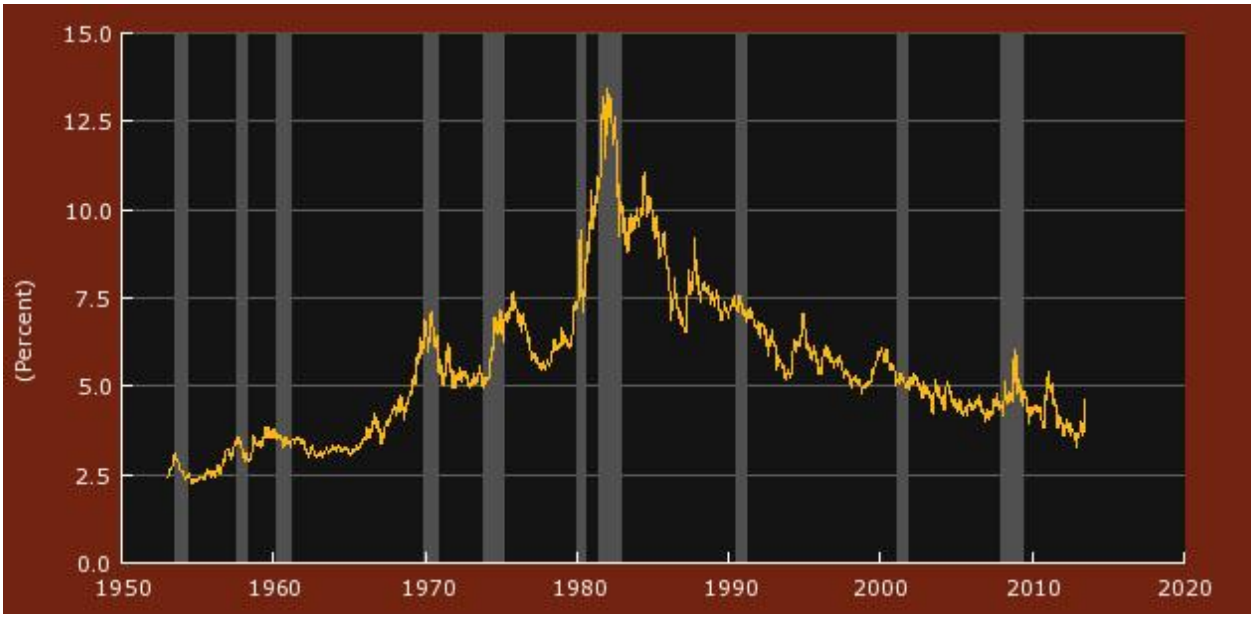


Examining the Behavior of Long-Term Interest Rates Using a Dynamic Taylor-Type Rule

by William L. Seyfried

PEER REVIEWED

William L. Seyfried wseyfried@rollins.edu is a Professor of Economics at Rollins College.

ABSTRACT

Though Taylor's rule has been extensively used to examine interest rates directly controlled by central banks, its application to the behavior of market-based interest rates has been limited. A dynamic version of Taylor's rule is employed to assess the primary factors that describe the behavior of two common measures of long-term interest rates, the yield on the ten-year Treasury bond and the average rate on thirty-year fixed-rate mortgages. Support for the Fisher effect is found in both cases along with estimates of the sensitivity of interest rates to the strength of the economy. In addition, the dynamic nature of adjustments in each interest rate is obtained, with Treasury bond rates displaying both a higher speed of adjustment and more persistence than mortgage rates.

INTRODUCTION

In 1993, John Taylor introduced a monetary rule that recommended the federal funds rate be adjusted in response to deviations of GDP from its potential (the output gap) and inflation from its desired rate (the inflation gap). Though not comprehensive, it was intended to capture the major factors that would affect decision making by the central bank. If the economy was perceived to be overheating, GDP would exceed its potential resulting in a positive output gap, putting upward pressure on inflation. In order to keep inflation contained, the central bank should increase the interest rate under its control in order to cool off the economy (engineer a soft landing). If inflation is already high, above its desired level, the central bank would attempt to slow down the economy, resulting in downward pressure on inflation.

Taylor's original model assigned an equal weight to the output gap and inflation gap. A considerable amount of research intended to further develop Taylor-type rules has taken place over time. Many have analyzed actual data to estimate the coefficients that proxy the behavior of the Fed and other central banks in their conduct of monetary policy. Some have adjusted the variables considered to include factors such as expected inflation (Clarida, Gali and Gertler, 2000). Others, such as Judd and Rudebusch (1998), proposed a modified version of Taylor's rule that accounts for a dynamic adjustment mechanism since the interest rate is unlikely to adjust immediately to its theoretically optimal rate.

Bond market participants consider many of the same factors as central banks when making decisions about bond purchases and sales which ultimately determine market interest rates. Inflation is one of the main motivators of decisions within the bond market. Higher inflation reduces the real return on bonds, thus decreasing the demand for bonds. As a result, bond prices decline and yields increase. In a similar way, a strong economy, as evidenced by a positive output gap, signals increasing inflationary pressures, putting upward pressure on interest rates. In addition, economic strength is likely to be accompanied by high demand for credit, also leading to rising interest rates. Given the complexity of economic information, in most cases, it takes time for the bond market to process information, leading to adjustments in interest rates over time. Therefore, as with monetary policy, a dynamic model of interest-rate behavior seems appropriate.

DESCRIPTIVE STATISTICS

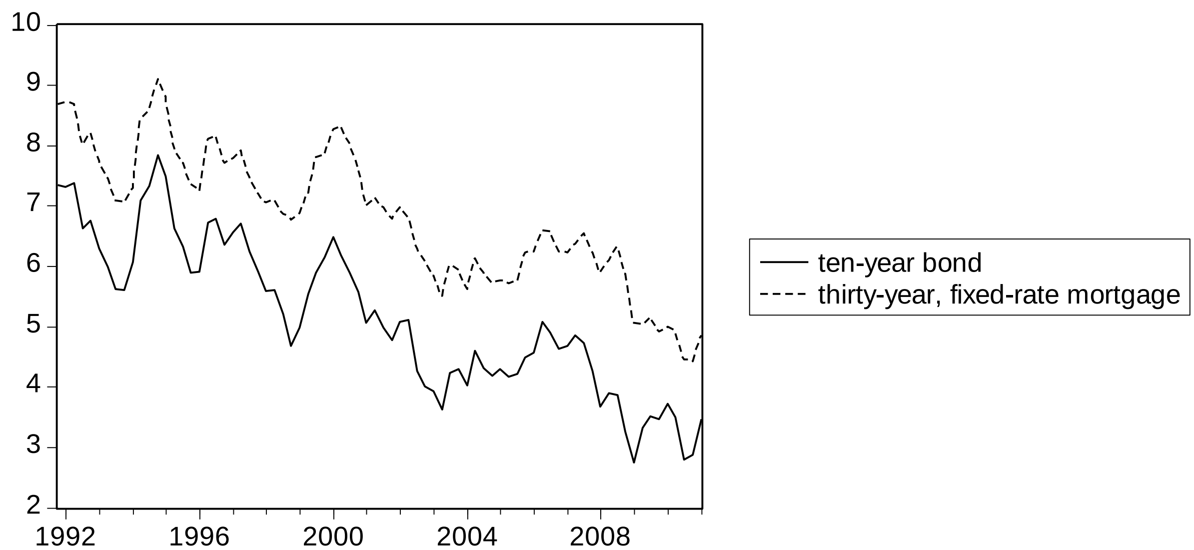
Quarterly data for the respective variables from 1991 to 2011 were obtained. The output gap was estimated using data from the Congressional Budget Office. Both thirty-year mortgage rates and ten-year Treasury bond rates using constant maturity were obtained from the Federal Reserve. Expected inflation was proxied using the median forecast based on the survey of the Philadelphia Federal Reserve Survey of Professional Forecasters. Expected inflation over the next ten years was used for both models.

Chart 1 illustrates the movement of both the yield on ten-year bonds and interest rates on thirty-year, fixed-rate mortgages over the entire period. Both interest rates show similar, downward trends, reaching lows following the financial crisis of 2008. Table 1 presents the basic descriptive statistics for each variable. Mortgage interest rates, as expected, tended to be higher than Treasury bond interest rates with the former averaging about 6.8% and the latter averaging 5.17%. In addition, the thirty-year fixed rate mortgage was slightly less volatile than the ten-year bond rate. The output gap exhibited the highest standard deviation of the variables considered, with both a mean and median that were slightly negative. Expected inflation had a mean and median of 2.74% and 2.5%, respectively, and displayed the most stability.

Table 1: Descriptive Statistics

	Mean	Median	Standard Deviation
Interest Rate on 30-year Mortgage	6.81%	6.87%	1.14
Interest Rate on 10-year Treasury	5.17%	5.06%	1.27
Expected Inflation (10 year)	2.74%	2.50%	0.46
Output Gap	-0.82%	-0.48%	2.45

Chart 1: Interest Rates, 1991-2011Q1



DYNAMIC VERSION OF TAYLOR'S RULE

An extensive amount of literature has been devoted to using Taylor-type rules to examine monetary policy (for example, see Gerlach and Schnabel, 1999; Orphanides, 2007, Smets, 1998; Taylor, 1999). The original Taylor's rule expressed the federal funds rate as a function of both the output and inflation gaps (see 1). If inflation exceeded its desired rate, the Fed should raise the federal funds rate. Similarly, if GDP exceeds its potential, inflationary pressures exist and the Fed should raise the federal funds rate to contain these pressures.

$$f_t^* = \pi_t + r_t + ½(\pi_t - \pi_t^*) + ½y_t \quad (1)$$

where f is the federal funds rate; π is the inflation rate; r is the equilibrium real federal funds rate; and y is the output gap. Taylor assigned a coefficient of ½ on both variables. Researchers sought develop the model further by estimating the relationship using a model similar to (2).

$$f_t^* = \pi_t + r^* + B_1(\pi_t - \pi^*) + B_2y_t \quad (2)$$

Further modifications were made including introducing a dynamic adjustment process to account for the speed and persistence of interest rate movements (Judd and Rudebusch, 1998).

$$\Delta f_t = \gamma(f_t^* - f_{t-1}) + \rho\Delta f_{t-1} \quad (3)$$

Gamma provides an estimate of the speed of adjustment. That is, how quickly the interest rate adjusts to its optimal value (f^*) while rho is a measure of the degree of persistence; how much changes in interest rates continue over time (with higher values implying more persistence). That is, if interest rates have been increasing recently, there's a greater likelihood that it will continue to increase. Combining (2) and (3) results in a dynamic version of Taylor's rule as expressed in (4):

$$\Delta f_t = \gamma\alpha - \gamma f_{t-1} + \rho\Delta f_{t-1} + \gamma(1+B_1)\pi_t + \gamma B_2y_t \quad (4)$$

where $\alpha = r^* - B_1\pi^*$.

Rather than just react to inflation after it has already risen, the Fed pays attention to expectations of inflation (for example, see Bernanke 2007). Thus, one could view π as inflation or expected inflation.

Many of the same forces and concerns that influence decisions regarding monetary policy also affect the bond market. Bond investors are very sensitive to increases in inflation as it would reduce the value of their bond holdings. Thus, when bond market participants expect higher inflation, they reduce their demand for bonds, resulting in lower bond prices and higher interest rates. In addition, economic strength impacts interest rates. A stronger economy is typically accompanied by an increase the demand for credit thus pushing up real interest rates. Also, a positive output gap is an indicator of future inflation, putting upward pressure on interest rates. Thus, Taylor's rule can be modified to describe the behavior of market-based interest rates as follows:

$$\Delta i_t = \gamma\alpha - \gamma i_{t-1} + \rho\Delta \iota_{t-1} + \gamma(1+B_1)\pi_t + \gamma B_2y_t \quad (5)$$

where i is the interest rate in question, whether it is the yield on the ten-year Treasury bond or thirty-year fixed-rate mortgage.

REVIEW OF THE LITERATURE

Though there is an extensive literature examining the application of Taylor's rule to setting the central bank interest rate (see above), there has been little application to financial market-based interest rates. Li, et. al. (2010) estimated the relationship between bond yields (up to five years) and inflation and the output gap. In each case, inflation was highly correlated with the bond yield, with coefficients ranging from a high of 0.85 for the three-month Treasury bill to 0.72 for the five-year Treasury note. The output gap had a less noticeable relationship, statistically significant only when the maturity was one year or less. Adjusted R-squares ranged from 0.38 for the model incorporating the five-year note to 0.48 for the three-month Treasury bill. Former president of the Saint Louis Federal Reserve, William Poole (2003), has discussed that one expects a one-for-one relationship between expected inflation and nominal interest rates. He adds that a strong economy increases real interest rates as businesses drive up credit demand by seeking new funds with which to invest. Rudebusch et. al. (2006) make use of the output and inflation gaps to examine the movement of short-term interest rates. Similarly, Diebold, et. al. (2006) analyze the behavior of interest rates by making use of inflation versus its average as well as the output gap.

Thus, though Taylor's rule has not been actively used to examine market-based interest rates, many of the principles embodied in Taylor's rule have been put to use in previous studies. This paper proceeds to the next step in modeling the behavior of long-term interest rates by using a dynamic version of Taylor's rule.

EMPIRICAL MODEL AND RESULTS

The model as described in equation 5 was estimated using quarterly data from 1991 to 2011. One would expect B_1 to be equal to one if the Fisher effect holds true. That is, a one percent increase in expected inflation leads to a corresponding one percent increase in nominal interest rates. Given that a strong economy puts upward pressure on real interest rates and that an overheated economy leads to higher inflation, B_2 is expected to be positive. The size of the coefficient indicates how sensitive the interest rate is to economic strength (or weakness). The speed of adjustment is estimated by γ – a higher value for γ would reveal a higher speed of adjustment to the appropriate rate based on macroeconomic conditions. The degree of persistence is estimated by ρ – a high value for ρ indicates that once interest rates start moving in a certain direction, they are likely to continue moving that way for an extended period of time.

Standard econometric tests for the validity of the model revealed no econometric issues[1] for either interest rate model other than heteroskedasticity. This was corrected for using Newey-West heteroskedasticity and autocorrelation consistent standard

[1] The model was tested for serial correlation, ARCH effects and other common econometric problems

errors (Newey and West, 1987). The empirical results can be seen in Tables 2 and 3. To test for the statistical significance of expected inflation and the output gap, one needs to employ indirect least squares since the estimation of (5) yields γB_2 and $\gamma(1+B_1)$ as the respective coefficients. Estimated values for B_1 and B_2 can be obtained by modifying both terms using the estimated coefficient on the lagged interest rate (γ). Specifically, to obtain an estimate of B_2, one needs to divide the estimated coefficient on expected inflation by the estimated value of γ while to obtain the estimate of B_1, one should divide the estimated coefficient on the output gap by γ and subtract 1. To test for the significance of the estimates of B_1 and B_2, given the use of indirect least squares, one must interpret the significance of a X^2 statistic derived from a Wald Test.

Table 2: Dynamic Model of Interest Rate on Thirty-Year Mortgages

	Estimated Coefficient	t-stat or χ^2	p-value
Speed of adjustment	0.33**	5.17	0.000
Degree of persistence	0.19*	2.19	0.030
Expected inflation	0.89**	8.02	0.000
Output gap	0.30**	47.60	0.000

Note: t-statistic used for speed of adjustment and degree of persistence; X^2 used for expected inflation and output gap. ** indicates 1% level of significance, * indicates 5% level of significance

Table 3: Dynamic Model of Interest Rate on Ten-Year Bonds

	Estimated Coefficient	t-stat or χ^2	p-value
Speed of adjustment	0.40**	6.07	0.000
Degree of persistence	0.29**	3.29	0.001
Expected inflation	1.00**	12.49	0.000
Output gap	0.28**	43.97	0.000

Note: t-statistic used for speed of adjustment and degree of persistence; X^2 used for expected inflation and output gap. ** indicates 1% level of significance, * indicates 5% level of significance

All of the coefficients were found to be statistically significant (most at the 1% level). In addition, the coefficients on expected inflation were tested to see whether they were statistically different from one (a test of the Fisher effect as described earlier in this section). When considering the thirty-year mortgage, the coefficient on expected inflation was estimated to be 0.89 with a X^2 of 0.14, indicating that it was not statistically different from one. Similarly, for the model of the ten-year Treasury bond, the estimated coefficient was 1.00 while the resulting X^2 was 0.00 indicating that it was not significantly different from one. Thus, support for the Fisher effect was found for both interest rates.

Comparable effects were detected for the coefficient of the output gap, with coefficients of close to 0.30 regardless of which interest rate was considered. In both cases, a positive output gap put upward pressure on interest rates, as expected. The results suggest that both interest rates display similar responses to economic conditions as represented by expected inflation or the output gap. The dynamics differed somewhat as the ten-year bond displayed both a higher speed of adjustment and degree of persistence than the mortgage rate, though only modestly so.

SUMMARY AND CONCLUSIONS

Whether one considers interest rates set by policymakers at central banks or bond market participants, similar factors play a role in explaining the behavior of interest rates. In both instances, interest rates are sensitive to signs of higher future inflation or economic strength, either of which results in higher interest rates. The dynamic Taylor-type rule presented in this paper incorporates these economic relationships in addition to accounting for dynamic adjustments in interest rates and thus provides insight into the behavior of long-term interest rates, whether one considers the yield on the ten-year Treasury bond or thirty-year fixed-rate mortgage. In both cases, support is found for the Fisher effect in that a one percent increase in expected inflation leads to a corresponding one percent increase in the nominal interest rate. Economic strength, as measured by the output gap, significantly affects real interest rates as a one percent increase in the output gap leads to approximately a 0.3% increase in the long-term interest rate (both the bond rate and mortgage rate).

Evidence was also found indicating that yields on ten-year Treasury bonds display both a higher degree of persistence and speed of adjustment than mortgage rates. This is probably due to the more active market for Treasuries, helping them to adjust more quickly in response to changing economic conditions. Taylor's rule appears to prove useful in providing insight into the behavior of long-term interest rates as they respond to changing economic conditions.

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