Further Evidence on the Relation Between Fiscal Policy and the Term Structure

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# FURTHER EVIDENCE ON THE RELATION BETWEEN FISCAL POLICY AND THE TERM STRUCTURE

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ABSTRACT

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This paper exploits market efficiency and a rational expectations version of the term structure to attempt to isolate the relation between monthly and quarterly innovations in government policy variables and both nominal and real rates of return to government securities of different maturities over a period extending through 1985. Overall, the results do not offer much support for the conventional view regarding public debt and interest rates. Nevertheless, the results appear somewhat sensitive to the time period. This should give some cause for concern when interpreting reduced form empirical results that rely on highly aggregated (such as yearly) data over long periods of time.

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## 1. INTRODUCTION

The debate regarding the relation between deficits and interest rates remains a contested issue in academic circles. While on Wall Street, and in most of the business press, it is taken as a foregone conclusion that increases in the public debt significantly increase interest rates (typically, both nominal and real rates).

The theoretical case for the view that for a given level of government spending economic agents are indifferent with respect to the decision to levy taxes or issue debt is detailed in Barro (1976) and Miller and Upton (1974) with variations and extensions by a number of subsequent authors. The argument, in its most simple terms, is that individuals view deficits as simply postponed tax liabilities and, therefore, deficits do not alter wealth or desired consumption paths. The opposing view does not dispute the logic of these arguments, but stresses the implausibility of many of the conditions necessary to generate the so-called 'Ricardian-Equivalence' or invariance proposition.

One set of arguments focuses on assumptions that, if not satisfied, imply that changes in government debt add to private wealth, increasing aggregate demand and hence interest rates and consumption. For example, the invariance proposition requires that individuals be effectively infinitely lived via an operative intergenerational bequest motive of some kind. When this intergenerational link is broken and agents become finite lived, government bonds become net wealth. Another set of arguments stresses the observation that taxes are not lump-sum as required by the invariance proposition. Unfortunately, unambiguous implications for financing decisions in the presence of an income tax are difficult to obtain (e.g., Chan (1983)). Thus, while there are numerous reasons why 'Ricardian-Equivalence' may fail, it's breakdown does not necessarily result in the prediction of a positive association between interest rates and changes in debt.

Resolution of these issues is important for macroeconomic policy. Unfortunately, the data have been less than cooperative in supplying either side with convincing results. One set of empirical tests has focused on the effects of deficits on consumption. Feldstein (1976, 1982) finds evidence he interprets as unfavorable to the invariance proposition while Kochin (1974), Barro (1978), Kormendi (1983), Seater (1985), Aschauer (1985) and Seater and Mariano (1985) interpret their results as consistent with 'Ricardian Equivalence'. Another set of tests has focused on the relation between deficits and interest rates. Plosser (1982), for example, fails to find significant evidence to support a positive association between changes in government debt and interest rates. Subsequently, Evans (1985, 1986, 1987) has reached similar conclusions after investigating numerous historical episodes including wars and periods surrounding the enactment of tax legislation.[1] Recently, Feldstein (1986b) presents results that suggest an important effect of expected future deficits on interest rates. Unfortunately, Feldstein's results do not hold fixed government spending and so it is difficult to

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[1]Another example is recent work by Huang (1986).

interpret these findings as direct evidence on the validity of the 'Ricardian Equivalence' proposition.

This paper is intended to refine and supplement the tests presented in Plosser (1982). One somewhat novel feature in this previous study was to exploit market efficiency and a rational expectations version of the term structure to attempt to isolate the relation between quarterly innovations in government policy variables (i.e., government purchases of goods and services, public debt and the Federal Reserves holdings of government debt) and rates of return to government securities of different maturities over a period extending through 1978. Although the results did not isolate significant correlations between debt shocks and interest rates, there did appear to be some evidence of a positive association between innovations in government purchases and interest rates.

This paper continues the basic strategy followed by Plosser (1982) but extends the results in several ways. First, the data are different; the results in this paper are based on both monthly and quarterly data and the time period has been extended to include the recent experience through 1985. By including the more dramatic experience of recent debt movements there may be a better chance of isolating asset responses. Second, an explicit effort is made to isolate the association between debt shocks and a measure of ex-ante real interest rate. Third, given that the previous finding of a positive correlation between government purchases and interest rates, an attempt is made to sharpen this result by decomposing spending into permanent and temporary components. Such a decomposition is suggested by the work of Barro (1981a,b) and Hall (1980) who emphasize the intertemporal substitution effects of temporary government purchases.

Fourth, the relation between expected future deficits and interest rates is explicitly investigated.

The paper is organized as follows. In section 2, various decompositions of the term structure are presented that help motive and organize the empirical results. Section 3 describes the data and the results are reported in section 4. A summary is provided in section 5.

## 2. REPRESENTATIONS OF THE TERM STRUCTURE

The empirical work in Section 4 exploits several characteristics of the term structure in analyzing the relations between policy variables and asset returns. There are many ways of expressing the relation between the returns to securities with different maturities. Some require more economic structure than others and not all are mutually consistent. In this section, various representations are illustrated to provide some background for interpreting the results in Section 4.

The financial instruments used in the empirical work are comprised predominately of the returns to U.S. Government Treasury bills with one to twelve months to maturity. Although these bills only cover the short end of the maturity spectrum, they are ideally suited in other respects, in that (i) they correspond to pure discount bonds, which are the most tractable analytically, and (ii) they are traded in active markets. The current price at time t of such a pure discount bond with a maturity value of $1 at time t+n is related to the continuously compounded n-period yield to maturity, by

$$Q_{n,t} = \exp(-nR_{n,t}).$$

Alternatively, the one period spot rate, $R_{1,t}$, and a sequence of forward rates can be used to express the price as

$$Q_{n,t} = \exp(-R_{1,t} - F_{2,t} - F_{3,t} - \cdots - F_{n,t}),$$

where $F_{\tau,t}$ is the one period forward rate from $t+\tau-1$ to $t+\tau$ observed at time t.

The holding period return to the bond from t to t+1 is given by

$$\begin{aligned} H_{n,t+1} &= \ln(Q_{n-1,t+1}/Q_{n,t}) \\ &= nR_{n,t} - (n-1)R_{n-1,t+1}, \end{aligned}$$

or, again, using the forward rates, by

$$H_{n,t+1} = R_{1,t} - (R_{1,t+1} - F_{2,t}) - (F_{2,t+1} - F_{3,t}) - \cdots - (F_{n-1,t+1} - F_{n,t}).$$

Thus, the excess holding period return can be written as

$$(1) \qquad H_{n,t+1} - R_{1,t} = -\sum_{\tau=1}^{n-1} (F_{\tau,t+1} - F_{\tau+1,t}),$$

or, in words, as the sum of the changes from t to t+1 in the forward rates, where $F_{1,t+1} = R_{1,t+1}$.[2]

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[2] If forward rates on average rise from t to t+1, then the excess holding period return is negative.

Athough $H_{n,t+1}$ and $R_{1,t}$ are nominal returns, the difference is equivalent to the ex-post real excess return or premium.[3] The right hand side of (1) could equivalently be rewritten in terms of changes in ex-post real forward rates. Thus, if we define $f_{\tau,t+1} = F_{\tau,t+1} - p_{t+\tau+1}$, where $f_{\tau,t+1}$ as the ex-post real forward rate and $p_{t+\tau+1}$ is the inflation rate from $t+\tau$ to $t+\tau+1$, and $r_{1,t+1} = R_{1,t+1} - p_{t+2}$ as the ex-post real one period rate at t+1, then

$$(2)\quad H_{n,t+1} - R_{1t} = -\sum_{\tau=1}^{n-1} (F_{\tau,t+1} - F_{\tau+1,t}) = -\sum_{\tau=1}^{n-1} (f_{\tau,t+1} - f_{\tau+1,t})$$

and variations in $H_{n,t+1} - R_{1,t}$ reflect variations in ex-post real returns and ex-post real forward rates.

Equation (2) can also be re-written in terms of ex-ante real forward rates and expected inflation by noting that $F_{\tau,t+1} = E_{t+1}f_{\tau,t+1} + E_{t+1}p_{t+\tau+1}$ so

$$H_{n,t+1} - R_{1,t} = -\sum_{\tau=1}^{n-1} (E_{t+1}f_{\tau,t+1} - E_t f_{\tau+1,t}) - \sum_{\tau=1}^{n-1} (E_{t+1}p_{t+\tau+1} - E_t p_{t,t+\tau+1}).$$

By assuming a simple linear term structure model the expected real forward rate can be equated to the expected real one period interest rate ($E_{t+1}f_{\tau,t+1} = E_{t+1}r_{1,t+\tau+1}$ where $r_{1,t+\tau+1}$ is the one-period interest rate from $t+\tau$ to $t+\tau+1$),

[3] In other words, the left hand side of (1) is unchanged by using ex-post real returns.

$$(3)\quad H_{n,t+1}-R_{1,t} = -\sum_{\tau=1}^{n-1} (E_{t+1}r_{1,t+\tau+1} - E_t r_{1,t+\tau+1}) - \sum_{\tau=1}^{n-1} (E_{t+1}p_{t+\tau+1} - E_t p_{t+\tau+1}).$$

Thus, given a measure of the changes in expected inflation, the revision in expected real interest rates can be isolated by rearranging (3) to obtain

$$(4)\quad (E_{t+1}r_{n-1,t+n} - E_t r_{n-1,t+n}) = \sum_{\tau=1}^{n-1} (E_{t+1}r_{1,t+\tau+1} - E_t r_{1,t+\tau+1})$$

$$= - \left[H_{n,t+1}-R_{1,t} + (E_{t+1}p_{t+1}(n-1) - E_t p_{t+1}(n-1)\right]$$

where $r_{n-1,t+n}$ is the interest rate on a bill with n-1 periods to maturity that matures at time t+n and $p_{t+1}(n-1)$ is the (n-1)-period inflation from t+1 to t+n. The left hand side of (4) is just the revision or change from t to t+1 in the n-1 period <u>ex-ante</u> real interest rate that is expected or prevail at t+1.[4] Thus to investigate the changes in ex-ante real rates of various maturities, a proxy for expected inflation is required for each maturity.

In order to provide somewhat more structure to the empirical analysis it is useful to summarize a simple equilibrium model of the term structure. Consider a single good economy of identical individuals. The representative consumer (Robinson Crusoe) chooses a consumption plan to maximize the expected value of his utility, U, subject to the standard

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[4]Of course, one can interpret the let-hand side of (4) as the revision in ex-ante real forward rates without imposing any term structure model.

sorts of resource constraints. At time $t=0$ it is convenient to assume that U takes the form,

$$U = \sum_{t=0}^{\infty} \beta^t u(C_t) \quad , \quad 0 < \beta < 1$$

where $\beta$ is a discount factor, $C_t$ is commodity consumption and u (.) is the momentary utility function. It follows from the first-order conditions that the commodity price at time t that Crusoe is willing to pay for a riskless claim to one unit of the consumption good to be delivered at time t+1 can be expressed as

$$(5) \quad q_{1t} = \beta\, E_t\, [u'(C_{t+1})]/u'(C_t).$$

where $E_t(.)$ indicates the expected value based on information available through time t.

Treasury bills, however, are claims whose prices and payoffs are given in dollars rather than commodity units. If it is assumed that $1/P_t$ is the commodity value of \$1 at time t, then the dollar price at time t of a claim to \$1 at time t+1 is simply

$$(6) \quad Q_{1t} = \beta\, E_t \left[ \frac{P_t}{P_{t+1}} \;\; u'(C_{t+1})\right] / u'(C_t),$$

and, the nominal continuously compounded return to a one-period bond is

$$(7) \quad R_{1,t} = -\ln \left\{ \beta\, E_t \left[ \frac{P_t}{P_{t+1}} \;\; u'(C_{t+1}) \;/ u'(C_t) \right] \right\} \quad .$$

More generally, for a Treasury bill with n periods to maturity (6) becomes

$$(8) \quad Q_{n,t} = \beta^n E_t \left[\frac{P_t}{P_{t+n}} u'(C_{t+n})\right] / u'(C_t).$$

The holding period return (continuously compounded) to an n-period bond is then

$$(9) \quad H_{n,t+1} = \ln(Q_{n-1,t+1}/Q_{n,t}) = -\ln \beta + \ln \left[\frac{E_{t+1}\left\{(P_{t+1}/P_{t+n})(u'(C_{t+n})/u'(C_{t+1}))\right\}}{E_t\left\{(P_t/P_{t+n})(u'(C_{t+n})/u'(C_t))\right\}}\right].$$

Assuming the momentary utility function to be of the constant relative risk aversion class,

$$u'(C_t) = C_t^{-\gamma},$$

(9) can be written as

$$(10) \quad \begin{aligned} H_{n,t+1} = &-\ln \beta + \ln [E_{t+1} \{(P_{t+1}/P_{t+n})(C_{t+n}/ C_{t+1})^{-\gamma}\}] \\ &-\ln [E_t\{(P_t/P_{t+n})(C_{t+n}/C_t)^{-\gamma}\}] . \end{aligned}$$

In order to simplify (10) it is convenient to set

$$P_{t+n}/P_t = \exp \{p_t(n)\}$$

and

$$C_{t+n}/C_t = \exp \{c_t(n)\}$$

where $p_t(n)$ and $c_t(n)$ are the n-period growth rates of prices and commodity consumption from t to t+n respectively. A Taylor series expansion can be used to set $E(\exp\{x\}) \doteq \exp \{E(x) + 1/2 \text{ var}(x)\}$. This approximation is, of course, exact for the log normal case. Based on this approximation, the excess holding period return can be written as

$$H_{n,t+1}-R_{1,t} = -[E_{t+1}p_{t+1}(n-1)-E_tp_{t+1}(n-1)] - \gamma[E_{t+1}c_{t+1}(n-1)-E_tc_{t+1}(n-1)]$$

$$+ 1/2[\sigma^2_{t+1}(p_{t+1}(n-1)) - \sigma^2_t(p_{t+1}(n-1))]+1/2\ \gamma^2[\sigma^2_{t+1}(c_{t+1}(n-1)) \quad (11)$$

$$- \sigma^2_t(c_{t+1}(n-1))] + \gamma[\sigma_{t+1}(c_{t+1}(n-1),p_{t+1}(n-1))$$

$$- \sigma_t\ (c_{t+1}(n-1),\ p_{t+t}(n-1))]$$

where $\sigma^2_{t+1}(x)$ denotes the conditional variance of $\tilde{x}$ at time t+1 and $\sigma_{t+1}(x,y)$ the conditional covariance of $\tilde{x}$ and $\tilde{y}$ at time t+1. <u>Equation (9) indicates that it is the revision in expected values of the first and second moments of commodity consumption growth and inflation over the remaining life of the bond that determines the excess return or premium.</u>[5]

If the bivariate stochastic process of one period growth rates $\underline{x}'_{t+1} = [p_{t+1}, c_{t+1}]$, is linear and stationary, then there exists a Wold representation

$$(12)\quad \underline{x}_{t+1} = \underline{\mu} + \psi(L)\ \underline{\varepsilon}_{t+1}$$

where $E(\underline{\varepsilon}_{t+1}) = 0$ and $E\ \underline{\varepsilon}_{t+1}\ \underline{\varepsilon}'_{t+1} = V$. In this linear case, the conditional second moments in (11) do not depend on t, but only on n, V and the elements of $\psi(L)$. Thus (11) can be simplified to

$$(13)\quad H_{n,t+1}-R_{1,t} = \delta(n,\ V,\ \psi_i,\ \underline{\mu}) - \underline{\theta}'\ (\sum_{i=1}^{n-1} \psi_i)\ \underline{\varepsilon}_{t+1}$$

where $\underline{\theta}' = [1\ \gamma]$. The premium, therefore, only varies through time as a function of new information about c and p, (i.e., the innovations, $\underline{\varepsilon}$). It is useful to note that this specification of the term structure is

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[5]Note that this model of the term structure is more complicated than that used to obtain equations (3) and (4) above.

reasonably general. In particular, it <u>does</u> <u>not</u> imply that the expected premium is zero ($E(H_{n,t+1}-R_{1,t}) = 0$) nor does it imply that the average premium, $\delta$, is monotonically increasing in term to maturity, n.[6] Equation (13) does imply, however, that average premia are constant; a constraint that appears inconsistent with recent results of Fama (1984a,b) and others. Time varying premiums could be generated, if the stochastic structure (12) was changing so that the conditional second monents in (9) varied in some systematic manner.

Equations (12) and (13) provide the framework for the empirical investigation that follows. The empirical strategy, however, is not intended as a test of this simple asset pricing model. The primary interest in empirical work is on the effects of government financing decisions, thus this asset pricing model cannot be interpreted literally since the model, as specified, contains no government or money. Nevertheless, if one thinks of the expectations in (11) as conditioned on some information set $\Omega$, it seems reasonable to begin by assuming that fiscal and monetary policy variables, at a minimum, are part of such an information set. In that case, their effects on rates of return (i.e., interest rates) might be viewed as working through commodity consumption and inflation. Alternatively, in the empirical work, fiscal and monetary variables will be allowed to have independent influences on rates of return. These specifications are detailed further.

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[6]Fama (1984a, 1984b) has recently documented the observation that the premium appears to peak for bills with nine months to maturity. Specifications such as (11) are not necessarily inconsistent with this finding as various patterns of premiums could be generated depending on the $\psi_i$'s.

## 3. THE DATA

The empirical investigation focuses on the behavior of the term structure of U.S. Government securities and their interaction with various macroeconomic variables. Treasury bills correspond most closely to the pure discount bonds discussed in Section 2. The basic Treasury bill data are montly returns to bills with one to twelve months to maturity. The continuously compounded holding period return from t to t+1 to each bill is denoted $H_{n,t+1}$ for n=2,...,12. Of course for n=1 the holding period return is equivalent to the yield to maturity and is observed at time t (i.e., $H_{1,t+1} = R_{1,t}$).

The twelve month bill return (continuously compounded) is computed by observing the bill closest to twelve months to maturity on the last trading day of the month, observing the price of the same bill on the last trading day of the following month (when it is an eleven month bill) and then taking the log of the ratio of these prices. This procedure is then followed for each bill with one to twelve months to maturity with the all monthly returns adjusted to a 30.4 day basis. The data are taken from the Center for Research in Security Prices (CRSP) U.S. Government Bond File. The Treasury bill data are summarized in panel A of Table I and are expressed in percent per month. The one period yield, $R_{1,t}$ is highly autocorrelated and most likely nonstationary. The empirical work is based on excess returns which tend to have more desirable statistical properties. These returns display only slight positive serial correlation at lag one. This serial correlation is inconsistent with stationarity assumptions used to obtain the reduced forms (12) and (13), but is not necessarily at odds with the general specification (11). The excess

## TABLE I

### SUMMARY STATISTICS FOR TERM STRUCTURE OF TREASURY SECURITIES

| Variable | Mean | Standard Deviation | Sample Autocorrelations $\hat{\rho}_1$ | $\hat{\rho}_2$ | $\hat{\rho}_3$ | $\hat{\rho}_4$ | $\hat{\rho}_6$ | $\hat{\rho}_{12}$ |
|---|---|---|---|---|---|---|---|---|
| | | | **A. Treasury Bills 8/67-12/85 N=221** | | | | | |
| $R_{1,t}$ | .600 | .234 | .94 | .89 | .84 | .87 | .75 | .61 |
| $H_{2,t+1}-R_{1,t}$ | .032 | .070 | .30 | -.01 | .01 | -.14 | -.03 | -.04 |
| $H_{3,t+1}-R_{1,t}$ | .061 | .128 | .24 | .03 | -.07 | -.09 | -.15 | -.12 |
| $H_{4,t+1}-R_{1,t}$ | .065 | .194 | .17 | .02 | -.07 | -.05 | -.12 | -.15 |
| $H_{5,t+1}-R_{1,t}$ | .081 | .261 | .20 | .02 | -.07 | -.04 | -.11 | -.10 |
| $H_{6,t+1}-R_{1,t}$ | .082 | .318 | .21 | -.01 | -.09 | -.09 | -.11 | -.13 |
| $H_{7,t+1}-R_{1,t}$ | .077 | .365 | .18 | -.01 | -.09 | -.08 | -.06 | -.09 |
| $H_{8,t+1}-R_{1,t}$ | .098 | .424 | .18 | .01 | -.12 | -.08 | -.09 | -.07 |
| $H_{9,t+1}-R_{1,t}$ | .105 | .500 | .20 | -.01 | -.14 | -.10 | -.09 | -.08 |
| $H_{10,t+1}-R_{1,t}$ | .075 | .566 | .19 | -.04 | -.11 | -.06 | -.07 | -.07 |
| $H_{11,t+1}-R_{1,t}$ | .079 | .615 | .18 | -.04 | -.13 | -.08 | -.03 | -.06 |
| $H_{12,t+1}-R_{1,t}$ | .068 | .680 | .18 | -.08 | -.12 | -.12 | -.01 | -.04 |
| | | | **B. Treasury Bond Portfolios 8/67-6/85 N=215** | | | | | |
| $B_{2,t+1}-R_{1,t}$ | .081 | .912 | .27 | -.06 | -.14 | -.09 | .00 | -.03 |
| $B_{3,t+1}-R_{1,t}$ | .066 | 1.300 | .21 | -.08 | -.12 | -.07 | .03 | -.01 |
| $B_{4,t+1}-R_{1,t}$ | .051 | 1.593 | .20 | -.06 | -.13 | -.05 | .04 | .01 |
| $B_{5,t+1}-R_{1,t}$ | .019 | 1.777 | .20 | -.06 | -.13 | -.03 | .05 | .03 |
| $B_{10,t+1}-R_{1,t}$ | .033 | 2.246 | .15 | -.07 | -.10 | -.04 | .03 | .00 |

NOTE -- $R_{1,t}$ is the yield at time t to a U.S. Treasury Bill with one month to maturity, $H_{n,t+1}$, n=2,...,12 is the holding period return from t to t+1 to a bill with n months to maturity at t. $B_{n,t+1}$, n=1,...5,10 is the return from t to t+1 to a portfolio of U.S. government bonds with between n-1 and n years to maturity. The large sample standard deviation of the sample autocorrelations, $\hat{\rho}_j$, is approximately .07 for both bills and bonds. All returns are expressed as percent per month.

return or average premium monotionically increases for n=2,...,6 but reaches its largest value at n=9 and then declines significantly.[7] Finally, the monthly standard deviation increases monotonically with n.

In order to extend the empirical investigation to securities with longer maturities, portfolios of Treasury bonds and notes are used. The Treasury does not systematically issue bonds or notes at all maturities. Therefore, to obtain monthly returns, portfolios of bonds must be formed over a range of maturities. For maturities up to 5 years, bonds are grouped within twelve-month intervals. In Table I panel B, $B_{2,t+1}$ is the return to a portfolio of bonds with between one and two years to maturity, etc. and $B_{10,t+1}$, the return to a portfolio of bonds with between five and ten years to maturity. These are exact returns, including both capital gains and coupon payments. Only bonds and notes with no special tax treatments are included (i.e., no 'flower' bonds). These data are also computed from the CRSP bond file.[8]

As can be seen from panel B, these returns also display some positive serial correlation. They also exhibit increased variability with time to maturity. Fama (1984b) notes that these bond data are consistent with a flat term structure of expected premiums. However, they contain enough variability, that it is difficult to reject many other hypotheses as well.

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[7] See Fama (1984a,b) for further discussion.

[8] These returns were kindly provided by Eugene Fama.

Summary statistics for the macroeconomic data are reported in Table II. All data are expressed in percent per month. None of the data employed has been subjected to seasonal adjustment. Seasonally adjusted data and unadjusted data often yield different results in empirical work. The two-sided filtering procedures used to compute the seasonally adjusted data suggest that the adjusted data may have statistical properties that are undesirable for empirical work.[9] All data are also expressed in per capita terms.

There does not exist a reliable measure of monthly seasonally unadjusted consumption. Instead, the growth rate of industrial production per capita (y) is employed.[10] The inflation rate (p) is the C.P.I.-W inflation rate. The growth rate of real per capita public debt (d) is computed from the privately held public debt net of government agency and Federal Reserve holdings, deflated by the C.P.I. The growth rate of real per capita Federal budget outlays (g) and military outlays ($g^m$) are both computed using the C.P.I. as the deflator. Finally, the real per capita growth in the Federal Reserve's holdings of the public debt (m) will, for convenience, be referred to as real money.[11]

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[9]See, for example, Wallis (1974), Plosser (1979a,b) and more recently Miron (1986) and Singleton (1986).

[10]While industrial production may be a long way from consumption, there are formulations of the intertemporal model of Section 2 that imply output and consumption are proportional. See Long and Plosser (1983) for an example.

[11]All data are taken from various issues of The Survey of Current Business and Business Statistics.

TABLE II

SUMMARY STATISTICS FOR
MACROECONOMIC VARIABLES
8/67 - 12/85
N-221

| Variable | Mean | Standard Deviation | Sample Autocorrelations $\hat{\rho}_1$ | $\hat{\rho}_2$ | $\hat{\rho}_3$ | $\hat{\rho}_4$ | $\hat{\rho}_6$ | $\hat{\rho}_{12}$ |
|---|---|---|---|---|---|---|---|---|
| $y_t$ | .169 | 2.827 | -.05 | -.21 | -.10 | .03 | .04 | .81 |
| $p_t$ | .530 | .342 | .64 | .54 | .46 | .40 | .34 | .40 |
| $d_t$ | .214 | 1.329 | .26 | .35 | .31 | .19 | .14 | .48 |
| $g_t$ | .170 | 12.199 | -.62 | .08 | .12 | -.14 | -.06 | .28 |
| $g_t^m$ | -.017 | 9.704 | -.58 | .06 | .10 | -.14 | -.03 | .50 |
| $m_t$ | -.005 | 2.781 | -.26 | -.24 | .11 | .10 | -.03 | .33 |

NOTE -- $y_t$ is the real per capita growth in industrial production; $p_t$ is the monthly inflation rate; $d_t$ is the growth in real per capita public debt (net of holdings by government agencies and the Federal Reserve); $g_t$ is the growth in real per capita federal budget outlays; $g_t^m$ is the growth in real per capita military expenditures, and $m_t$ is the growth in real per capita holdings of government debt by the Federal Reserve. All variables are reported as percent per month and have not been subjected to seasonal adjustment. The large sample standard error of the sample autocorrelations is approximately .07.

In addition to their wide range of variability, the most notable feature of these data is that they all display significant serial correlation at lag twelve, suggesting seasonal variation. Indeed, plots of these data would show this quite clearly.

Table III reports the monthly means of each of these series along with $R_{1,t}$. Only for inflation (p) and $R_{1,t}$ is the F-statistic for equality of monthly means not far in the right tail of the distribution. For industrial production, the month to month variation is quite striking, particularly the average of 5% per month decline in July of each year.[12] Other variables also display systematic seasonally fluctuations in much the manner one would expect. Growth of real debt (d), for example, is substantially negative in April of each year, as well as in June, and to a lesser extent September. Real money growth (m) is positive in December, but negative in January. Both measures of spending are extremely volatile over the year with apparently different seasonal patterns.

Table IV summarizes the data in deviations from the monthly means. The standard deviation falls substantially for most series and the autocorrelation patterns are altered. Output (y), for example, which exhibited a little autocorrelation in Table II, displays a more pronounced positive pattern in Table III. Three of the series (m, g, $g^m$), however, retain a negative serial correlation pattern indicating that univariate innovations in these series are at least partially offset in subsequent months. Finally, it is worth pointing out that $g^m$ and to a lesser extent

[12] See Long and Plosser (1986) for further discussion and corroboration of this finding across industries.

TABLE III

MONTHLY MEANS

8/67 - 12/85

| VARIABLE | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC | s.e. | F(11,209) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $y_t$ | .30 | 3.22 | .57 | -.40 | .30 | 2.76 | -4.99 | 3.72 | 2.55 | -.52 | -2.19 | -3.28 | .27 | 95.21(.00) |
| $p_t$ | .45 | .61 | .56 | .59 | .63 | .69 | .53 | .55 | .50 | .45 | .40 | .40 | .08 | 1.37(.18) |
| $d_t$ | .76 | .32 | .48 | -1.23 | -.04 | -1.33 | .91 | .53 | -.29 | .87 | .81 | .70 | .26 | 8.82(.00) |
| $g_t$ | 1.53 | -6.20 | 6.56 | .59 | -3.71 | -.06 | 1.93 | 3.34 | -9.23 | 11.63 | -5.89 | 1.52 | 2.57 | 5.09(.00) |
| $g_t^m$ | -1.96 | -2.68 | 6.54 | -2.73 | .37 | 5.14 | -11.64 | 3.95 | -2.27 | 2.96 | .62 | 1.12 | 2.04 | 5.44(.00) |
| $m_t$ | -2.58 | -.58 | 1.29 | 1.90 | -1.52 | .63 | -1.14 | .65 | .86 | -1.64 | .58 | 1.38 | .58 | 6.00(.00) |
| $R_{1t}$ | .57 | .61 | .60 | .64 | .60 | .61 | .59 | .59 | .62 | .60 | .60 | .59 | .05 | .09(.99) |

NOTE -- All variables are in percent per month and s.e. is an approximate standard error for each month. F(11, 209) is the F-statistic associated with the hypotheses that all months have the same mean and significance level appears in parenthesis.

TABLE IV

SUMMARY STATISTICS OF
DEVIATIONS FROM MONTHLY MEANS

8/67 - 12/85

| Variable | Standard Deviation | Sample Autocorrelations | | | | | |
|---|---|---|---|---|---|---|---|
| | | $\hat{\rho}_1$ | $\hat{\rho}_2$ | $\hat{\rho}_3$ | $\hat{\rho}_4$ | $\hat{\rho}_6$ | $\hat{\rho}_{12}$ |
| $y_t$ | 1.183 | .50 | .24 | .14 | .11 | .02 | .08 |
| $p_t$ | .339 | .65 | .56 | .50 | .45 | .42 | .35 |
| $d_t$ | 1.126 | .38 | .39 | .50 | .39 | .43 | .26 |
| $g_t$ | 11.113 | -.59 | .06 | .10 | -.11 | -.00 | .09 |
| $g_t^m$ | 8.778 | -.58 | .04 | .10 | -.08 | -.04 | .37 |
| $m_t$ | 2.487 | -.25 | -.18 | .10 | .09 | -.04 | .15 |
| $R_{1t}$ | .239 | .94 | .90 | .85 | .80 | .75 | .61 |

NOTE -- Variables are defined in Table II. The large sample standard error of the sample autocorrelations is approximately .07.

m and d retain some evidence of seasonality after adjusting for monthly means.

## 4. EMPIRICAL RESULTS

The empirical results in this paper are based on estimating vector autoregressive models for the variables in Table II to compute an estimated set of innovations. These innovations are then used to estimate reduced form equations like (13) for bill and bond returns. Although two-step procedures such as just described are generally not efficient, Pagan (1984) has shown that, in this case, using residuals in the return equation is asymptotically efficient and that the usually computed standard errors are correct. Before investigating the results and associated statistical issues, summarizing behavior of the VAR system of macroeconomic variables is of some independent interest.

### 4.1 Interactions Among Policy Variables

The following six variables are included in a sixth order VAR that includes twelve seasonal dummy varaiables; y, p, d, $g^m$, m, $r_1$,.[13]

$$(14)\quad \underline{X}_{t+1} = A(L)\,\underline{X}_t + S\underline{d}_{s,t+1} + \underline{\varepsilon}_{t+1}$$

[13] The results have also been obtained using g in place of $g^m$. The variable $g^m$ is marginally preferred since it is more closely related to expenditures on goods and services than total outlays, g, in accordance with the arguments in Barro (1981) and Hall (1981). However, the qualitative results to not change significantly so only the results with $g^m$ are reported.

Where $\underline{X}' = [y, p, d, g^m, m, R_1]$, A(L) is a sixth order matrix polynomial and $\underline{d}_{s,t+1}$ is a dummy variable vector that has a one in the $j^{th}$ row when t+1 corresponds to the $j^{th}$ month. Summary statistics from the estimation are provided in Tables V and VI. Table V reports the F-statistics associated with each variable in the system. Without exception, and not surprisingly, own lags are consistently the most significant. Interestingly, output appears significant in the most equations other than its own, including public debt (d), military outlays ($g^m$) and one-period interest rates ($R_1$). There are other interesting observations worth noting. For example, consistent with the findings of King and Plosser (1985), privately held debt shocks have no significant explanatory for either inflation or money creation. Thus, evidence for a tight link between debt growth and monetization during this period is quite weak. Table VI reports the correlation matrix of the innovations. With perhaps the exception of the negative correlation between surprise inflation and surprise movements in real debt and between surprises in real money and surprises in real debt these correlations are all fairly small.

## 4.2 Macroeconomic Variables and the Return to Treasury Securities

After obtaining the innovations from the vector system (14) two formulations of (13) are estimated. First, the innovations in the policy variables are ignored and

$$(15)\quad H_{n,t+1} - R_{1,t} = \hat{a}_0 + \hat{a}_1(y_{t+1} - \hat{y}_{t+1}) + \hat{a}_2(p_{t+1} - \hat{p}_{t+1}) + \hat{e}_{t+1}$$

TABLE V

VECTOR AUTOREGRESSION
SUMMARY STATISTICS

2/68 - 11/85

$$\underline{X}_{t+1} = A(L)\underline{X}_t + S\underline{d}_{s,t+1} + \underline{\varepsilon}_{t+1}$$

| Dependent Variable | F-Statistics: y | p | d | $g^m$ | m | $R_1$ | $\bar{R}^2$ | $s(\hat{\varepsilon})$ |
|---|---|---|---|---|---|---|---|---|
| $y_t$ | 4.81 (.00) | 1.54 (.17) | 3.51 (.00) | 1.47 (.19) | 2.04 (.06) | 1.41 (.21) | .89 | .94 |
| $p_t$ | 1.49 (.19) | 12.17 (.00) | .92 (.49) | 1.70 (.12) | 1.33 (.27) | 3.56 (.00) | .56 | .23 |
| $d_t$ | 2.31 (.04) | .86 (.52) | 13.59 (.00) | .31 (.93) | 1.43 (.20) | .57 (.75) | .90 | .55 |
| $g^m_t$ | 1.89 (.08) | 1.54 (.17) | .37 (.90) | 30.49 (.00) | .63 (.71) | 1.62 (.14) | .61 | 6.07 |
| $m_t$ | .79 (.58) | 1.21 (.30) | .33 (.92) | .99 (.43) | 5.68 (.00) | 1.28 (.27) | .33 | 2.28 |
| $R_{1t}$ | 3.13 (.01) | 1.63 (.14) | .67 (.68) | .45 (.84) | .36 (.91) | 195.7 (.00) | .89 | .08 |

NOTE -- The variables are as defined in Table II. The matrix polynomial A(L) is of order 6. The matrix S is a 6x12 matrix of monthly means and the dummy variable $d_{st+1}$ is 12x1 with a 1 in the $j^{th}$ row for observations occurring in the $j^{th}$ month. F-statistics are for the six lags of the corresponding variables and have (3,166) degrees of freedom. The significance level is in parenthesis. $\bar{R}^2$ is the adjusted $R^2$ and $s(\hat{\varepsilon})$ is the standard error of the regression.

TABLE VI

CORRELATION MATRIX OF RESIDUALS

| | $(y-\hat{y})$ | $(p-\hat{p})$ | $(d-\hat{d})$ | $(g^m-\hat{g}^m)$ | $(m-\hat{m})$ | $(R_1-\hat{R}_1)$ |
|---|---|---|---|---|---|---|
| $(y-\hat{y})$ | 1.00 | .07 | -.10 | .01 | -.01 | .19 |
| $(p-\hat{p})$ | | 1.00 | -.31 | .08 | -.08 | .09 |
| $(d-\hat{d})$ | | | 1.00 | -.04 | -.25 | -.01 |
| $(g^m-\hat{g}^m)$ | | | | 1.00 | .06 | .03 |
| $(m-\hat{m})$ | | | | | 1.00 | -.09 |
| $(R_1-\hat{R}_1)$ | | | | | | 1.00 |

NOTE -- The variables correspond to the d residuals (i.e., deviations from predicted values, denoted by ^) from the six equations in the vector autoregression summarized in Table .

is estimated for each bill and bond portfolio using ordinary least squares. This procedure assumes the innovations are orthogonal to $e_{t+1}$.[14]

The results of estimating (15) are reported in Tables VII and VIII. To reduce the amount of numbers reported the results for bills with 2, 4, 6, 8, 10 and 12 months to maturity are reported since the returns to bills of adjacent maturities tend to be highly correlated. The results are generally consistent with the qualitative predictions of the simple model, although formal testing would undoubtedly reject the restrictions. Nevertheless, real output growth has a statistically significant negative impact on nominal returns indicating a tendency for output surprises to be associated with <u>lower</u> bill <u>prices</u> and thus <u>higher</u> future <u>returns</u> throughout the term structure. Alternatively, using equation (2), these results indicate that forward rates are, on average, revised upward. Moreover, since $\hat{a}_1$ appears to increase monotonically with n, all forward rates captured by the securities investigated appear to rise. The effects of unexpected inflation are similar but not as significant. When looking at the coefficients in (15), one should also keep in mind that one standard deviation in $y-\hat{y}$ is approximately four times a standard deviation in $p-\hat{p}$. Thus, since $\hat{a}_2$ is roughly twice $\hat{a}_1$, a typical output shock has approximately twice the impact on returns as a typical inflation shock.

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[14]Trying to think of instruments for $(y-\hat{y})$ and $(p-\hat{p})$ is challenging since rational expectations would rule out lagged values of any variable. Other contemporaneous innovations may be candidates, but as can be seen from Table VI, the variables used in this study are not likely to be very useful.

## TABLE VII

Regressions of the Monthly Excess Return to Treasury Bills on Unexpected Components of Real Output Growth and Inflation

$$H_{n,t+1} - R_{1,t} = \hat{a}_0 + \hat{a}_1 (y_{t+1} - \hat{y}_{t+1}) + \hat{a}_2 (p_{t+1} - \hat{p}_{t+1}) + \hat{e}_{t+1}$$

| Months to Maturity n | $\hat{a}_0$ | $t(\hat{a}_0)$ | $\hat{a}_1$ | $t(\hat{a}_1)$ | $\hat{a}_2$ | $t(\hat{a}_2)$ | $\bar{R}^2$ | $s(\hat{e})$ |
|---|---|---|---|---|---|---|---|---|
| | | | A. 2/68 - 11/85 | | | | | |
| 2 | .032 | 6.53 | -.010 | -1.78 | -.041 | -1.71 | .02 | .071 |
| 4 | .066 | 5.00 | -.044 | -2.77 | -.098 | -1.51 | .04 | .192 |
| 6 | .080 | 3.75 | -.088 | -4.41 | -.185 | -1.74 | .06 | .312 |
| 8 | .097 | 3.39 | -.120 | -3.47 | -.206 | -1.45 | .06 | .418 |
| 10 | .076 | 2.01 | -.173 | -3.78 | -.304 | -1.62 | .07 | .554 |
| 12 | .065 | 1.42 | -.199 | -3.62 | -.428 | -1.90 | .07 | .665 |
| | | | B. 2/68 - 12/76 | | | | | |
| 2 | .025 | 5.30 | .001 | .01 | -.033 | -1.17 | .00 | .048 |
| 4 | .056 | 4.23 | -.003 | -.17 | -.110 | -1.35 | .00 | .138 |
| 6 | .076 | 3.55 | -.014 | -.46 | -.187 | -1.43 | .01 | .220 |
| 8 | .104 | 3.59 | -.041 | -1.01 | -.210 | -1.19 | .01 | .299 |
| 10 | .058 | 1.48 | -.084 | -1.55 | -.248 | -1.03 | .02 | .403 |
| 12 | .100 | 2.22 | -.052 | -.83 | -.617 | -2.22 | .04 | .467 |
| | | | C. 1/77 - 12/85 | | | | | |
| 2 | .038 | 4.63 | -.031 | -2.22 | -.082 | -1.57 | .07 | .085 |
| 4 | .075 | 3.45 | -.127 | -3.51 | -.216 | -1.57 | .13 | .224 |
| 6 | .085 | 2.37 | -.214 | -3.60 | -.449 | -1.99 | .15 | .369 |
| 8 | .090 | 1.88 | -.277 | -3.47 | -.536 | -1.76 | .14 | .494 |
| 10 | .095 | 1.50 | -.379 | -3.61 | -.712 | -1.78 | .15 | .651 |
| 12 | .029 | .38 | -.458 | -3.58 | -.685 | -1.41 | .13 | .795 |

NOTE -- See Tables I and II for a precise definition of the variables. The t-statistics associated with the regression coefficients $\hat{a}_0$, $\hat{a}_1$, and $\hat{a}_2$ are $t(\hat{a}_0)$, $t(\hat{a}_1)$ and $t(\hat{a}_2)$ respectively. $\bar{R}^2$ is the adjusted $R^2$ and $s(\hat{e})$ is the standard error of the regression.

TABLE VIII

Regressions of the Monthly Excess Return to Treasury Bond Portfolios on the Unexpected Components of Real Output Growth and Inflation

$$B_{n,t+1} - R_{1,t} = \hat{a}_0 + \hat{a}_1 (y_{t+1} - \hat{y}_{t+1}) + \hat{a} (p_{t+1} - \hat{p}_{t+1}) + \hat{e}_{t+1}$$

| Months to Maturity | $\hat{a}_0$ | $t(\hat{a}_0)$ | $\hat{a}_1$ | $t(\hat{a}_1)$ | $\hat{a}_2$ | $t(\hat{a}_2)$ | $\bar{R}^2$ | $s(\hat{e})$ |
|---|---|---|---|---|---|---|---|---|
| | | | | A. 2/68 - 11/85 | | | | |
| $12< n \leq 24$ | .083 | 1.34 | -.265 | -3.55 | -.486 | -1.59 | .06 | .90 |
| $24< n \leq 36$ | .071 | .81 | -.341 | -3.20 | -.677 | -1.55 | .05 | 1.28 |
| $36< n \leq 48$ | .056 | .52 | -.424 | -3.24 | -.730 | -1.36 | .05 | 1.57 |
| $48< n \leq 60$ | .025 | .21 | -.501 | -3.46 | -1.081 | -1.82 | .06 | 1.74 |
| $60< n \leq 120$ | .041 | .26 | -.492 | -2.46 | -.678 | -.89 | .03 | 2.24 |
| | | | | B. 2/68 - 12/76 | | | | |
| $12< n \leq 24$ | .086 | 1.44 | -.124 | -1.50 | -.393 | -1.06 | .02 | .62 |
| $24< n \leq 36$ | .093 | 1.09 | -.155 | -1.35 | -.602 | -1.15 | .01 | .88 |
| $36< n \leq 48$ | .071 | .68 | -.207 | -1.42 | -.575 | -.90 | .01 | 1.08 |
| $48< n \leq 60$ | .046 | .39 | -.230 | -1.39 | -.941 | -1.29 | .02 | 1.23 |
| $60< n \leq 120$ | .100 | .67 | -.104 | -.50 | -.358 | -.39 | .00 | 1.54 |
| | | | | C. 1/77 - 11/85 | | | | |
| $12< n \leq 24$ | .079 | .74 | -.578 | -3.20 | -1.478 | -2.18 | .15 | 1.07 |
| $24< n \leq 36$ | .050 | .33 | -.772 | -2.98 | -2.086 | -2.15 | .13 | 1.54 |
| $36< n \leq 48$ | .042 | .22 | -.893 | -2.78 | -2.433 | -2.02 | .11 | 1.91 |
| $48< n \leq 60$ | .003 | .01 | -.987 | -2.79 | -2.889 | -2.17 | .12 | 2.11 |
| $60< n \leq 120$ | -.020 | -.07 | -1.191 | -2.61 | -3.228 | -1.89 | .10 | 2.71 |

NOTE -- See Tables II and III for a precise definition of the variables. The regression coefficients $\hat{a}_2,..\hat{a}_3$ have associated with then t-statistics $t(\hat{a}),...t(\hat{a}_3)$ respectively. $\bar{R}^2$ is the adjusted $R^2$ and $s(\hat{e})$ is the standard error of the regression.

The tables also report the results from splitting the sample into approximately equal sub-periods.[15] Note that the strong output effect appears to arise predominately from the 1977-1985 period while the inflation effects are more similar across periods. The smaller impact of inflation in the first period may be due in part to price controls that probably caused reported inflation to be less than actual inflation. Also, notice the almost doubling of the residual standard deviation from the first to the second half of the sample. The results for the longer term bond portfolios are reported in Table VIII and are broadly consistent with the bill returns: strong output effects are apparent and arise most notably in the latter period. Innovations in both of these variables are associated with lower bond prices and higher expected returns.

In order to incorporate the policy variables into the analysis these variables are permitted to have influence on rates of return independent of the movements in $(y-\hat{y})$ and $(p-\hat{p})$. Table IX reports the results from including five innovations in the regression. Also reported in Table IX is the F-statistic associated with the hypothesis that the coefficients for $(d-\hat{d})$, $(g-\hat{g}^m)$ and $(m-\hat{m})$ are jointly equal to zero. The general characterization of these results is that the coefficients for $(y-\hat{y})$ changes little in magnitude or significance from Tables VII and VIII. This could have been anticipated given the lack of correlation between the innovations reported in Table VI. The magnitude and significance of $(p-\hat{p})$ is diminished due to the <u>negative</u> correlation between it and $(d-\hat{d})$

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[15] The surprises are computed using only data in the relevant subperiod.

TABLE IX

Regression of the Excess Return to Treasury Bills on Unexpected Components of Real Output, Inflation and 'Policy' Variables

$$H_{n,t+1} - R_{1,t} = \hat{a}_0 + \hat{a}_1 (y_{t+1} - \hat{y}_{t+1}) + \hat{a}_2 (p_{t+1} - \hat{p}_{t+1}) + \hat{a}_3 (d_{t+1} + \partial_{t+1}) + \hat{a}_4 (g^m_{t+1} - \hat{g}^m_{t+1}) + \hat{a}_5 (m_{t+1} - \hat{m}_{t+1}) + \hat{e}_{t+1}$$

| Months to Maturity | $\hat{a}_0$ | $t(\hat{a}_0)$ | $\hat{a}_1$ | $t(\hat{a}_1)$ | $\hat{a}_2$ | $t(\hat{a}_2)$ | $\hat{a}_3$ | $t(\hat{a}_3)$ | $\hat{a}_4$ | $t(\hat{a}_4)$ | $\hat{a}_5$ | $t(\hat{a}_5)$ | $\bar{R}^2$ | $s(\hat{e})$ | F-Statistic $H_0$: $a_3=a_4=a_5=0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | A. 2/68 - 11/85 | | | | | | | | |
| 2 | .032 | 6.53 | -.010 | -1.65 | -.027 | -1.04 | .008 | 1.26 | -.001 | -.63 | .003 | 1.31 | .02 | .071 | .96(.41) |
| 4 | .066 | 5.00 | -.042 | -2.60 | -.052 | -.74 | .033 | 1.78 | .000 | -.10 | .007 | 1.05 | .04 | .192 | 1.17(.32) |
| 6 | .080 | 3.77 | -.083 | -3.22 | -.093 | -.82 | .064 | 2.15 | -.001 | -.32 | .013 | 1.21 | .07 | .311 | 1.69(.17) |
| 8 | .097 | 3.40 | -.114 | -3.30 | -.095 | -.62 | .077 | 1.73 | -.002 | -.36 | .017 | 1.17 | .06 | .417 | 1.41(.24) |
| 10 | .076 | 2.02 | -.165 | -3.60 | -.148 | -.74 | .106 | 2.01 | -.005 | -.70 | .020 | 1.03 | .08 | .552 | 1.57(.20) |
| 12 | .065 | 1.43 | -.190 | -3.45 | -.256 | -1.05 | .121 | 1.91 | -.002 | -.27 | .024 | 1.02 | .07 | .664 | 1.31(.27) |
| | | | | | | | B. 2/68 - 12/76 | | | | | | | | |
| 2 | .025 | 5.25 | .001 | .12 | -.025 | -.80 | .003 | .39 | -.001 | -.98 | .002 | .45 | .00 | .048 | .42(.74) |
| 4 | .056 | 4.21 | -.001 | -.05 | -.082 | -.92 | .012 | .59 | -.003 | -1.20 | .003 | .26 | .00 | .139 | .59(.62) |
| 6 | .076 | 3.57 | -.009 | -.30 | -.108 | -.77 | .040 | 1.24 | -.007 | -1.58 | .005 | .32 | .01 | .219 | 1.30(.28) |
| 8 | .104 | 3.59 | -.035 | -.86 | -.098 | -.51 | .058 | 1.32 | -.006 | -1.13 | .001 | .49 | .01 | .299 | 1.00(.40) |
| 10 | .058 | 1.48 | -.077 | -1.40 | -.118 | -.45 | .068 | 1.14 | -.011 | -1.42 | .007 | .23 | .02 | .403 | 1.08(.36) |
| 12 | .100 | 2.22 | -.043 | -.68 | -.442 | -1.45 | .092 | 1.33 | -.009 | -.93 | .019 | .54 | .04 | .468 | .89(.45) |
| | | | | | | | C. 1/77 - 11/85 | | | | | | | | |
| 2 | .038 | 4.64 | -.035 | -2.52 | -.029 | -.48 | .029 | 1.73 | .001 | .19 | .007 | 1.49 | .07 | .085 | 1.18(.32) |
| 4 | .075 | 3.46 | -.138 | -3.73 | -.089 | -.56 | .072 | 1.62 | .003 | .44 | .016 | 1.22 | .13 | .225 | 1.03(.38) |
| 6 | .085 | 2.37 | -.228 | -3.74 | -.275 | -1.04 | .103 | 1.41 | .007 | .54 | .020 | .92 | .15 | .370 | .78(.51) |
| 8 | .090 | 1.88 | -.297 | -3.64 | -.272 | -.77 | .148 | 1.51 | .002 | .14 | .030 | 1.02 | .13 | .496 | .79(.50) |
| 10 | .095 | 1.50 | -.403 | -3.75 | -.339 | -.73 | .211 | 1.64 | .001 | .04 | .034 | .89 | .14 | .652 | .90(.44) |
| 12 | .029 | .38 | -.487 | -3.71 | -.291 | -.51 | .213 | 1.35 | -.004 | -.16 | .044 | .93 | .12 | .799 | .64(.59) |

NOTE -- See Tables II and III for precise definition of variables. The t-statistics associated with the regression coefficients $\hat{a}_0, \ldots \hat{a}_5$ are $t(\hat{a}_0) \ldots t(\hat{a}_5)$ respectively. $\bar{R}^2$ is the adjusted $R^2$ and $s(\hat{e})$ is the standard error of the regression. The F-statistic for the hypothesis that $a_3=a_4=a_5=0$ is reported in the last column and the corresponding significance level is in parentheses.

TABLE X

Regression of the Monthly Excess Return to Treasury Bond Portfolios on Unexpected Components of Real Output, Inflation and 'Policy' Variables

$$B_{n,t+1} - R_{1,t} = \hat{a}_0 + \hat{a}_1 (y_{t+1} - \hat{y}_{t+1}) + \hat{a}_2 (p_{t+1} - \hat{p}_{t+1}) + \hat{a}_3 (d_{t+1} + \partial_{t+1}) + \hat{a}_4 (g^m_{t+1} - \hat{g}^m_{t+1}) + \hat{a}_5 (m_{t+1} - \hat{m}_{t+1}) + \hat{e}_{t+1}$$

| Months to Maturity | $\hat{a}_0$ | $t(\hat{a}_0)$ | $\hat{a}_1$ | $t(\hat{a}_1)$ | $\hat{a}_2$ | $t(\hat{a}_2)$ | $\hat{a}_3$ | $t(\hat{a}_3)$ | $\hat{a}_4$ | $t(\hat{a}_4)$ | $\hat{a}_5$ | $t(\hat{a}_5)$ | $\bar{R}^2$ | $s(\hat{e})$ | F-Statistic $H_0$: $a_3=a_4=a_5=0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | A. 2/68 - 11/85 | | | | | | | | |
| $12< n \leq 24$ | .081 | 1.31 | -.254 | -3.38 | -.299 | -.90 | .121 | 1.38 | -.001 | -.06 | .041 | 1.27 | .06 | .896 | .90(.44) |
| $24< n \leq 36$ | .069 | .78 | -.328 | -3.05 | -.446 | -.94 | .136 | 1.09 | -.009 | -.51 | .047 | 1.01 | .05 | 1.283 | .63(.59) |
| $36< n \leq 48$ | .054 | .50 | -.407 | -3.09 | -.424 | -.73 | .195 | 1.27 | -.013 | -.60 | .036 | .63 | .05 | 1.575 | .66(.52) |
| $48< n \leq 60$ | .023 | .19 | -.482 | -3.30 | -.762 | -1.19 | .215 | 1.26 | -.009 | -.38 | .031 | .50 | .06 | 1.745 | .58(.63) |
| $60< n \leq 120$ | .040 | .26 | -.469 | -2.49 | -.306 | -.37 | .278 | 1.27 | -.001 | -.04 | .019 | .23 | .02 | 2.247 | .55(.65) |
| | | | | | | | B. 2/68 - 12/76 | | | | | | | | |
| $12< n \leq 24$ | .086 | 1.43 | -.117 | -1.38 | -.230 | -.57 | .085 | .92 | -.003 | -.26 | .027 | .57 | .00 | .63 | 1.10(.35) |
| $24< n \leq 36$ | .093 | 1.08 | -.138 | -1.15 | -.341 | -.60 | .110 | .84 | -.011 | -.65 | .059 | .89 | .00 | .89 | .55(.65) |
| $36< n \leq 48$ | .071 | .67 | -.186 | -1.27 | -.283 | -.40 | .120 | .75 | -.017 | -.79 | .063 | .76 | .00 | 1.09 | .52(.67) |
| $48< n \leq 60$ | .046 | .39 | -.206 | -1.23 | -.624 | -.78 | .119 | .65 | -.027 | -1.16 | .067 | .71 | .01 | 1.24 | .68(.57) |
| $60< n \leq 120$ | .100 | .67 | -.065 | -.31 | .240 | .24 | .251 | 1.10 | -.024 | -.81 | .141 | 1.21 | .00 | 1.54 | .96(.42) |
| | | | | | | | C. 1/77 - 11/85 | | | | | | | | |
| $12< n \leq 24$ | .079 | .73 | -.606 | -3.26 | -1.05 | -1.26 | .217 | .93 | .010 | .27 | .056 | .86 | .13 | 1.09 | .41(.75) |
| $24< n \leq 36$ | .049 | .32 | -.794 | -2.96 | -1.70 | -1.42 | .190 | .57 | .003 | .06 | .045 | .48 | .10 | 1.56 | .13(.94) |
| $36< n \leq 48$ | .040 | .21 | -.906 | -2.73 | -1.87 | -1.26 | .274 | .66 | -.009 | -.14 | .039 | .33 | .09 | 1.94 | .15(.93) |
| $48< n \leq 60$ | .002 | .01 | -.996 | -2.73 | -2.33 | -1.43 | .295 | .65 | .005 | .06 | .031 | .24 | .10 | 2.13 | .15(.93) |
| $60< n \leq 120$ | -.018 | -.07 | -1.17 | -2.49 | -2.90 | -1.37 | .215 | .37 | .016 | .17 | -.020 | -.11 | .07 | 2.75 | .10(.96) |

NOTE -- See Tables II and III for precise definition of variables. The t-statistics associated with the regression coefficients $\hat{a}_0, \ldots \hat{a}_5$ are $t(\hat{a}_0) \ldots t(\hat{a}_5)$ respectively. $\bar{R}^2$ is the adjusted $R^2$ and $s(\hat{e})$ is the standard error of the regression. The F-statistic for the hypothesis that $a_3=a_4=a_5=0$ is reported in the last column and the corresponding significance level is in parentheses.

particularly in the latter period. The significance of $(y-\hat{y})$, as before, arises primarily from the latter half of the sample.

The Treasury bill results suggest that debt surprises $(d-\hat{d})$ appear to be associated with higher bill prices and thus <u>lower forward rates</u> (i.e., lower interest rates.) This tendency occurs in both sub-periods.[16] It is not only inconsistent with the conventional wisdom, it is also inconsistent with 'Ricadian Equivalence' as well. Although the sign is the same the results are less significant for the Treasury bond portfolios reported in Table X. As regards to military spending surprises, the earlier period seems to suggest that $(g^m-\hat{g}^m)$ is associated with higher nominal interest rates (lower prices) for the shorter term securities (Treasury bills). The latter period does not display any such tendency. Given that the earlier period more closely coresponds to the sample used in Plosser (1982), the results seem qualitatively consistent. The fact that recent surprises in $g^m$ do not have a similar tendency would be consistent with the Barro/Hall scenario if these shocks in the later period were more permanent. Finally, real money surprises show little association with nominal returns in either period. In all instances, the joint hypothesis that the policy variables can be omitted from the equation is not rejected at reasonable significance levels. It is sometimes argued that monthly regressions have so much 'noise' that the results tend to indicate no relation. It is important to recognize that the significance of output in these results argues against such a

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[16]The t-statistics associated with the entire sample regressions should be interpreted with caution due to the obvious heteroscedasticity of returns.

conclusion in part because it is probably the least accurately measured of any of the data. Below, in section 4.4, the specification is re-estimated with quarterly data as a check on the conclusion.

4.3 Expected Future Deficits

Feldstein (1986a,b) has argued that the empirical strategy employed in Plosser (1982) and in this paper does not corporate measures of the expected future deficit. Feldstein argues that "multiyear" budget deficits will have a larger impact on interest rates than transitory deficits. It is not correct, however, to say that the empirical strategy employed here and in Plosser (1982) does not deal with this issue. Innovations in the public debt are correlated with future changes in debt via the vector autoregression to the extent that the impulse response of the public debt to its own innovation is positive, current innovations simultaneously are predicting future increases in the debt. This link is explicit in the link between the forecasting equation (12) and the reduced form (13). Thus, because of the correlation between innovations and future debt, looking at longer term securities and their relation to current innovations is closely related to looking at expected future deficits. If future debt is not forcastable for the historical series used here, then one has to establish an explicit case for using actual future deficits in interest rate equations.

In order to emphasize that this issue is not central to the results reported thus far, the expected future growth in real public debt for two years ahead has been computed from the vector autoregression for each month. The predicted future growth in real public debt is then added to equations estimated in Table IX. The results are similar across securities, so rather than report all the equations, two are presented which are representative; for the six-month Treasury bill:

$$H_{6,t+1}-R_{1,t} = \underset{(.024)}{.049}-\underset{(.026)}{.083}(y_{t+1}-\hat{y}_{t+1})-\underset{(.111)}{.093}(p_{t+1}-\hat{p}_{t+1})+\underset{(.029)}{.064}(d_{t+1}-\hat{d}_{t+1})$$

$$+\underset{(.002)}{.005}\left(\sum_{i=1}^{24}\hat{d}_{t+i}\right)-\underset{(.004)}{.001}(g^m_{t+1}-\hat{g}^m_{t+1})+\underset{(.011)}{.013}(m_{t+1}-\hat{m}_{t+1})+\hat{e}_{t+1}$$

$\bar{R}^2 = .12 \quad s(\hat{e}) = .302;$

and for the ten year bond

$$B_{10,t+1}-R_{1,t} = \underset{(.177)}{-.119}-\underset{(.187)}{.470}(y_{t+1}-\hat{y}_{t+1})-\underset{(.822)}{.316}(p_{t+1}-\hat{p}_{t+1})+\underset{(.217)}{.274}(d_{t+1}-\hat{d}_{t+1})$$

$$+\underset{(.015)}{.028}\left(\sum_{i=1}^{24}\hat{d}_{t+i}\right)+\underset{(.029)}{.000}(g^m_{t+1}-\hat{g}^m_{t+1})+\underset{(.081)}{.017}(m_{t+1}-\hat{m}_{t+1})+\hat{e}_{t+1}$$

$\bar{R}^2 = .03 \quad s(\hat{e}) = 2.23.$

where standard errors are in parentheses. While it is interesting that the expected future growth in public debt enters these equations significantly, the sign remains positive, that is, expected future values raise bill and bond prices, thus reducing interest rates.[17]

As a final check the expected future debt variable is replaced with 24 actual future debt variables. For the six-month bill return the F-statistic on the 24 future real public debt variables is 1.66 which is

[17]Term structure equations like (11) actually suggest that it is the change in the expected future debt that should be relevant. Replacing the $\Sigma\, \hat{d}_{t+i}$ term with the change in the forecasted debt leaves all variables (except the constant) largely unchanged and the coefficient on the change in expected debt is .013 with a standard error of .008 for the six month bill and .068 with a standard error of .061 for the ten year bond.

significant at the 5% level. The sum of the coefficients of these 24 future values is .069 with a standard error .038. Thus, the accumulated future deficits do not seem to raise interest rates as the sum of the coefficients is positive. Rather, bill prices rise and interest rates fall. For the ten year bond the corresponding F-statistic is 1.93 which is also significant and the sum of the coefficients is .259 with a standard error of .257. Once again, the results indicate that if future deficits move interest rates, it is in the opposite direction from that predicted by the conventional wisdom.

### 4.4 Time Aggregation

It is sometimes argued that monthly results, such as presented above, are biased towards finding no relation among the variables. While it is possible that this is the case, it requires very explicit assumptions regarding the stochastic structure of some form of measurement error. In order to guard against these possibilities, Tables IX and X have been re-estimated using quarterly data. The formulation was chosen to conform as closely as possible to the monthly specification. For example, the forecasting equations (14) for monthly data included six lags, so for the quarterly specification two quarters are used. Excess holding period returns are computed as the difference between the quarterly return to the security and the one-quarter (three month) bill return. Thus, the equations of section 2 can be applied directly by interpreting a period as a quarter rather than a month.

Tables XI and XII summarize the results of the quarterly specification. The results are qualitatively similar to those obtained with the monthly data. Output displays persistently negative correlation

TABLE XI

Regression of the Quarterly Excess Return to Treasury Bills on Unexpected Components of Real Output, Inflation and 'Policy' Variables

$$H_{n,t+1}-R_{1,t} = \hat{a}_0 + \hat{a}_1\,(y_{t+1} - \hat{y}_{t+1}) + \hat{a}_2(p_{t+1} - \hat{p}_{t+1}) + \hat{a}_3\,(d_{t+1} + \partial_{t+1}) + \hat{a}_4\,(g^m_{t+1} - \hat{g}^m_{t+1}) + \hat{a}_5\,(m_{t+1} - \hat{m}_{t+1}) + \hat{e}_{t+1}$$

| Quarters to Maturity | $\hat{a}_0$ | $t(\hat{a}_0)$ | $\hat{a}_1$ | $t(\hat{a}_1)$ | $\hat{a}_2$ | $t(\hat{a}_2)$ | $\hat{a}_3$ | $t(\hat{a}_3)$ | $\hat{a}_4$ | $t(\hat{a}_4)$ | $\hat{a}_5$ | $t(\hat{a}_5)$ | $\bar{R}^2$ | $s(\hat{e})$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | A. 68Q4 - 85Q2 | | | | | | | |
| 2 | .062 | 1.27 | -.091 | -3.42 | -.165 | -1.33 | .051 | 1.27 | -.006 | -.62 | .035 | 1.34 | .24 | .398 |
| 3 | .128 | 1.44 | -.191 | -3.97 | -.287 | -1.27 | .071 | .97 | -.011 | -.74 | .067 | 1.41 | .27 | .725 |
| 4 | -.002 | -.02 | -.275 | -4.05 | -.561 | -1.76 | .050 | .49 | -.019 | -.94 | .082 | 1.22 | .28 | 1.022 |
| | | | | | | | B. 68Q4 - 76Q4 | | | | | | | |
| 2 | .088 | 2.19 | -.019 | -.82 | -.353 | -1.79 | .050 | 1.00 | -.002 | -.27 | -.027 | -.83 | .23 | .233 |
| 3 | .180 | 2.26 | -.067 | -1.47 | -.511 | -1.31 | .081 | .81 | .002 | .14 | -.021 | -.33 | .17 | .457 |
| 4 | .140 | 1.16 | -.085 | -1.23 | -.787 | -1.33 | .094 | .62 | .003 | .13 | -.053 | -.56 | .11 | .694 |
| | | | | | | | C. 77Q1 - 85Q2 | | | | | | | |
| 2 | .037 | .40 | -.177 | -2.71 | -.362 | -.97 | -.021 | -.17 | -.025 | -.45 | -.012 | -.20 | .18 | .540 |
| 3 | .077 | .46 | -.339 | -2.86 | -.653 | -.96 | -.035 | -.16 | -.063 | -.64 | -.007 | -.07 | .19 | .981 |
| 4 | -.140 | -.62 | -.472 | -2.93 | -1.203 | -1.31 | -.128 | -.42 | -.110 | -.82 | -.011 | -.08 | .24 | 1.329 |

NOTE -- See Tables II and III for precise definition of variables. The t-statistics associated with the regression coefficients $\hat{a}_0,\ldots\hat{a}_5$ are $t(\hat{a}_0)\ldots t(\hat{a}_5)$ respectively. $\bar{R}^2$ is the adjusted $R^2$ and $s(\hat{e})$ is the standard error of the regression.

TABLE XII

Regression of the Quarterly Excess Return to Treasury Bond Portfolios on Unexpected Components of Real Output, Inflation and 'Policy' Variables

$$B_{n,t+1}-R_{1,t} = \hat{a}_0 + \hat{a}_1 (y_{t+1} - \hat{y}_{t+1}) + \hat{a}_2(p_{t+1} - \hat{p}_{t+1}) + \hat{a}_3 (d_{t+1} + \hat{d}_{t+1}) + \hat{a}_4 (g^m_{t+1} - \hat{g}^m_{t+1}) + \hat{a}_5 (m_{t+1} - \hat{m}_{t+1}) + \hat{e}_{t+1}$$

| Quarters to Maturity | $\hat{a}_0$ | $t(\hat{a}_0)$ | $\hat{a}_1$ | $t(\hat{a}_1)$ | $\hat{a}_2$ | $t(\hat{a}_2)$ | $\hat{a}_3$ | $t(\hat{a}_3)$ | $\hat{a}_4$ | $t(\hat{a}_4)$ | $\hat{a}_5$ | $t(\hat{a}_5)$ | $\bar{R}^2$ | $s(\hat{e})$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | A. 68Q4 - 85Q2 | | | | | | | |
| $4< n \leq 8$ | .064 | .34 | -.423 | -4.16 | -.83 | -1.76 | .025 | .16 | -.027 | -.87 | .130 | 1.30 | .28 | 1.52 |
| $8< n \leq 12$ | .027 | .10 | -.606 | -4.05 | -1.46 | -2.09 | -.073 | -.32 | -.053 | -1.14 | .160 | 1.07 | .27 | 2.25 |
| $12< n \leq 16$ | -.026 | .08 | -.734 | -3.98 | -1.52 | -1.75 | -.019 | -.07 | -.050 | -.88 | .204 | 1.12 | .25 | 2.77 |
| $16< n \leq 20$ | -.128 | -.33 | -.842 | -4.01 | -1.51 | -1.53 | -.016 | -.05 | -.057 | -.88 | .169 | .82 | .23 | 3.16 |
| $20< n \leq 40$ | -.075 | -.15 | -.930 | -3.47 | -2.00 | -1.59 | -.026 | -.06 | -.059 | -.71 | .261 | .99 | .20 | 4.03 |
| | | | | | | | B. 68Q4 - 76Q4 | | | | | | | |
| $4< n \leq 8$ | .118 | .62 | -.191 | -1.75 | -.84 | -.90 | .131 | .55 | .001 | .24 | .035 | .23 | .11 | 1.09 |
| $8< n \leq 12$ | .135 | .44 | -.321 | -1.83 | -1.33 | -.88 | .005 | .01 | -.011 | -.20 | .060 | .25 | .04 | 1.76 |
| $12< n \leq 16$ | .053 | .14 | -.445 | -2.01 | -1.73 | -.92 | -.136 | -.28 | -.017 | -.26 | .109 | .36 | .06 | 2.22 |
| $16< n \leq 20$ | -.034 | -.07 | -.524 | -1.99 | -2.11 | -.94 | -.205 | -.35 | -.024 | -.30 | .007 | .02 | .03 | 2.65 |
| $20< n \leq 120$ | .147 | .28 | -.463 | -1.57 | -1.52 | -.60 | .141 | .22 | .000 | .00 | .202 | .49 | .01 | 2.97 |
| | | | | | | | C. 77Q1 - 85Q2 | | | | | | | |
| $4< n \leq 8$ | .012 | .04 | -.691 | -2.85 | -1.87 | -1.35 | -.238 | -.51 | -.127 | -.63 | -.054 | -.25 | .23 | 2.00 |
| $8< n \leq 12$ | -.078 | -.16 | -.937 | -2.69 | -3.27 | -1.65 | -.486 | -.73 | -.203 | -.70 | -.132 | -.43 | .29 | 2.87 |
| $12< n \leq 16$ | -.102 | -.17 | -1.132 | -2.65 | -3.48 | -1.43 | -.473 | -.58 | -.207 | -.59 | -.148 | -.40 | .20 | 3.52 |
| $16< n \leq 20$ | -.219 | -.67 | -1.180 | -2.50 | -4.55 | -1.69 | -.808 | -.90 | -.265 | -.67 | -.267 | -.64 | .19 | 3.89 |
| $20< n \leq 120$ | -.290 | -.33 | -1.49 | -2.42 | -6.14 | -1.75 | -1.119 | -.95 | -.306 | -.60 | -.448 | -.83 | .18 | 5.09 |

NOTE -- See Tables II and III for precise definition of variables. The t-statistics associated with the regression coefficients $\hat{a}_0, \ldots \hat{a}_5$ are $t(\hat{a}_0) \ldots t(\hat{a}_5)$ respectively. $\bar{R}^2$ is the adjusted $R^2$ and $s(\hat{e})$ is the standard error of the regressipn.

with bill and bond prices, particularly in the second sub-period while the policy variables display little relation with the returns in any period. As to be expected, the time aggregation raises the $R^2$'s from Tables IX and X to XI and XII so while for monthly returns the $R^2$'s are less than .10, for quarterly returns they cluster around .20 and sometimes greater. Thus, aggregating to quarterly data does not alter the results in any significant way.

4.5 Ex-ante Real Rates

While the results presented to this point suggest significant correlations between output information and changes in bill and bond prices, they do not decompose that change into a revision of expected real interest rates and expected inflation. It may also be true that the lack of association between rates of return and the policy variables is the result of offsetting effects on ex-ante real rates and expected inflation. In this section one method for obtaining such a decomposition is explored.

In section 2, equation (4) shows how, assuming the absence of any changing maturity premium, revisions of expected real rates of interest can be obtained from excess returns. All that is required is an estimate of expected inflation over the life of the bill. It seems the most natural procedure for obtaining an estimate of expected inflation is to use the forecasting equations used to estimate the innovations. The estimate of the revision in expected real interest rates obtained in this manner is denoted $({}_{t+1}\hat{r}_{n-1,t+n} - {}_{t}\hat{r}_{n-1,t+n})$ where ${}_{t+1}\hat{r}_{n-1,t+n}$ is the time t+1 estimate of the n-1 period ex-ante real interest rate from t+1 to t+n. The regression results for

$$
{}_{t+1}\hat{r}_{n-1,t+n} - {}_{t}\hat{r}_{n-1,t+n} = \hat{b}_0 + \hat{b}_1(y_{t+1} - \hat{y}_{t+1}) + \hat{b}_2(p_{t+1} - \hat{p}_{t+1}) + \hat{b}_3(d_{t+1} - \hat{d}_{t+1}) \\ + \hat{b}_4(g_{t+1} - \hat{g}^m_{t+1}) + \hat{b}_5(m_{t+1} - \hat{m}_{t+1}) + \hat{e}_{t+1} \quad (16)
$$

are reported in Table XIII. It is important to keep in mind that these results are conditional on an estimate of expected inflation and that the b's coefficient are positive when real rates are revised upward and vice-versa (i.e., the oppposite sign of the results in the previous table.)

The results in Table XIII are both interesting and puzzling. First unexpected output growth is significantly negatively related to changes in ex-ante real rates for all maturities in the early period and somewhat less so in the latter perios. Only in the latter period, at maturities of 10 and 12 months, are the point estimates positive. This is puzzling given the results for nominal rates because it suggests that output surprises are associated with higher nominal rates but lower real rates of interest. The results for real rate could be consistent with the standard theory if output growth rates were negatively serially correlated. Based on the moving average representation of the VAR, however, they are not. And, if they were, the results for the nominal returns would become the puzzle. The persistently negative response of ex-ante real rates to inflation surprises is also troubling. Nevertheless, these two variables account for a substantial amount of the explanatory power of the monthly regressions.

The coefficients associated with the policy variables are of perhaps more interest. However, given the somewhat puzzling results for output and inflation, the results should probably be interpreted with some caution. Most interesting is the fact that the results for $(d-\hat{d})$, $(g^m-\hat{g}^m)$

TABLE XIII

Regression of the Monthly Revision in Real Interest Rates on Treasury Bills on Unexpected Components of Real Output, Inflation and 'Policy' Variables

$$_{t+1}\hat{r}_{n-1,t+n} - {}_{t}\hat{r}_{n-1,t+n} = \beta_0 + \beta_1 (y_{t+1} - \hat{y}_{t+1}) + \beta_2(p_{t+1} - \hat{p}_{t+1}) + \beta_3 ((d_{t+1} + \hat{d}_{t+1}) + \beta_4 (g^m_{t+1} - \hat{g}^m_{t+1}) + \beta_5 (m_{t+1} - \hat{m}_{t+1}) + \hat{e}_{t+1}$$

| Months to Maturity | $\beta_0$ | $t(\beta_0)$ | $\beta_1$ | $t(\beta_1)$ | $\beta_2$ | $t(\beta_2)$ | $\beta_3$ | $t(\beta_3)$ | $\beta_4$ | $t(\beta_4)$ | $\beta_5$ | $t(\beta_5)$ | $\bar{R}^2$ | $s(\hat{e})$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | A. 2/68 - 11/85 | | | | | | | |
| 2 | -.032 | -7.73 | -.012 | -2.50 | -.285 | -13.18 | .016 | 2.80 | .002 | 3.16 | .002 | 1.11 | .54 | .059 |
| 4 | -.066 | -5.94 | -.099 | -7.35 | -.585 | -9.94 | .016 | 1.01 | .001 | .66 | .026 | 4.43 | .50 | .162 |
| 6 | -.080 | -4.40 | -.142 | -6.44 | -.848 | -8.77 | .005 | .20 | .004 | 1.18 | .020 | 2.11 | .40 | .266 |
| 8 | -.097 | -3.84 | -.161 | -5.26 | -1.096 | -8.18 | .023 | .65 | .007 | 1.50 | .029 | 1.74 | .36 | .368 |
| 10 | -.076 | -2.32 | -.158 | -3.97 | -1.438 | -8.24 | .011 | .25 | .012 | 1.98 | .031 | 1.80 | .33 | .480 |
| 12 | -.065 | -1.64 | -.175 | -3.65 | -1.678 | -8.02 | .019 | .35 | .010 | 1.33 | .036 | 1.73 | .31 | .576 |
| | | | | | | | B. 2/68 - 12/76 | | | | | | | |
| 2 | -.025 | -3.56 | -.022 | -2.23 | -.034 | -.76 | .019 | 1.83 | .003 | 2.38 | -.015 | -2.81 | .17 | .070 |
| 4 | -.056 | -4.47 | -.093 | -5.26 | -.224 | -2.67 | -.041 | -2.16 | .006 | 2.31 | -.010 | -.99 | .26 | .129 |
| 6 | -.076 | -4.06 | -.171 | -6.47 | -.409 | -3.27 | -.065 | -2.28 | .010 | 2.61 | -.016 | -1.13 | .35 | .192 |
| 8 | -.104 | -3.63 | -.217 | -5.40 | -.716 | -3.76 | -.068 | -1.58 | .013 | 2.16 | -.034 | -1.52 | .30 | .293 |
| 10 | -.056 | -1.41 | -.238 | -4.24 | -.929 | -3.49 | -.137 | -2.25 | .019 | 2.38 | -.044 | -1.41 | .24 | .410 |
| 12 | -.098 | -2.09 | -.324 | -4.95 | -.779 | -2.51 | -.163 | -2.29 | .017 | 1.81 | -.070 | -1.93 | .23 | .479 |
| | | | | | | | C. 1/77 - 11/85 | | | | | | | |
| 2 | -.038 | -4.95 | -.016 | -1.21 | -.535 | -9.41 | -.052 | -3.29 | -.003 | -1.37 | .006 | 1.17 | .52 | .080 |
| 4 | -.077 | -3.85 | -.103 | -3.06 | -.425 | -2.92 | .082 | 2.03 | -.007 | -1.90 | .063 | 5.25 | .34 | .204 |
| 6 | -.088 | -2.66 | -.169 | -3.03 | -.393 | -1.63 | .121 | 1.80 | -.002 | -.15 | .072 | 3.63 | .21 | .340 |
| 8 | -.094 | -2.06 | -.086 | -1.12 | -.513 | -1.54 | .138 | 1.49 | .009 | .58 | .087 | 3.16 | .13 | .467 |
| 10 | -.098 | -1.66 | .023 | .23 | -.821 | -1.89 | .126 | 1.04 | .006 | .29 | .115 | 3.24 | .14 | .611 |
| 12 | -.034 | -.45 | .109 | .87 | -1.297 | -2.41 | .208 | 1.38 | .010 | .41 | .146 | 3.29 | .25 | .758 |

NOTE -- See Tables II and III for precise definition of variables. The t-statistics associated with the regression coefficients $\hat{a}_0, \ldots \hat{a}_5$ are $t(\hat{a}_0) \ldots t(\hat{a}_5)$ respectively. $\bar{R}^2$ is the adjusted $R^2$ and $s(\hat{e})$ is the standard error of the regression.

and $(m-\hat{m})$ are so different in the two sub-periods. In the early period, debt shocks appear to be associated with lower ex-ante real rates for all maturities except for the very shortest one-month (n=2) rate. In addition, military spending shocks appear to be associated with a significant upward revision in ex-ante real rates. Finally, monetary surprises have a marginally negative correlation with real rates changes.

In the latter the results almost completely reverse themselves for the policy variables. First, except for (n=2), debt shocks are positively correlated with real rates but only marginally significant. Second, military spending seems unrelated to real rates. One interpretation may be that spending shocks in the early period might have been perceived as more temporary than the shocks in the latter period, in which case the models of Barro and Hall predict a positive effect in the first period and little effect in the latter. Finally, monetary shocks appear to have a significantly positive association with real rates in this latter period.

The quarterly specification of these real rates equations adds to the confusion because they do not tell a completely consistent story. The most consistent results are those for military spending surprises, which seem to be associated with higher real rates in both periods but with greater significance in the ealier period. Debt shocks, on the other hand, show no significant correlation in either period while output shocks are significant, but change signs in the two periods.

These quarterly results, while offering some advantages over the monthly regression from the standpoint of measurement error, are also more likely to be confounded by simultaneous equation bias, particularly for variables such as output, debt shocks and monetary policy. The fact that

## TABLE XIV

Regression of the Quarterly Revision in Real Interest Rates on Treasury Bills on Unexpected Components of Real Output, Inflation and 'Policy' Variables

$$_{t+1}\hat{r}_{n-1,t+n} - {}_{t}\hat{r}_{n-1,t+n} = \hat{a}_0 + \hat{a}_1 (y_{t+1} - \hat{y}_{t+1}) + \hat{a}_2(p_{t+1} - \hat{p}_{t+1}) + \hat{a}_3 ((d_{t+1} + \hat{d}_{t+1}) + \hat{a}_4 (g^m_{t+1} - \hat{g}^m_{t+1}) + \hat{a}_5 (m_{t+1} - \hat{m}_{t+1}) + \hat{e}_{t+1}$$

| Quarters to Maturity | $\hat{a}_0$ | $t(\hat{a}_0)$ | $\hat{a}_1$ | $t(\hat{a}_1)$ | $\hat{a}_2$ | $t(\hat{a}_2)$ | $\hat{a}_3$ | $t(\hat{a}_3)$ | $\hat{a}_4$ | $t(\hat{a}_4)$ | $\hat{a}_5$ | $t(\hat{a}_5)$ | $R^2$ | $s(\hat{e})$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | A. 68Q4 - 85Q2 | | | | | | | |
| 2 | -.066 | -1.53 | -.049 | -2.08 | -.177 | -1.57 | -.039 | -1.06 | .009 | 1.30 | .051 | 2.12 | .24 | .351 |
| 3 | -.125 | -1.49 | -.296 | -1.36 | -.296 | -1.36 | -.018 | -.26 | .014 | .97 | .049 | 1.06 | .04 | .679 |
| 4 | .016 | .13 | .033 | .50 | -.463 | -1.45 | .054 | .51 | .019 | .93 | .044 | .65 | .04 | .995 |
| | | | | | | | B. 68Q4 - 76Q4 | | | | | | | |
| 2 | -.080 | -2.08 | -.093 | -4.32 | -.108 | -.57 | -.062 | -1.28 | .015 | 2.40 | -.061 | -2.01 | .48 | .217 |
| 3 | -.162 | -2.08 | -.129 | -2.95 | -.669 | -1.75 | -.094 | -.95 | .031 | 2.40 | -.104 | -1.68 | .39 | .441 |
| 4 | -.115 | -.98 | -.187 | -2.83 | -.690 | -1.19 | -.091 | -.61 | .029 | 1.47 | -.108 | -1.16 | .26 | .664 |
| | | | | | | | C. 77Q1 - 85Q2 | | | | | | | |
| 2 | -.031 | -.32 | .017 | .26 | .204 | .54 | .087 | .68 | .029 | .54 | .106 | 1.79 | .01 | .542 |
| 3 | -.047 | -.28 | .208 | 1.78 | .474 | .71 | .147 | .65 | .133 | 1.37 | .158 | 1.49 | .07 | .964 |
| 4 | .202 | .89 | .384 | 2.42 | .404 | .45 | .256 | .84 | .138 | 1.05 | .198 | 1.39 | .12 | 1.302 |

NOTE -- See Tables II and III for precise definition of variables. The t-statistics associated with the regression coefficients $\hat{a}_0, \ldots \hat{a}_5$ are $t(\hat{a}_0) \ldots t(\hat{a}_5)$ respectively. $R^2$ is the adjusted $R^2$ and $s(\hat{e})$ is the standard error of the regression.

for military spending, the results are more consistent with the monthly results suggests that for this variable simultaneous equation bias may be less of a problem.

Summarizing the results of Tables XIII and XIV is difficult. First, while the early period seems to suggest that innovations in debt significantly lower real rates, the latter period seems to suggest the opposite, although the results are less significant. Unfortunately, the results for the debt shocks are not corroborated by the quarterly specification. Second, military spending innovations are associated with significantly higher real rates in the early period only. These results are generally supported by the quarterly results. The most troubling results are (a) the significantly positive coefficients for money surprises in the latter period and (b) the significantly negative coefficients for output.

4.6 Temporary Military Expenditures

Barro (1981a,b) and Hall (1980) have emphasized the intertemporal substitution effects of temporary movements in government purchases of goods and services. In these set-ups, temporary increases in government purchases induce intertemporal substitution of work effort and production via a rise in the real interest rate. The evidence from the nominal monthly data presented in this paper do not suggest a strong association between the measure of spending (military outlays, $g^m$) and rates of return. On the other hand the real rate equations seem to suggest a significantly positive association between real rates and spending surprises especially during the first half of the sample. The Barro/Hall model, however, makes the prediction that temporary spending is likely to have more pronounced interest rate effects than permanent spending.

Beveridge and Nelson (1981) suggest a method of decomposing a univariate time series into a permanent component, which is a random walk, and a temporary component. The permanent component of a series at time t is defined in the long-run forecast of the series (less any drift). This long-run forecast could be thought of as the normal level of the series and behaves as a random walk with drift. The temporary or transitory component is just the difference between the actual series and the permanent or normal component. The multivariate generalization is applied to the forecasting equations in (14). Since $\underline{X}_{t+1}$ is specified in growth rates (14) is assumed to be a stationary vector process. Denote the levels of $\underline{X}_{t+1}$ as $\underline{Z}_{t+1}$ and the moving average matrix polynominal associated with (14) as $(I-A(L)L)^{-1} = C(L)$. Then the change in the permanent component of $\underline{Z}_{t+1}$, $\Delta\underline{Z}^{p}_{t+1}$, is computed as $\Delta Z^{p}_{t+1} = C(1)\underline{\varepsilon}_{t+1}$ where $C(1) = C(L=1)$. The temporary component of $\underline{Z}_{t+1}$ is then $\underline{Z}_{t+1} - \underline{Z}^{p}_{t+1} = \underline{Z}^{t}_{t+1}$.[18]

Following the above procedure, the permanent component for military spending, $gp^{m}$, and the temporary component, $gt^{m}$, are computed and substituted for the innovation $(g^{m}-\hat{g}^{m})$ in the real rate regressions reported in Table XIII. The results for the six-month bill (n=6) are representative of the first and second sub-periods:

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[18]Note that this implies that seasonal movements are impounded in the temporary component.

$$ {}_{t+1}\hat{r}_{5,t+5} - {}_{t}\hat{r}_{5,t+1} = \underset{(.042)}{-.004} \underset{(.026)}{-.167}(y_{t+1}-\hat{y}_{t+1}) \underset{(.126)}{-.366}(p_{t+1}-\hat{p}_{t+1}) \underset{(.029)}{-.059}(d_{t+1}-\hat{d}_{t+1}) $$

$$ + \underset{(.001)}{.000}\, gp^{m}_{t+1} + \underset{(.002)}{.006}\, gt^{m}_{t+1} + \underset{(.015)}{-.018}\,(m_{t+1}-\hat{m}_{t+1}) + \hat{e}_{t+1} $$

$\bar{R}^2 = .35$ $s(\hat{e}) = .194$ **Period: 2/68 - 11/76**

$$ {}_{t+1}\hat{r}_{5,t+5} - {}_{t}\hat{r}_{5,t+1} = \underset{(.092)}{.068} \underset{(.056)}{-.154}(y_{t+1}-\hat{y}_{t+1}) \underset{(.251)}{-.362}(p_{t+1}-\hat{p}_{t+1}) \underset{(.070)}{+.142}(d_{t+1}-\hat{d}_{t+1}) $$

$$ - \underset{(.003)}{.005}\, gp^{m}_{t+1} + \underset{(.006)}{.006}\, gt^{m}_{t+1} + \underset{(.020)}{.075}\,(m_{t+1}-\hat{m}_{t+1}) + \hat{e}_{t+1} $$

$\bar{R}^2 = .22$ $s(\hat{e}) = .336$ **Period: 1/77 - 10/85**

where as before, standard errors are in parentheses. These results are consistent with the hypothesis that temporary military spending and not permanent spending is associated with higher real rates in the early period, but while the magnitude of the coefficient is similar, the significancae of the results are less apparent in the latter period. The other coefficients are largely unchanged. Debt shocks show negative correlation with real interest rates in the early period and positive correlation in the latter half of the sample.

Some caution is advised, however, in interpreting these results. Only one simple procedure for decomposing $g^m$ into permanent and transitory component has been explored and it does not necessarily correspond to the only or best procedure. For example, the economic concept of permanent spending used by Barro involves not the long-run forecast profile computed here, but the discounted present value of the future values.[19] In addition, the procedure here depends on the estimated stochastic structure (14) and given the differing results across sub-periods, assuming a stable

[19] The concepts are not likely to differ much if the discount factor is close to one.

representation may be wishful thinking, even for the shorter sub-periods.[20] Nevertheless, the results are suggestive and point to potential benefits of futher exploration of the different periods.

## 5. SUMMARY

This paper investigates the behavior of the term structure of returns to Treasury securities and implicity the behavior of forward interest rates in response to innovations in several key macroeconomic measures including output, inflation, real public debt, real military spending and real public debt held by the Federal Reserve. The primary focus is on the association between changes in the real value of the public debt and the term structure. The results are interesting, but somewhat conflicting. First, the nominal holding period returns are consistent with the quarterly results in Plosser (1982) where debt shocks appeared unrelated to excess returns and government spending was associated with lower returns and higher nominal interest rates. The correspondence is closest for the 1968-1976 sample. The second half of the sample 1977-1985 shows less association between excess returns and government military spending and more of a tendency for debt shocks to be associated with higher nominal interest rates but the coefficients remain insignificant by the usual criteria.

The paper also attempts to isolate the relation between the macro-variables and real interest rates. Such an exercise is always fraught

[20]This is likely to be a bigger problem for the permanent-temporary decomposition than for just computing the innovations used previously since the decomposition compounds the estimation error already inherent in the innovations.

with problems. Nevertheless, the results are interesting. First output innovations, which appear to raise nominal interest rates, appear to lower real rates throughout the sample. Second, debt shocks appear to significantly lower real rates in the period 1968-1976 but to raise them in the latter period, albeit not with a high degree of significance. Finally, military spending shocks are significantly related to higher real rates in the early period, but show no relation in the latter period.

Overall, these results do not offer much support for the conventional view regarding public debt and interest rates. Nevertheless, there does appear to be distinctly different results in different time periods from these reduced forms. This should give some cause for concern when interpreting reduced form empirical results that rely on highly aggregated (such as yearly) data over long periods of time. The results also suggest that futher interesting work could be done exploring on more detail why these relations appear to change sometime in the late 1970's.

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