spread between GS3 and GS2; s2to1 is the spread between GS2 and GS1; s1to6m is the spread between GS1 and GS6M; s6mto3m is the spread between GS6M and GS3M; c5toa6m10 is the curvature calculated as "GS5 minus the average of GS6M and GS10"; c5toa3m10 is the curvature calculated as "GS5 minus the average of GS3M and GS10".

Dependent variable	θ_0	θ_1	θ_2	Adj. R^2	Dependent variable	θ_0	θ_1	θ_2	Adj. R^2
AAA	3.709	1.610	0.290	0.506	Btoa	0.726	0.133	-0.146	0.308
	(9.127***)	(11.019***)	(2.591**)			(7.542***)	(3.838***)	(-5.488***)	
BAA	4.435	1.743	0.144	0.501	bto10	2.694	-0.171	-0.327	0.372
	(9.971***)	(10.897***)	(1.179)			(18.727***)	(-3.301***)	(-8.239***)	
GS10	1.741	1.914	0.471	0.567	s10to7	0.373	-0.078	-0.035	0.167
	(4.031***)	(12.323***)	(3.958***)			(8.027***)	(-4.663***)	(-2.73***)	
GS7	1.368	1.992	0.506	0.566	s7to5	0.515	-0.096	-0.038	0.278
	(3.035***)	(12.285***)	(4.073***)			(12.502***)	(-6.482***)	(-3.361***)	
GS5	0.853	2.088	0.544	0.582	s5to3	0.648	-0.113	-0.048	0.145
	(1.862*)	(12.671***)	(4.31***)			(8.996***)	(-4.362***)	(-2.441**)	
GS3	0.206	2.201	0.593	0.589	s3to2	0.360	-0.054	-0.024	0.092
	(0.431)	(12.827***)	(4.507***)			(8.376***)	(-3.462***)	(-1.992**)	
GS2	-0.155	2.254	0.616	0.594	s2to1	0.362	0.016	0.012	-0.012
	(-0.319)	(12.955***)	(4.621***)			(5.117***)	(0.615)	(0.61)	
GS1	-0.516	2.239	0.604	0.603	s1to6m	0.093	0.039	0.033	0.072
	(-1.095)	(13.194***)	(4.648***)			(2.076**)	(2.421**)	(2.69***)	
GS6M	-0.610	2.200	0.571	0.598	s6mto3m	-0.059	0.105	0.034	0.327
	(-1.305)	(13.093***)	(4.435***)			(-1.504)	(7.443***)	(3.143***)	
GS3M	-0.551	2.095	0.537	0.578	c5toa6m10	0.288	0.031	0.023	0.000
	(-1.19)	(12.588***)	(4.212***)			(3.623***)	(1.088)	(1.057)	
					c5toa3m10	0.258	0.084	0.040	0.048
						(2.838***)	(2.555**)	(1.601)	

Table 3

Panel A: Principal Component Analysis (PCA) results with bond yields, spreads, and curvatures that are orthogonalized with respect to inflation and the output gap

$$R_{it} = B_{it} - (\hat{\theta}_0 + \hat{\theta}_1 \pi_t + \hat{\theta}_2 y_t)$$

We conduct principal component analysis of the bond market variables after orthogonalizing with respect to inflation, π_t, and the output gap, y_t. The results are based on the sample period from 1982Q1 to 2011Q2. B_{it} is the ith bond market variable such as Treasury and corporate bond yields, spreads, and curvatures. Coefficients of $\hat{\theta}_0$, $\hat{\theta}_1$, and $\hat{\theta}_2$ are estimated based on regression results from the previous table. AAA is quarterly Moody's seasoned Aaa corporate bond yield; BAA is quarterly Moody's seasoned Baa corporate bond yield; GS10 is quarterly 10-year Treasury constant maturity rate; GS7 is quarterly 7-year Treasury constant maturity rate; GS5 is quarterly 5-year Treasury constant maturity rate; GS3 is quarterly 3-year Treasury constant maturity rate; GS2 is quarterly 2-year Treasury constant maturity rate; GS1 is quarterly 1-year Treasury constant maturity rate; GS6M is quarterly 6-month Treasury constant maturity rate; GS3M is quarterly 3-month Treasury constant maturity rate; btoa is the spread between AAA and BAA; bto10 is the spread between BAA and GS10; s10to7 is the spread between GS10 and GS7; s7to5 is the spread between GS7 and GS5; s5to3 is the spread between GS5 and GS3; s3to2 is the spread between GS3 and GS2; s2to1 is the spread between GS2 and GS1; s1to6m is the spread between GS1 and GS6M; s6mto3m is the spread between GS6M and GS3M; c5toa6m10 is the curvature calculated as "GS5 minus the average of GS6M and GS10"; c5toa3m10 is the curvature calculated as "GS5 minus the average of GS3M and GS10".

	PC1	PC2	PC3	PC4	PC5	PC6
residual_AAA	-0.295	0.074	-0.052	-0.179	-0.042	0.163
residual_BAA	-0.282	0.106	-0.181	-0.155	-0.016	0.057
residual_GS10	-0.302	0.052	0.024	-0.140	-0.126	-0.027
residual_ GS 7	-0.306	0.021	0.029	-0.111	-0.065	0.010
residual_ GS 5	-0.308	-0.009	0.032	-0.078	-0.043	-0.019
residual_ GS 3	-0.305	-0.061	0.015	-0.036	-0.022	-0.038
residual_ GS 2	-0.300	-0.092	0.001	-0.024	-0.028	-0.034
residual_ GS 1	-0.287	-0.142	-0.027	-0.026	-0.081	-0.045
residual_ GS 6M	-0.276	-0.170	-0.033	-0.062	-0.071	0.003
residual_ GS 3M	-0.267	-0.185	-0.019	-0.117	-0.033	-0.036
residual_btoa	-0.061	0.175	-0.619	0.038	0.101	-0.423
residual_bto10	0.033	0.172	-0.632	-0.059	0.329	0.258
residual_s10to7	0.165	0.278	-0.057	-0.222	-0.545	-0.347
residual_s7to5	0.072	0.323	-0.040	-0.351	-0.235	0.316
residual_s5to3	0.063	0.348	0.103	-0.255	-0.124	0.132
residual_s3to2	-0.008	0.364	0.159	-0.137	0.064	-0.044
residual_s2to1	-0.140	0.313	0.187	0.008	0.350	0.069
residual_s1to6m	-0.143	0.278	0.058	0.373	-0.106	-0.505
residual_s6mto3m	-0.128	0.159	-0.168	0.645	-0.464	0.461
residual_c5toa6m10	-0.144	0.309	0.216	0.113	0.307	-0.045
residual_c5toa3m10	-0.153	0.304	0.153	0.237	0.168	0.060
Standard deviation	3.233	2.617	1.342	1.104	0.537	0.389
Proportion of Variance	0.498	0.326	0.086	0.058	0.014	0.007
Cumulative Proportion	0.498	0.824	0.910	0.968	0.982	0.989

Panel B: Principal Component Analysis (PCA) results with the original data for bond yields, spreads, and curvatures

The descriptive statistics is based on the sample period from 1982Q1 to 2011Q2. AAA is quarterly Moody's seasoned Aaa corporate bond yield; BAA is quarterly Moody's seasoned Baa corporate bond yield; GS10 is quarterly 10-year Treasury constant maturity rate; GS7 is quarterly 7-year Treasury constant maturity rate; GS5 is quarterly 5-year Treasury constant maturity rate; GS3 is quarterly 3-year Treasury constant maturity rate; GS2 is quarterly 2-year Treasury constant maturity rate; GS1 is quarterly 1-year Treasury constant maturity rate; GS6M is quarterly 6-month Treasury constant maturity rate; GS3M is quarterly 3-month Treasury constant maturity rate; btoa is the spread between AAA and BAA; bto10 is the spread between BAA and GS10; s10to7 is the spread between GS10 and GS7; s7to5 is the spread between GS7 and GS5; s5to3 is the spread between GS5 and GS3; s3to2 is the spread between GS3 and GS2; s2to1 is the spread between GS2 and GS1; s1to6m is the spread between GS1 and GS6M; s6mto3m is the spread between GS6M and GS3M; c5toa6m10 is the curvature calculated as "GS5 minus the average of GS6M and GS10"; c5toa3m10 is the curvature calculated as "GS5 minus the average of GS3M and GS10".

	PC1	PC2	PC3	PC4	PC5	PC6
AAA	-0.276	0.089	-0.088	-0.187	-0.027	0.048
BAA	-0.266	0.111	-0.199	-0.143	-0.016	0.010
GS10	-0.283	0.066	-0.020	-0.159	-0.112	-0.012
GS7	-0.286	0.046	-0.010	-0.141	-0.060	0.005
GS5	-0.289	0.025	-0.004	-0.116	-0.049	0.003
GS3	-0.290	-0.011	-0.004	-0.083	-0.025	-0.025
GS2	-0.289	-0.034	-0.009	-0.070	-0.026	-0.028
GS1	-0.286	-0.069	-0.025	-0.064	-0.058	-0.034
GS6M	-0.282	-0.090	-0.035	-0.090	-0.054	0.011
GS3M	-0.279	-0.102	-0.033	-0.136	-0.029	-0.025
btoa	-0.068	0.159	-0.641	0.155	0.046	-0.183
bto10	0.100	0.147	-0.618	0.078	0.351	0.077
s10to7	0.200	0.234	-0.118	-0.149	-0.642	-0.224
s7to5	0.176	0.285	-0.095	-0.293	-0.135	0.032
s5to3	0.144	0.335	0.009	-0.267	-0.203	0.270
s3to2	0.089	0.381	0.075	-0.186	0.031	0.060
s2to1	-0.081	0.372	0.169	-0.073	0.334	0.051
s1to6m	-0.128	0.308	0.154	0.397	-0.087	-0.715
s6mto3m	-0.193	0.141	-0.049	0.630	-0.399	0.537
c5toa6m10	-0.095	0.365	0.212	0.038	0.278	0.024
c5toa3m10	-0.130	0.347	0.168	0.194	0.135	0.158
Standard deviation	3.437	2.416	1.341	0.936	0.589	0.340
Proportion of Variance	0.563	0.278	0.086	0.042	0.017	0.006
Cumulative Proportion	0.563	0.840	0.926	0.968	0.984	0.990

Table 4

The Taylor Rule and the Augmented Taylor rule over Time

$$\mathrm{i}_t = \gamma_0 + \alpha\pi_t + \beta y_t + \gamma_1 \mathrm{i}_{t-1} + \kappa_1 R_{1t} + \kappa_2 R_{2t} + \kappa_3 R_{3t} + \kappa_4 R_{4t} + \kappa_5 R_{5t} + \varepsilon_t$$

R_{it} is the ith principal component analysis of the orthogonalized bond market data; π_t is the inflation rate over the last four quarters; and y_t is the output gap as percentage deviation of real GDP from its trend.

	γ_0	α	β	γ_1	κ_1	κ_2	κ_3	κ_4	κ_5	*Adj.* R^2	*AIC*
Prevolker (1965:3-1979:2)											
	0.080	-0.019	0.263	1.035						0.834	150.432
	(-0.189)	(-0.232)	(4.323***)	(12.880***)							
	1.794	0.381	0.149	0.417	-0.280	-1.205	0.812	1.678	0.147	0.958	78.397
	(6.789***)	(6.873***)	(4.586***)	(6.008***)	(-4.755***)	(-10.889***)	(3.117***)	(4.299***)	(0.437)		
Postvolker (1979:3-2011:2)											
	-0.288	0.420	0.304	0.827						0.954	325.560
	(-1.971*)	(6.094***)	(5.390***)	(25.277***)							
	0.181	1.417	0.461	0.237	-0.007	3.603	-0.343	0.019	1.753	0.984	194.211
	(1.966*)	(17.468***)	(13.179***)	(5.167***)	(-0.010)	(5.982***)	(-0.548)	(0.367)	(0.184)		
Greenspan (1987:4-2011:2)											
	-0.253	0.156	0.251	0.965						0.976	94.371
	(-2.134**)	(2.722***)	(7.571***)	(49.984***)							
	0.035	1.263	0.301	0.294	-0.279	-1.152	-0.112	0.460	0.125	0.966	-79.900
	(0.716)	(21.549***)	(22.822***)	(8.722***)	(-17.800***)	(-13.498***)	(-2.024**)	(1.104)	(0.414)		

Table 5

Augmented Taylor rule with residual bond market variables for different subsamples

$$\mathrm{i_t} = \gamma_0 + \alpha\pi_t + \beta y_t + \gamma_1 \mathrm{i}_{t-1} + \kappa_1 R_{1t} + \kappa_2 R_{2t} + \kappa_3 R_{3t} + \kappa_4 R_{4t} + \kappa_5 R_{5t} + \varepsilon_t$$

R_{it} is formed as principle component analysis results based on residual variables from equation $R_{it} = B_{it} - (\hat{\theta}_0 + \hat{\theta}_1\pi_t + \hat{\theta}_2 y_t)$. π_t is the inflation rate over the last four quarters; and y_t is the output gap as percentage deviation of real GDP from its trend.

Start	*End*	γ_0	α	β	γ_1	κ_1	κ_2	κ_3	κ_4	κ_5	*Adj. R^2*	*AIC*
1982:1	2005:4	-0.126	0.210	0.237	0.905						0.961	168.729
		(-0.748)	(2.586**)	(5.238***)	(32.803***)							
		-0.440	1.828	0.420	0.168	-0.317	-1.381	0.028	-0.215	-0.530	0.996	-35.172
		(-6.528***)	(25.546***)	(23.189***)	(5.246***)	(-23.14***)	(-16.113***)	(0.583)	(-0.836)	(-1.138)		
	2007:3	-0.130	0.218	0.239	0.903						0.961	197.881
		(-0.807)	(2.890***)	(5.527***)	(34.976***)							
		-0.429	1.818	0.417	0.171	-0.317	-1.387	0.030	-0.168	-0.623	0.996	-44.656
		(-6.653***)	(26.607***)	(24.071***)	(5.584***)	(-24.444***)	(-17.029***)	(0.641)	(-0.688)	(-1.41)		
	2011:2	-0.136	0.182	0.218	0.916						0.968	199.962
		(-1.003)	(2.51**)	(5.732***)	(38.06***)							
		-0.498	1.747	0.431	0.215	-0.300	-1.270	0.138	-0.305	-0.356	0.996	-46.169
		(-10.208***)	(28.166***)	(28.281***)	(8.036***)	(-25.593***)	(-18.428***)	(3.767***)	(-1.37)	(-1.022)		
1987:4	2005:4	-0.533	0.243	0.345	0.982						0.980	45.786
		(-3.993***)	(4.457***)	(9.637***)	(53.029***)							
		-0.678	1.685	0.440	0.294	-0.274	-1.053	-0.106	-0.330	0.097	0.997	-75.340
		(-9.55***)	(17.633***)	(17.622***)	(6.533***)	(-14.303***)	(-10.685***)	(-1.828)	(-0.922)	(0.257)		
	2007:3	-0.533	0.243	0.345	0.982						0.980	42.859
		(-4.233***)	(4.910***)	(10.227***)	(55.735***)							
		-0.649	1.639	0.425	0.312	-0.266	-1.072	-0.091	-0.103	-0.058	0.996	-87.866
		(-9.818***)	(18.483***)	(18.878***)	(7.334***)	(-14.837***)	(-11.629***)	(-1.672)	(-0.323)	(-0.164)		
	2011:2	-0.253	0.156	0.251	0.965						0.976	94.371
		(-2.134**)	(2.722***)	(7.571***)	(49.984***)							
		-0.526	1.597	0.423	0.297	-0.265	-1.085	0.113	-0.142	-0.052	0.996	-79.773
		(-9.38***)	(21.261***)	(22.527***)	(8.828***)	(-17.706***)	(-13.817***)	(2.484**)	(-0.518)	(-0.174)		

Table 6

Properties of the Out-of-Sample Forecast Errors

Start	End	N		Linear	TAR	Oppor.	Full oppor.	Bond Linear
						Recursive estimation		
1987:4	2005:4	22	Mean	-0.119	-0.263	-0.266	-0.116	0.056
			Variance	0.110	0.317	0.244	0.105	0.089
	2007:3	29	Mean	-0.104	-0.215	-0.213	-0.098	0.053
			Variance	0.085	0.250	0.195	0.083	0.096
						Full-period estimation		
1983:1	2005:4			0.184	0.158	0.171	0.160	0.167
	2007:3			0.171	0.154	0.160	0.149	0.157
1987:4	2005:4			0.097	0.090	0.093	0.072	0.071
	2007:3			0.090	0.083	0.086	0.066	0.067

Note: Each estimated model has at least 50 observations. N refers to the number of out of sample 1-period forecasts. As a comparison, we take out-of-sample forecast errors results (Column 5 to 8) directly from Bunzel and Enders (2010). “Linear” refers to linear Taylor rule models without new variables besides inflation, output gap, and lagged values of the federal funds rate; “TAR” refers to a threshold autoregressive model; “Oppor.” refers to the opportunistic model with an interim target rate of inflation; “Full oppor.” refers to the full “opportunistic model” with both an interim target inflation rate and output gap level (negative or positive); “Bond Linear” refers to augmented Taylor rule with 3 principle components based on residual bond market variables as the Equation (5) and Equation (6) .