An Examination of the Impact of Changes in the Maturity Mix of Government Borrowing on Long-Term Interest Rates

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The relationship between federal government deficits and interest rates has been discussed widely and analyzed extensively. The Clinton administration's attempt to reduce the cost of funding the government debt by reducing long-term borrowing and replacing it with short-term debt highlights interesting questions about how the maturity structure of federal debt influences the effects of deficit spending. This paper empirically analyzes the relationship between the federal government's reliance on long-term borrowing and long-term interest rates. We find changes in long-term borrowing and changes in the ratio of long-term to total Treasury borrowing Granger cause changes in the 30 year Treasury bond rate. Beyond suggesting a relationship between the mix of maturities issued by the Treasury and the cost of funding the deficit, our results suggest that Treasury actions may impact the cost of long-term borrowing in markets where rates are influenced by changes in Treasury bond rates.

INTRODUCTION

Evans (1985) states that: "In over a century of U.S. history, large deficits have never been associated with high interest rates" (p. 86). In contrast, Hoelscher (1986) claims that the "deficit-interest rate connection is strong, robust, and very significant for the postwar period ..." (p. 14). Which of these claims is correct, and what accounts for the dramatic divergence in these results? If a positive relationship between deficits and interest rates exists, then higher deficits would crowd out private investment spending and hamper economic growth. In contrast, if deficit financing has no impact on interest rates, then deficit spending instead may promote economic growth. For example, if fiscal deficits result from investments in infrastructure and other productivity-enhancing expenditures, then deficit spending may increase output and incomes. Finally, as Eisner (1989) argues, if

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there are unemployed resources in an economy, then fiscal deficits may stimulate aggregate demand and drive the economy toward full employment without necessarily crowding out private investment or causing inflation. Thus, the effects of fiscal deficits depend critically on the type of federal spending and on the private sector's response to government borrowing.

The Clinton administration's attempt to reduce government debt expense by replacing long-term borrowing with short-term debt highlights interesting questions concerning the role played by the mix of securities used to finance the deficit. In 1990 the 30 year Treasury bond interest rate ranged from 8.24 percent to 9.03 percent. The rate fell below 6 percent by the summer of 1993, following the Clinton administration's change in the mix of securities used to finance the deficit. This decrease in long-term interest rates occurred while the federal government's annual budget deficit increased from $163.5 billion to $225.8 billion. These figures suggest an inverse relationship between deficits and interest rates. A cursory glance at the deficit-interest rate figures, however, does not reveal several complex and complicating factors. The Treasury's Operation Twist resulted in a change in the maturity mix of securities used to finance the deficit during this period. Additionally, in an attempt to stimulate the economy, the Federal Reserve increased the money supply and lowered the discount rate and federal funds target rate. While these factors cloud the relationship between government borrowing and long-term interest rates, the Clinton administration's term experiment illustrates the importance of considering the maturity mix of Treasury sales when analyzing the relationship between interest rates and fiscal deficits.

To date, research on the link between deficits and interest rates has focused on the relationship between various deficit measures and a particular interest rate, often a long-term Treasury bond rate.[1] Interest rates used in these analyses include three, six, and 12 month Treasury bill rates, ten and 20 year Treasury bond rates and corporate and municipal bond rates. Deficit measures include the cyclically adjusted federal budget deficit, expected budget deficits, and the sum of federal, state, and local budget deficits. Some authors refer to the composition of government debt as they interpret the statistical relationships identified by their models, but no one provides a systematic analysis of the *term structure* of deficit financing and its role in this debate. We contend that the term structure of Treasury sales influences the effect of deficit financing on long-term rates, and we expect that the impact on long-term rates of a deficit financed primarily by the sale of six month Treasury bills will differ dramatically from the impact of the same deficit financed with mostly 30 year bonds.

The crowding out hypothesis suggests that government borrowing will increase interest rates and reduce private capital investment, which is typically financed for relatively long periods of time. If private investment responds to changes in long-term interest rates, then an increase in long-term interest rates may reduce private investment and the rate of economic growth. We estimate the relationship between long-term government borrowing and long-term interest rates. Our results indicate that estimates of the relation-

[1] The work of Canto and Rapp (1982), Plosser (1982), Hoelscher (1986), Evans (1985, 1987a, 1987b), and Darrat (1989) illustrates the various measures of the deficit and interest rates. Akhtar (1995) provides a useful summary of related work.

ship between government borrowing and long-term interest rates depend crucially on the portion of the deficit financed with long-term bonds. Consequently, the structure or mix of maturities used to finance government spending is an important aspect that must be considered in the policy-making process.

DATA

Following Hoelscher (1986), we employ a loanable funds model of the long-term interest rate. To avoid potential bias arising from the simultaneous determination of both long- and short-term interest rates and to enable us to test for Granger causality between the maturity mix of securities issued by the Treasury and the long-term interest rate, we propose the following model:

(1) $LR_t = f(LR_{t-i}, SR_{t-i}, \pi_{t-i}, y_{t-i}, g_{t-i})$

where:

LR_{t-i} = Past long-term interest rates;
SR_{t-i} = Past short-term interest rates;
π_{t-i} = Past inflation;
y_{t-i} = Past values of income; and
g_{t-i} = Past values of federal government borrowing.[2]

We measure inflation using lags of the 12 month percentage change in the Consumer Price Index (CPI), π_{t-i}.[3] The 12 month Treasury note rate proxies the short-term interest rate. The rate on 30 year Treasury bonds is chosen as the long-term rate.

We choose the 30 year Treasury bond rate because the Treasury reports the par value of outstanding Treasury securities in the following maturities: less than one year, from one to five years, between five and ten years, between ten and 20 years, and more than 20 years to maturity. Interest rate data are also available for several maturities. Two long-term rates available on the Citibase data tape are 20 and 30 year rates. The 20 year rate series terminates in December 1986. Selecting the 30 year rate enables us to extend the analysis through the Clinton administration's Operation Twist and allows the closest match between the interest rate and Treasury bond maturity data. To reflect the influence of the business cycle and the changes in demand for loanable funds accompanying changes in output, we include disposable personal income. Our data are monthly and cover the period from October 1979 through June 1994.[4]

As noted above, we expect that the maturity mix of securities sold by the Treasury to finance the federal deficit will influence interest rates. To identify the impact of the structure of Treasury borrowing on interest rates and to test the robustness of our results, we estimate the model using three different measures of long-term government borrowing.

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[2] In an adaptive expectations model, each of these variables may be considered as a proxy for the expected value.

[3] As described below, the lag structure, t - i, will be allowed to vary across variables in the regression equations.

[4] To avoid any impact of the October 1979 change in Federal Reserve Bank operating procedures, we focus on the post-October 1979 period.

First, we include the average term to maturity of outstanding Treasury securities, along with the par value of outstanding Treasury securities.[5] We also examine the impact of the par value of outstanding Treasury bonds with more than 20 years to maturity and the ratio of the par value of Treasury securities with more than 20 years to maturity to total Treasury securities outstanding, or the fraction of total Treasury securities with more than 20 years to maturity, on long-term rates.[6] These data reflect changes in the term structure of government borrowing. For example, changes in the average term to maturity of privately held Treasury securities peaked at 74 months in May 1990 and fell five to 69 months by May 1994. Table 1 provides a more complete description of each of the data series.

Equation (1) describes a loanable funds model of interest rates; however, we believe the model omits a potentially important factor: a measure of Federal Reserve bank actions. According to stabilization theorists, after an increase in the money supply households will find themselves with excess money holdings and will either spend those dollars or increase saving.[7] Also, increasing the money supply results in increased bank reserves and, in turn, is likely to result in increased lending. Finally, the impact of Federal Reserve actions on interest rates continues to be a topic of discussion in the financial and academic press. Sales (purchases) of Treasury securities by the Federal Reserve System will decrease (increase) the money base and the supply of loanable funds; therefore, we expect Federal Reserve actions to impact interest rates. Consequently, we add the money base to the variables shown in equation (1).

We convert all nominal dollar values to constant dollar values using the CPI (1982-1984 = 100). Also, Hoelscher (1986) notes, "aggregating from the microeconomic level to the macro level requires that magnitudes be scaled by the population, especially when time series data which cover several decades are used" (p. 4). Therefore, we divide all data, with the exception of the interest rate and the inflation data, by the U.S. population so that disposable personal income, outstanding Treasury securities, and the money base are all measured in real dollars per capita. To further reduce heteroskedasticity, we use the natural logarithm of each variable in the regression equations.[8]

MODEL AND RESULTS

Many macroeconomic time series are nonstationary. Therefore, prior to estimating our loanable funds model, we test each of the variables for unit roots using the augmented

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[5] Data considerations motivate the use of par value in the regressions that follow. Because the Treasury typically issues bonds with coupon rates that are approximately equal to market rates of interest, changes in the par value of outstanding Treasury securities will be approximately equal to changes in total Treasury borrowing. While changes in market rates of interest will impact the market value of outstanding Treasury securities (amounting to a transfer of wealth when secondary market transactions occur), changes in the market rate of interest will not impact interest payments made on outstanding Treasury securities or the number of dollars raised by earlier sales of Treasury securities.

[6] During the period under analysis, 1979 to 1994, *The Treasury Bulletin* includes a table called "Maturity Distribution and Average Length of Marketable Interest-Bearing Public Debt Held by Private Investors" from which we obtain the par value of outstanding debt by maturity and the average term to maturity of outstanding Treasury securities.

[7] For a brief description of various channels through which monetary policy may impact the economy, see Mishkin (1995).

[8] In the discussion that follows, *log* will refer to the natural logarithm of the relevant variable.

Table 1—Descriptive Statistics of Variables Considered as Explanatory Variables

Variable*	Mean	Standard Deviation
30 Year Treasury Bond Rate (FYGT30)	9.67	2.19
1 Year Treasury Rate (FYGT1)	8.39	3.33
CPI Inflation Rate (PUNEW)	4.96	3.01
Per Capita Disposable Personal Income (GMYD)	11,646.92	847.37
Per Capita Money Base (FMBASE)	910.99	102.86
Average Term to Maturity of Outstanding Treasury Securities (Months)	61.10	10.49
Par Value of Outstanding Treasury Securities	4,724.66	1,433.51
Treasury Bonds w/20+ Years to Maturity (Per Capita)	475.56	265.87
Ratio of Long-Term Treasury Bonds[a] to Total Treasury Securities	0.09	0.03

*Where appropriate, parentheses contain the Citibase variable name. The Citibase variables POP and PUNEW (1982-1984 = 100) are used to make the per capita and inflation adjustments, respectively. Dollar-denominated variables are measured in constant dollars per capita
[a]20+ years to maturity

Dickey-Fuller (ADF) test. Table 2 reports the results of these tests for all variables in log-levels and in first differences of the log levels.

With the exception of inflation, we fail to reject the null hypothesis of a unit root for each variable, but the hypothesis of two unit roots can be rejected. We reject the null hypothesis of a unit root in the case of the inflation rate; therefore inflation enters each of the regression models in log level. Next, we test each of the regression models for cointegration.[9] First, we inspect the Durbin-Watson statistic from the cointegrating regressions, as Engle and Granger describe (1987). Next, we use the two step procedure suggested by Engle and Yoo (1987). In the first step we estimate the cointegrating regressions with all variables expressed in log levels. Next we test residuals from the cointegrating regressions for stationarity using the ADF test. When the 30 year bond rate is the dependent variable and the average term to maturity of outstanding Treasury securities proxies for long-term Treasury borrowing, the ADF statistic (five lags) is -3.43. When the log of per capita long-term borrowing proxies for long-term borrowing the ADF statistic is -2.73 (three lags), and when we use the ratio of long-term to total treasuries outstanding the ADF statistic is 3.05 (3 lags).[10] Given these results, we fail to reject the null hypothesis of no cointegration at the $\alpha = 0.05$ level.[11] These results are invariant to the choice of conditioning variables and the inclusion of a trend. Given the outcome of these diagnostic tests, we convert all variables included in the regression models to loga-

[9] In our tests for cointegration, we include in levels those variables shown to be stationary in first differences. TSP version 4.3, which we use for all regression analysis, calculates the critical values for the Engle-Granger test using response surface estimates given by MacKinnon (1994).

[10] Determination of the number of lags included in the ADF tests follows a modified version of the Akaike information criterion. For further details, see the COINT command in the *TSP 4.3 Reference Manual* (p. 40) or Pantula *et al.* (1994).

[11] These results come from models including only those variables that survive the model building process described below. We fail to reject the null of no cointegration when we include all macroeconomic variables in each of the three specifications of the cointegrating regressions. Because we define the inflation rate to be the 12 month change in the CPI, we also include the price level in the models tested for cointegration, with similar results.

Table 2—Augmented Dickey-Fuller Unit Root Test Results

Variable*	Log Levels**	First Differences**
30 Year Treasury Bond Rate (FYGT30)	-1.28[1] (4)	-6.22 (3)
1 Year Treasury Rate (FYGT1)	-0.97[1] (4)	-3.35 (9)
CPI Inflation Rate (PUNEW)	-2.94 (3)	
Per Capita Disposable Personal Income (GMYD)	0.47[1] (4)	-7.64 (3)
Per Capita Money Base (FMBASE)	-0.02[1] (12)	-3.99 (4)
Average Term to Maturity of Outstanding Treasury Securities (Months)	0.53[1] (8)	-3.56 (7)
Par Value of Outstanding Treasury Securities	0.11[1] (5)	-4.73 (4)
Treasury Bonds w/20+ Years to Maturity (Per Capita)	0.27[1] (8)	7.37 (6)
Ratio of Long-Term Treasury Bonds to Total Treasury Securities	-0.73[1] (9)	5.88 (8)

[1]Indicates that the null hypothesis of a unit root is not rejected at the $\alpha = 0.05$ level
- * Where appropriate, parentheses contain the Citibase variable name. The Citibase variables POP and PUNEW (1982-1984 = 100) are used to make the per capita and inflation adjustments, respectively
- ** Parentheses report number of lags included in the augmented Dickey-Fuller regressions

rithmic first differences, with the exception of the inflation rate which enters the equations in log levels.

Rather than impose a common lag structure on all variables which may produce biased results (Ahking and Miller, 1985), we allow the lag length to vary within ten monthly lags.[12] We use the Akaike minimum final prediction error (FPE) criterion to select the lag profile for each variable. In building each equation, we begin with a constant and run three series of six (or seven) bivariate regressions (one series of regressions for each proxy for long-term Treasury borrowing). From each series of regressions we select the variable and lag profile that minimizes the FPE. In the next round we include the variable and lag length that minimize the FPE in each series of bivariate regressions and select the variable and lag profile that minimize the FPE from the trivariate regressions. We include only variables that reduce the FPE when added to the regression model in our final specification. In this way we consider each variable and lag profile for inclusion in the regression model. The FPE criterion essentially balances the reduced variance of the regression residuals against the decrease in efficiency as the lag length increases. Finally, we identify Granger causal relationships between each of the variables meeting the FPE criterion for inclusion in the regression model and the long-term bond interest rate. We follow this procedure to build alternate regression models for each of the three measures of long-term Treasury borrowing described above.

The first measure of long-term borrowing we use is the average term to maturity of outstanding Treasury securities. To capture the influence of government demand for loanable funds, we add the par value of outstanding Treasury securities to the variables consid-

[12] If the variable lag length for any variable is ten months, we extend the maximum lag profile by at least two months to determine the appropriate lag length.

ered in this specification of the model. Equation (2) shows the final form of the regression model, with the order of the variables in the equation reflecting the FPE-determined selection order of the independent variables.

$$(2)\ DLR_t = \alpha + \beta_1^3 DLR + \beta_2^3 DAVTRM + \beta_3^2 \pi + \beta_4^2 DMB + \beta_5^2 Dy$$

where:

DLR_t	=	The logarithmic first difference of the 30 year Treasury bond rate in period t;
DAVTRM	=	The logarithmic first difference of the average term to maturity of outstanding Treasury securities held by the public;
π	=	The log of the CPI inflation rate; and
DMB and Dy	=	The logarithmic first differences of the real per capita money base and real per capita disposable personal income, respectively.

Superscripts on the β coefficients represent the number of lags of the associated variable in the regression equation.[13] With the mid-point used as the breakpoint, this regression passes the Chow test for homogeneity of the regression coefficients at the $\alpha = 0.05$ level. In addition, the residuals pass Durbin's h alternative test for serial correlation, the Chi-squared test for ARCH errors and the Jarque-Bera test for normality, each at the 0.05 level. Table 3, Panel A reports the results of log-likelihood ratio tests for Granger causality.

We find DAVTRM Granger causes changes in the 30 year Treasury bond rate at the $\alpha = 0.05$ level of significance. The only other Granger causal relationship we identify in this equation is between the inflation rate and the 30 year bond rate. The measure of total government borrowing does not meet the FPE criterion for inclusion in the regression model, suggesting that changes in the average term to maturity of Treasury securities and the inflation rate each have a larger impact on long-term interest rates than the level of borrowing by the Treasury. As expected, although they do not appear to Granger cause changes in interest rates, both the log of real per capita disposable personal income and the money base meet the FPE criterion for inclusion in the regression model. Thus, the final specification includes variables representing past long-term interest rates, the term structure of government borrowing, the inflation rate, Federal Reserve bank actions, and disposable personal income. Macroeconomic influences and the average term to maturity of Treasury securities appear to impact the long-term interest rate.

Next, we drop total Treasury securities outstanding and substitute the fraction of outstanding Treasury securities with more than 20 years to maturity for the average term to maturity and repeat the estimation procedure. Equation (3) shows the results.

$$(3)\ DLR_t = \alpha + \beta_1^3 DLR + \beta_2^9 DRATIO + \beta_3^2 \pi + \beta_4^2 Dy + \beta_4^5 DMB$$

where:

[13] In all cases, only lags of independent variables, not contemporaneous observations, enter regression Equations (2), (3), and (4). Table 5 reports the individual coefficient estimates and their t-statistics.

Table 3—Granger-Causality Test Results Log Likelihood Ratio Tests of the Joint Significance of Coefficient Estimates

Panel A: Equation (2)

$$DLR_t = \alpha + \beta_1^3 DLR + \beta_2^3 DAVTRM + \beta_3^2 \pi + \beta_4^2 DMB + \beta_5^2 Dy$$

DLR	DAVTRM	π	DMB	Dy
13.75*	3.01**	5.85**	2.78	2.52

Panel B: Equation (3)

$$DLR_t = \alpha + \beta_1^3 DLR + \beta_2^9 DRATIO + \beta_3^2 \pi + \beta_4^2 Dy + \beta_4^5 DMB$$

DLR	DRATIO	π	DMB	Dy
23.98*	3.73*	6.03*	2.10**	3.37**

Panel C: Equation (4)

$$DLR_t = \alpha + \beta_1^3 DLR + \beta_2^9 DTREA20 + \beta_3^2 \pi + \beta_4^2 Dy + \beta_5^4 DMB$$

DLR	DTREA20	π	DMB	Dy
24.13*	3.64*	5.84*	2.05	3.30**

* Coefficients are jointly significant at the $\alpha = .01$ level
** Coefficients are jointly significant at the $\alpha = .05$ level.

The number of lags of each variable included in the regression equations is given by the superscripts on the β coefficients in equations (2) through (4). The degrees of freedom for the χ^2 test statistics are equal to the number of constraints imposed, i.e., the number of lags of the variable being tested. There are 177 observations in each regression

In all regressions the dependent variable is the log of the first difference of the 30 year Treasury bond interest rate (DLR). DAVTRM, DRATIO, and DTREA20 represent the logarithmic first difference of the average term to maturity of outstanding Treasury securities, the logarithmic first difference of the ratio of Treasury securities with more than 20 years to maturity to total Treasury securities outstanding and the logarithmic first difference of the real per capita par value of outstanding Treasury securities with more than 20 years to maturity, respectively. π represents the CPI inflation rate, while DMB and Dy are the log-differences of the real per capita money base and the log-difference of real per capita disposable personal income, respectively

DRATIO = The logarithmic first difference of the ratio of Treasury securities with more than 20 years to maturity to total treasury securities outstanding, and the remaining variables are as defined above.

This equation also passes the Chow test for homogeneity of the regression coefficients (using the midpoint of the data), and the residuals pass Durbin's h alternative test for serial correlation, the Jarque-Bera test for normality, and the Chi-squared test for ARCH errors at the $\alpha = 0.05$ level. Table 3, Panel B shows that the measure of the term structure of government borrowing meets the FPE criteria for inclusion in the model and Granger causes changes in the long-term interest rate ($\alpha = 0.01$ level). In addition, we find Granger causality from the inflation rate, the money base, and disposable personal income to long-term rates. Once again, macroeconomic conditions and the structure of Treasury borrowing impact long-term interest rates.

Finally, we substitute changes in the log of the real per capita par value of outstanding Treasury securities with more than 20 years to maturity (DTREA) for the ratio of long-term to total borrowing. We find evidence that changes in the federal government's demand for long-term borrowing impact the 30 year bond rate. Equation (4) shows the final specification of the model.

Table 4—Long-Term Effects of Policy and Macroeconomic Variables on Long-Term Interest Rates[1]

Panel A: Equation (2)

$$DLR_t = \alpha + \beta_1^3 DLR + \beta_2^3 DAVTRM + \beta_3^2 \pi + \beta_4^2 DMB + \beta_5^2 Dy$$

DLR	DAVTRM	π	DMB	Dy
0.229	(.860*	0.003	1.825*	0.960*
(0.148)	(0.395)	(0.017)	(0.823)	(0.459)

Panel B: Equation (3)

$$DLR_t = \alpha + \beta_1^3 DLR + \beta_2^9 DRATIO + \beta_3^2 \pi + \beta_4^2 Dy + \beta_4^5 DMB$$

DLR	DRATIO	π	DMB	Dy
0.294*	0.038	0.003*	1.867**	1.061*
(9.104)	(0.218)	(0.001)	(0.993)	(0.461)

Panel C: Equation (4)

$$DLR_t = \alpha + \beta_1^3 DLR + \beta_2^9 DTREA20 + \beta_3^2 \pi + \beta_4^2 Dy + \beta_5^4 DMB$$

DLR	DTREA20	π	DMB	Dy
0.301*	-0.030	0.003*	1.798	1.059*
(0.151)	(0.197)	(0.001)	(1.249)	(0.442)

[1]Long-term effects are defined to be equal to the sum of the lagged coefficients of each variable. Standard errors appear in parentheses. Standard errors are reported to provide some information about the distribution of the sum of the coefficient estimates

* Sum of the β coefficients plus or minus one standard error > 0

** Sum of the β coefficients plus or minus two standard errors > 0

In all regressions the dependent variable is the log of the first difference of the 30 year Treasury bond interest rate (DLR). DAVTRM, DRATIO, and DTREA20 represent the logarithmic first difference of the average term to maturity of outstanding Treasury securities, the logarithmic first difference of the ratio of Treasury securities with more than 20 years to maturity to total Treasury securities outstanding and the logarithmic first difference of the real per capita par value of outstanding Treasury securities with more than 20 years to maturity, respectively. π represents the CPI inflation rate, while DMB and Dy are the log-difference of the real per capita money base and the log-difference of real per capita disposable personal income, respectively

(4) $DLR_t = \alpha + \beta_1^3 DLR + \beta_2^9 DTREA20 + \beta_3^2 \pi + \beta_4^2 Dy + \beta_5^4 DMB$

This equation also passes the specification tests described for equations (2) and (3). Table 3 shows that changes in long-term Treasury borrowing Granger cause changes in the long-term interest rate (α = 0.01 level). As in equation (3), we also identify Granger causality from disposable personal income and the inflation rate to the 30 year bond rate. While the money base meets the FPE criterion for inclusion in the regression model, it does not appear to Granger cause changes in the 30 year bond rate.

In addition to the impact of macroeconomic influences, these regression models consistently point to a significant Granger causal relationship between the term structure of Treasury borrowing and the long-term interest rate. Changes in the short-term interest rate do not enter the models. It is possible that changes in long-term interest rates are coincident with changes in short-term rates or that the impact of changes in short-term rates is reflected in past changes in long-term rates and inflation.

To summarize the long-term impact of the independent variables, Table 4 reports the sum of the lagged coefficients for each variable and the associated standard errors.[14] While the sum and the significance of the sum of the coefficients largely confirm the results of

[14] We would like to thank one of the referees for suggesting the inclusion of this summary table in the paper.

Table 5—Coefficient Estimates of Lagged Variables, Equations (2)-(4)[1]

Panel A: Equation (2) $DLR_t = \alpha + \beta_1^3 DLR + \beta_2^3 DAVTRM + \beta_3^2 \pi + \beta_4^2 DMB + \beta_5^2 Dy$
(Constant: -0.23, t-stat = 3.22)

Lag/Variable	DLR	DAVTRM	π	DMB	DY
-1	0.455*	0.126	0.022*	0.703	0.386
	(5.90)	(0.80)	(2.64)	(0.98)	(1.36)
-2	-3.42*	0.337**	-0.019**	1.122	0.574**
	(4.25)	(2.13)	(2.36)	(1.69)	(2.04)
-3	0.116	0.397*			
	(1.49)	(2.58)			

Panel B: Equation (3) $DLR_t = \alpha + \beta_1^3 DLR + \beta_2^9 DRATIO + \beta_3^2 \pi + \beta_4^2 Dy + \beta_4^5 DMB$
(Constant: -0.021*, t-stat = 2.62)

Lag/Variable	DLR	DRATIO	π	DY	DMB
-1	0.598*	-0.031	0.022*	0.458	0.321
	(7.65)	(1.17)	(2.58)	(1.69)	(0.46)
-2	-0.459*	0.028	-0.019**	0.603**	1.189
	(5.51)	(0.84)	(2.26)	(2.23)	(1.71)
-3	0.155	0.043			-0.867
	(0.078)	(1.16)			(1.25)
-4		-0.026			1.224
		(0.69)			(1.86)
-5		0.048			
		(1.28)			
-6		0.004			
		(0.11)			
-7		0.013			
		(0.35)			
-8		0.008			
		(0.24)			
-9		-0.049			
		(1.90)			

Panel C: Equation (4) $DLR_t = \alpha + \beta_1^3 DLR + \beta_2^9 DTREA20 + \beta_3^2 \pi + \beta_4^2 Dy + \beta_5^4 DMB$
(Constant: -0.020**, t-stat = 2.39)

Lag/Variable	DLR	DTREA20	π	DY	DMB
-1	0.600*	-0.039	0.022*	0.470	0.343
	(7.69)	(1.52)	(2.59)	(1.73)	(0.49)
-2	-0.455*	0.019	-0.019**	0.589**	1.125
	(5.46)	(0.58)	(2.28)	(2.17)	(1.62)
-3	0.156**	0.031			-0.905
	(2.01)	(0.90)			(1.31)
-4		-0.037			1.235
		(1.05)			(1.88)
-5		0.40			
		(1.12)			
-6		-0.003			
		(0.09)			
-7		0.009			
		(0.35)			
-8		0.002			
		(0.08)			
-9		-0.052**			
		(2.06)			

[1]The absolute value of the t-statistic is in parentheses. *Coefficients are significant at the α = .01 level. **Coefficients are significant at the α = .05 level. There are 177 observations in each regression, and the superscript on the β coefficients in equations (2) through (4) represent the number of lags of the associated variable appearing in the regression equation. In all regressions the dependent variable is the log of the first difference of the 30 year Treasury bond interest rate (DLR). DAVTRM, DRATIO and DTREA20 represent the logarithmic first difference of the average term to maturity of outstanding Treasury securities, the logarithmic first difference of the ratio of Treasury securities with more than 20 years to maturity to total Treasury securities outstanding and the logarithmic first difference of the real per capita par value of outstanding Treasury securities with more than 20 years to maturity, respectively. π represents the CPI inflation rate, while DMB and Dy are the log-difference of the real per capita money base and the log-difference of real per capita disposable personal income, respectively

the Granger causality tests, the sum of the coefficients from the measures of the term structure of Treasury borrowing is significantly different from zero in only one case. The results indicate that an increase in the average term to maturity of outstanding Treasury securities is associated with an increase in long-term rates. The sums of the coefficients associated with the variables DRATIO and DTREA20 are not significantly different from zero.

Table 5 reports the individual coefficient estimates and their t-statistics. Focusing on the variables reflecting Treasury borrowing, these results confirm those recorded in Table 4. In equation (2) (Panel A), the coefficient estimates for both the two and three period lags of the average term to maturity are positive and significant at the $\alpha = 0.05$ level, while the one period lag is not significantly different from zero. As suggested by the results in Table 4, this result indicates that an increase in the average term to maturity of privately held Treasury securities is associated with an increase in the interest rate on the 30 year Treasury bond. Further, as panels B and C of Table 5 show, only one of the coefficients on the remaining measures of the term structure of Treasury borrowing is significant ($\alpha = 0.05$ level): the negative coefficient on the nine month lag of outstanding Treasury securities with more than 20 years to maturity. This suggests a perverse effect of an increase in long-term Treasury borrowing. As shown in Table 4, however, the sum of the coefficients on Treasury securities with more than 20 years to maturity is not significantly different from zero.

SUMMARY AND CONCLUSIONS

Recent changes in Treasury borrowing patterns and changes in long-term interest rates suggest the importance of allowing for the structure of Treasury borrowing when estimating the relationship between government borrowing and interest rates. By focusing on changes in the real per capita par value of long-term Treasury securities and measures of the term structure of Treasury borrowing, we are able to identify more accurately the effects of changes in long-term government borrowing on long-term rates. Although the majority of Treasury borrowing is for periods somewhat less than 30 years in length, we identify significant Granger causal relationships between changes in each of the three measures of long-term Treasury borrowing and changes in the 30 year Treasury rate. These results provide some indication of the impact of government borrowing on the long-term loanable funds market and the sensitivity of the long-term interest rate to Treasury actions. While not a part of this study, long-term government borrowing may impact other interest rates, such as long-term mortgage and corporate bond rates. This possibility is an area for future research.

We also find evidence of a relationship between inflation, the money base, disposable personal income, and long-term interest rates. Given these results, we contend that the influence of government borrowing on the long-term capital markets is significant and that the neoclassical prediction of government deficits crowding out private borrowers and investment is a potential impediment to economic growth in the U.S.

Given our results, we expect that short-term Treasury borrowing will impact short-term rates. It is also possible that a bi-directional relationship between short-term Treasury borrowing and long-term rates, and between long-term Treasury borrowing and short-term rates may exist. These issues of the bi-directional impact of Treasury borrowing on interest rates require future research.

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