EMPIRICAL RESEARCH ON BOND PRICING

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AN EMPIRICAL ANALYSIS OF THE PRICING OF MORTGAGE-BACKED SECURITIES

KENNETH B. DUNN and KENNETH J. SINGLETON*

1. Introduction

EQUILIBRIUM PRICES OF FIXED-RATE securities have recently been calculated for a limited set of parametric specifications of investors' preferences, production technologies, and economic uncertainty. For instance, in one example, Cox, Ingersoll and Ross (1978) solve for the equilibrium bond prices implied by a linear technology and the assumption that investors exhibit logarithmic utility. Subsequently, Dunn and McConnell (1981b) adopted these assumptions in order to calculate and study the prices of Government National Mortgage Association (GNMA) mortgage-backed securities. The distributions (and, therefore, the magnitudes and time paths) of the asset prices calculated from these models depend in an important way on the underlying specifications of the economic environment. Consequently, inferences about the time series behavior of individual and relative prices of fixed-rate securities may not be robust to alternative model specifications. Therefore, before proceeding with tests of explicit pricing equations, it seems worthwhile to investigate empirically whether the restrictions on asset prices implied by particular classes of preference functions are consistent with the data, without imposing the auxiliary restrictions associated with the specification of technology and uncertainty.

The primary purpose of this paper is to test a discrete time, consumption-based model of prices of GNMA securities and U. S. Treasury bonds in which the specification of preferences is more general than the logarithmic form and in which minimal structure is imposed on the stochastic processes generating consumption and returns. By focusing on the necessary conditions for intertemporal utility maximization, we are able to estimate the parameters characterizing preferences and test restrictions on the temporal behavior of the prices of GNMAs and U.S. Treasury bonds, without having to solve for the stochastic equilibrium. Our estimates of the preference parameters hopefully will provide guidance for structuring analyses of bond pricing models, which require that preferences be specified a priori. In addition, the issue of whether the relative prices of GNMAs

† University of Rochester.

* Graduate School of Industrial Administration, Carnegie-Mellon University. We are grateful to Elton Peller and Jim Thompson of the GNMA and to Dexter Senft of the First Boston Corporation for helpful discussions and to Stewart Turnbull for helpful comments.

and U.S. Treasury bonds are consistent with the equilibrium model considered can be investigated by testing the cross-sectional restrictions on these prices. This issue is of interest, in part, because it is often suggested that GNMAs are not properly priced relative to Government bonds and other investment alternatives. If this is true, then the GNMA mortgage-backed securities program may not have met its objective of providing individuals with the opportunity to compete for mortgage funds in the capital market on the same terms as the U.S. Government and the corporate sector of the economy. Our analysis provides some evidence on this issue in the absence of auxiliary hypotheses about the production technology or the distributions of variables in the model.

A GNMA security provides the owner of the security with a pro-rata claim to the cash flows from a portfolio of nearly homogeneous FHA and VA mortgage loans. The FHA and VA mortgage loans which back GNMAs are fully amortizing, assumable loans which can be prepaid (i.e., called by the owner of the mortgaged single family residence who issued the mortgage loan) at any time without a prepayment penalty. The cash flows to the owners of a GNMA pool consist of scheduled interest and principal payments plus unscheduled recoveries of principal. Thus, to derive the equilibrium pricing function for GNMA securities in terms of the underlying determinants of individual portfolio decisions would require a model of the prepayment decisions of homeowners. This task is beyond the scope of the present paper.

Instead, we follow Grossman and Shiller (1981), Hansen and Singleton (1982, 1983), and Hansen, Richard, and Singleton (1982) and investigate the restrictions on equilibrium prices implied by the first-order conditions of investors' discrete-time, intertemporal utility maximization problems in an uncertain environment. The assumption that time is discrete amounts to the assumption that the decision interval of agents is at least as long as the sampling interval of the data, in our case monthly. In return for this assumption, we need impose little more than the assumption of stationarity on the joint distribution of consumption growth rates and security returns. This is to be contrasted with empirical analyses of continuous time models, which must overcome the problem of temporal aggregation. Our approach requires that the class of admissible preference functions be given parametrically. In this paper we employ methods developed recently by Eichenbaum Hansen, and Singleton (1983) for analyzing models with nonseparable utility, and consider a nonseparable form of constant relative risk averse (CRRA) preferences. This specification has the conventional CRRA specification, and hence the logarithmic function considered by Dunn and McConnell, as special cases.

The remainder of this paper is organized as follows. In section 2 we describe the pricing relation to be tested and the assumed form of the preference function. In section 3 we describe the data and our dating conventions. Following a brief description of the estimation procedures, the empirical results are presented in section 4. Finally, concluding remarks are given in section 5.

2. The Pricing of GNMA Securities

Consider an economy with a finite number of infinitely lived investors, each of which has preferences over an infinite stream of future consumption levels of a single good. Let C_t be the level of consumption at date t of the good by an individual consumer. Following Prescott and Mehra (1980), Kydland and Prescott (1982), and Eichenbaum, Hansen, and Singleton (1983), we suppose consumers maximize the expected value of a concave von Neumann-Morgenstern utility function in which utility of consumption in the current period may depend on past decisions. Specifically, we suppose each consumer chooses consumption and investment plans so as to maximize[1]

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\{A(L)C_t\}^{\gamma} - 1}{\gamma}, \gamma < 1, \tag{2.1}$$

where E_t denotes the expectation conditioned on the information of the consumer at date t, say I_t, $\beta \in (0, 1)$ is a subjective discount factor, L is the lag operator defined by $L^jC_t = C_{t-j}$, and the polynomial is the lag operator, $A(L)$, is given by

$$A(L) = \sum_{j=0}^{n} A_jL^j, A_0 = 1, A_j \geq 0,$$

with n finite. When $n > 0$, preferences are nonseparable over time and A_jC_{t-j} captures the "service flow" in period t from goods consumed in period $t - j$. The restriction that A_j be nonnegative assures that marginal utilities are positive for all consumption sequences, $\{C_t\}$, and that there is diminishing marginal utility.

The marginal utility of consumption, $MU_c(t)$, is given by

$$MU_c(t) = E_t[A(L^{-1})\{\beta^t\{A(L)C_t\}^{\alpha}\}], \alpha \equiv \gamma - 1, \tag{2.2}$$

where L^{-1} is the forward-shift operator.[2] Let R_{jt+1} denote the real one-period holding period return between dates t and $t + 1$ on the jth GNMA pool of mortgage loans. Then the first-order conditions for the maximization of (2.1) subject to an intertemporal budget constraint imply the equilibrium condition

$$E_t[MU_c(t) - MU_c(t + 1)R_{jt+1}] = 0, \tag{2.3}$$

which, after substitution from (2.2), can be rewritten as

$$E_t[A(L^{-1})\{\beta^t\{A(L)C_t\}^{\alpha}\} - R_{jt+1}A(L^{-1})\{\beta^{t+1}\{A(L)C_{t+1}\}^{\alpha}\}] = 0. \tag{2.4}$$

If $n = 0$, then (2.4) simplifies to

$$E_t[C_t^{\alpha} - \beta C_{t+1}^{\alpha}R_{jt+1}] = 0, \tag{2.5}$$

which is the stochastic Euler equation for a model with time-separable, constant relative risk averse preferences ($|\alpha|$ is the coefficient of relative risk aversion). Expressions analogous to (2.4) and (2.5) were derived by Rubinstein (1976), Lucas (1978), and Brock (1980) for models with time-separable preferences, and by Prescott and Mehra (1980) and Eichenbaum, Hansen, and Singleton (1983) for models with nonseparable preferences.

Versions of the Euler equations (2.4) and (2.5) hold for each consumer, while only aggregate data on consumption are available for empirical analyses. Rubinstein (1974) has shown that (2.5) can be aggregated across consumers if agents

[1] This specification of preferences is a special case of the specification considered in Eichenbaum, Hansen and Singleton (1983), to which the reader is referred for a more detailed discussion of its properties.

[2] Conditional expectations appear in (2.2) because $U(\cdot)$ is nonseparable over time when $n > 1$.

have common beliefs and preference parameters and if intertemporal marginal rates of substitution equate across consumers. Hansen, Richard, and Singleton (1982) have extended Rubinstein's results for a class of nonseparable utility functions, that includes (2.1) as a special case, under the additional assumption that none of the roots of the polynomial $A(L)$ lie inside the unit circle. We henceforth maintain these assumptions and interpret C_t in (2.4) and (2.5) as aggregate real per capita consumption. A version of (2.4) must also hold for weighted combinations of returns as long as the weights are in I_t and sum to unity. In particular, R_{jt+1} in (2.4) may be taken to be the value—weighted return on some subset of the GNMA pools outstanding at date t.

The resulting aggregate return relation differs in several respects from the pricing equations for GNMA mortgage-backed securities studied previously in the literature. The goal of these previous studies was to calculate prices and this required a complete specification of the economic environment. To accomplish our objectives, it is not necessary to calculate prices or expected returns and, therefore, we are able to allow for a much richer probabilistic structure than those underlying existing pricing equations. Curley and Guttentag (1974, 1977), for example, used linear regression and actuarial data to estimate the conditional probabilities of a loan prepayment given that it is outstanding at the beginning of the month. They assume that the term structure is flat and certain and that the probabilities of prepayments conditional on the loan being outstanding are not state dependent (see Dunn and McConnell 1981a). This, and other yield-based approaches, severely restricts the relevant conditioning information. More recently, Dunn and McConnell (1981a, b) considered a continuous time model of GNMA prices in which the current interest rate for instantaneous riskless borrowing and lending completely summarizes all information relevant for pricing default-free, fixed-interest rate securities. Also, the riskfree rate was assumed to follow a mean-reverting diffusion process. Although their model can be generalized to include additional sources of uncertainty, doing so requires making additional distributional assumptions.

In contrast, here we allow for a very general conditioning information set, I_t, that will in general include much more information than Curley and Guttentag or Dunn and McConnell allowed. Further, we do not need to model explicitly the conditional probabilities of prepayments. The possibility of prepayments and the effect of callability are reflected in the joint distribution, conditional on agents' information set, of security prices, outstanding balances, and unscheduled prepayments, but knowledge of this joint distribution is not required to obtain consistent estimates of the unknown parameters in (2.4). Following Hansen and Singleton (1982) and Eichenbaum, Hansen, and Singleton (1983), we exploit the fact that the term in brackets in (2.4) is orthogonal to all of the variables in agents' information set at date t in order to construct estimators of the parameters and to test the model.

3. Data and Dating Conventions

In this paper we restrict our attention to 8 percent, fixed-rate, single family, concurrent date GNMA securities. The GNMA requires that the issuer of the security, generally a mortgage banker, make monthly payments by the 15th of the month to the registered GNMA holders of record on the 1st of the month. This monthly cash flow consists of scheduled interest and principal payments plus unscheduled recoveries of principal. The scheduled interest payment equals one twelfth of the security rate (i.e., .08/12) times the remaining principal balance of the security at the beginning of the previous month. The scheduled payment of principal due to security holders on the 15th of the month equals the scheduled principal payments from the underlying mortgage loans due to the issuer on the first of the month. Unscheduled principal payments include loan prepayments and/or claims settlements from the FHA or VA on those loans in the pool which have been foreclosed. The portion of the cash flow represented by unscheduled principal payments is that amount collected by the issuer on or before the reporting cut-off date (between the 25th and the end of the month) of the previous month. The data necessary to compute the monthly cash flows from GNMA securities for the period February 1972 through June of 1978 were provided by Loeb, Rhoads & Co. These data were updated with additional data obtained directly from the GNMA.

As of the reporting cut-off date, a GNMA security's remaining principal balance and cash flow for the following month have been determined. The principal balance must be reported to the GNMA on the 2nd of the month and is announced by the GNMA on about the 7th of the month. Hence, at the end of any month t, agents' information set includes the scheduled interest and principal payments which will be paid on the 15th of month $t + 1$ to the holders of record on the first of month $t + 1$ (i.e., those who purchased the security on a settlement date prior to about the 25th of month t). Although the amount of the unscheduled principal payment is not officially announced until about the 7th day of month $t + 1$, this information is known by the issuer at the end of month t. Further, the amount of the unscheduled principal payment and the remaining principal balance for month $t + 1$ are not influenced by events which occur after the end of month t. Hence, we assume that agents' information set at the end of month t includes the remaining principal balance and the unscheduled principal payment due on the 15th of month $t + 1$.

GNMAs are traded in an over-the-counter market. The settlement or delivery date is agreed upon by the parties to the transaction at the time of the trade (the trade date) and it normally takes about 5 days after the settlement date to become the holder of record. The First Boston Corporation has generously provided us with bid prices for "current month" delivery. The current month is defined by settlement dates which occur prior to about the 25th of the month so that the purchaser will be the holder of record on the first of the following month and be entitled to the cash flow paid on the 15th of the following month. Trades after about the 25th of the month generally are not settled before the new security balance has been officially announced in the following month.

To compute the holding period return on a GNMA pool for month $t + 1$ we assume the security is purchased at the beginning of the month and sold at the end of the month. Hence, the nominal return, r_{jt+1}, on pool j for month $t + 1$ is computed as

$$r_{jt+1} = \frac{P_{t+1}B_{jt+1} + q_{jt+1}}{P_t B_{jt}}, \tag{3.1}$$

where P_t and P_{t+1} are the prices per dollar of remaining principal balance, B_{jt} and B_{jt+1}, at the beginning and end of month $t + 1$, respectively. P_t is a price quoted on trade dates between the 26th of month t and the 2nd of month $t + 1$ and P_{t+1} is a price observed on trade dates between the 26th of month $t + 1$ and the 2nd of month $t + 2$. The B_{jt}'s are the remaining balances at the end of month t, which are officially announced on about the 7th of month $t + 1$. Purchasing at the beginning of month $t + 1$ and selling at the end of the month entitles the purchaser to the cash flow, q_{jt+1}, which will be paid on the 15th of month $t + 2$. The cash flow is computed as

$$q_{jt+1} = (.08/12)B_{jt} + B_{jt} - B_{jt+1}.$$

Our use of the subscript t on B_{jt} indicates we are assuming that the remaining principal balance at the end of month t, and therefore unscheduled prepayments, are in agents' information set at the end of month t. The real one-period return, R_{jt+1}, which appears in (2.4), is calculated from (3.1) by dividing the numerator and denominator of r_{jt+1} by the implicit consumption deflator for periods $t + 1$ and t, respectively.

There are several adjustments to our return calculation which might seem appropriate. The settlement dates corresponding to the trade dates we have used are generally between the 7th and 15th of the month and the price actually paid includes accrued interest from the 1st of the month. Thus, the timing of the actual cash transactions corresponding to the return computed for month $t + 1$ is as follows: The purchase price plus 6 days accrued interest is paid on the 7th of month $t + 1$. The proceeds from the sale are received on the 7th of month $t + 2$. The cash flow from the security are received on the 15th of month $t + 2$. In principle, these (real) payments should be discounted back to the end of the previous month by the expected marginal rate of substitution over the relevant one- or two-week period, but we do not observe mid-month consumption. Hence, we treat q_{jt+1} as if it were received at the end of month $t + 1$ and deflate by the end-of-month $t + 1$ deflator.[3] We also ignore accrued interest.

Most of the transactions in the GNMA market call for the delivery of GNMAs with an agreed-upon coupon rate but leave unspecified the maturity date and pool numbers of securities to be delivered. The prices we have obtained from the First Boston Corporation are for this type of transaction. However, not all GNMA pools with the same coupon rate have the same value: They may differ in their maturity dates and expected repayment rates. Because the standard trading practices permit the seller to choose the actual securities to be delivered, the quoted prices represent the value of the least valuable GNMA securities. The least valuable securities will be those with the longest terms to maturity and with the lowest expected prepayment rates. In fact, those pools which have been identified as "fast prepay" pools sell at a premium and are traded in special transactions where the pool to be delivered is specified on the trade date. Thus, given our price data, only the least valuable pools should be used to compute returns.

[3] While it might seem that an appropriate adjustment would be to discount at the nominal Treasury bill rate, our model is a real model and a riskless real security does not exist.

These are the pools we have used to construct a time series of value-weighted returns on 8 percent GNMA securities from January 1973 to December 1978. To compute the value-weighted return for month t, we initially considered only those securities which were issued at the beginning of month t. If less than 10 GNMA pools satisfied this restriction, we then considered securities issued in month $t-1$. We continued to look backward for up to six months, one month at a time, until we obtained as least 10 GNMA securities meeting our data requirements.[4]

The monthly series on real consumption of nondurables and services was obtained from the CITIBASE data type. A per capita series was constructed by dividing each observation by the corresponding observation in the monthly population series published by the Census Bureau. The deflator used to construct real returns was the implicit deflator for this consumption series. By using monthly consumption data in our analysis of (2.4), we are assuming that agents make their consumption decisions at monthly time intervals, and that agents know the values of the returns R_{jt+1} when making their consumption decisions during the month.[5]

4. Empirical Results

The parameter vector $b_0' = (\alpha, \beta, A_1, \ldots, A_n)$ was estimated using the instrumental variable (IV) procedures proposed by Hansen (1982) and Hansen and Singleton (1982). To map our problem into the general nonlinear, rational expectations model considered by Hansen and Singleton (1982), let R_{jt+1}, $j = 1, \ldots, m$, be the real returns on the securities under consideration. We shall interpret u_{jt}, given by

$$u_{jt} \equiv [A(L^{-1})\{\beta^t\{A(L)C_t\}^{\alpha}\} - R_{jt+1}A(L^{-1})\{\beta^{t+1}\{A(L)C_{t+1}\}^{\alpha}\}]/(\beta^t\{A(L)C_t\}^{\alpha}), \quad (4.1)$$

as the disturbance associated with the jth return in our econometric analysis.[6] The vector of m disturbances is denoted by $u_t \equiv (u_{1t}, \ldots, u_{mt})'$. Eichenbaum, Hansen, and Singleton (1983) show that

$$E_t(u_{t+k}u_t') = 0, \quad \text{for} \quad |k| \geq n+1.$$

That is, the economic theory underlying the pricing equation (2.4) implies that the disturbances in our model have the covariance structure of a moving average process of order n (i.e., $MA(n)$). When preferences are time-separable ($n = 0$), the theoretical model implies that $\{u_t\}$ is a serially uncorrelated process.

[4] The only exception is that to compute the value-weighted return for April 1976 we used 3 pools which were issued between 48 and 60 months prior to April 1976. Of the total of 72 monthly returns, 50 were computed using only those pools which were issued at the beginning of the month for which the return was calculated. The number of pools used to compute the monthly returns ranged from 3 to 500. In terms of market value, the range was from \$10 million to \$1,362 million.

[5] This assumption represents a conservative endowment of information for investors. It implies that at the beginning of month $t+1$ agents cannot use consumption for month $t+1$ to forecast the return over that month.

[6] The numerator of (4.1) is scaled by $\beta^t\{A(L)C_t\}^{\alpha}$ so that the minimum of the criterion function we used in estimation is not obtained at the value of $\hat{\alpha} = -\infty$. Since this scale factor is in I_t, equation (2.4) implies that u_{jt} satisfies $E_t u_{jt} = 0$.

Next we let

$$x'_{t+n+1} = \left(\frac{C_{t-n}}{C_t}, \frac{C_{t-n+1}}{C_t}, \cdots, \frac{C_{t+n+1}}{C_t}, R_{1t+1}, \cdots, R_{mt+1}\right), \tag{4.2}$$

and define the function h by the relation

$$u_t = h(x_{t+n+1}, b_0). \tag{4.3}$$

The model presented in section two implies that $E_t[h(x_{t+n+1}, b_0)] = 0$ and, hence, for any q dimensional vector $z_t \in I_t$ it follows from the law of iterated expectations that

$$E[h(x_{t+n+1}, b_0) \otimes z_t] = 0, \tag{4.4}$$

where $\otimes$ is the Kronecker product and E is the unconditional expectations operator. Equation (4.4) represents $m \cdot q$ population orthogonality conditions from which a consistent estimator of b_0 can be constructed. For details, see Hansen and Singleton (1982).

The instrument vector, z_t, consisted of the constant unity and values of the growth rate of real per capita consumption and real returns dated t and earlier. That is, letting NLAG denote the number of lagged values of the variables used as instruments, z_t was given by[7]

$$z'_t = (1, C_t/C_{t-1} - 1, \cdots, C_{t-NLAG}/C_{t-NLAG-1} - 1, R_{1t}, \cdots, R_{mt-NLAG}). \tag{4.5}$$

Because consumption enters (4.1) and (4.4) in the form of ratios, the assumption that the vectors x_t and z_t are jointly stationary does not preclude certain types of growth (for example, an exponential trend) in aggregate real per capita consumption. Also, we emphasize that the estimation procedure accommodates conditional heteroskedasticity of the error term; that is, the conditional variance matrix $E[u_t u'_t \mid z_t, z_{t-1}, \ldots]$ need not be constant over time.

We first considered a non-time-separable model for the one-month holding period returns on eight-percent GNMA securities (GNMA8) and the Ibbotson and Sinquefield (1982) one-month holding period returns on long-term government bonds (LTGB). The polynomial $A(L)$ in (2.1) was of the form $A(L) = 1 + A_1 L$ (i.e., $n = 1$). For this value of n, the disturbance process, $\{u_t\}$, has a $MA(1)$ autocovariance structure, a fact which is accounted for in our choice of the criterion function used in estimation.[8] Interestingly, upon convergence, the point estimate of A_1 was always zero up to machine precision. Evidently, when consumption of nondurables plus services is used for C_t, the form of

[7] In our empirical work, NLAG ranged from zero to three. Larger values were not considered in order to keep the value of NLAG small relative to our sample size.

[8] The criterion function is the quadratic form $g_T(b)' W_T g_T(b)$, where $g_T(b)$ denotes the sample versions of the population orthogonality conditions given by (4.4) and W_T is the weighting matrix (see Hansen and Singleton 1982, section 3). The optimal choice of the weighting matrix W_T^*, in the sense of providing the smallest asymptotic covariance matrix of the estimator, for our choice of z_t was used for our empirical analysis (see Hansen 1982). The serial correlation properties of the disturbances have implications for the choice of W_T^*: see Hansen (1982) and Hansen and Singleton (1982). To construct W_T^*, we used the "modified Durbin" procedure proposed by Eichenbaum, Hansen, and Singleton (1983).

nonseparability admitted by (2.1) is not important for explaining the cross-sectional or temporal behavior of the returns GNMA8 and LTGB. Since the estimates of α and β and the test statistics were virtually identical to those reported below for the time-separable specification of preferences, we shall not consider the nonseparable model further.

The results for the model (2.5) with a time-separable parameterization of preferences (i.e., $n = 0$) are displayed in Table I. Estimates were obtained using GNMA8 alone and GNMA8 together with LTGB (hereafter, GNMA8-LTGB). The statistic (displayed in column five) for testing the validity of the overidentifying restrictions is equal to the product of the sample size (the number of time series observations) and the minimized value of the criterion function used in estimation of the two-dimensional vector b_0.[9] For the criterion function used in our analysis, Hansen (1982) shows that this product is distributed asymptotically as a chi-square with mq − 2 degrees of freedom (DF).

None of the test statistics indicate rejection of the model at conventional significance levels. The estimated coefficients of relative risk aversion, $|\hat{\alpha}|$, obtained using GNMA8 alone are between three and four. The results obtained for the returns GNMA8-LTGB suggest a smaller degree of risk aversion, with $|\hat{\alpha}|$ being about 1.9. All of these values of $|\alpha|$ are larger than unity, which is the value of $|\alpha|$ associated with logarithmic preferences. However, the standard errors are sufficiently large for the value of 1.0 to be within two standard errors of $|\hat{\alpha}|$. To provide further evidence about the validity of the null hypothesis $|\hat{\alpha}| = 1$, we re-estimated the models with α constrained to equal -1, using the weighting matrices (see footnote 7) associated with the unrestricted models. The difference between the chi-square statistics displayed in column 5 of Table I and the corresponding statistics for the restricted models are displayed in the last column of Table I. These statistics, which are the analogues of the likelihood ratio statistics for our problem, are distributed asymptotically as chi-square variates with one degree of freedom. The results for GNMA8 alone are less supportive of the null hypothesis than those for GNMA8-LTGB, but only in the case of GNMA8 with NLAG = 3 is the null rejected at the ten percent level.

Another interesting feature of the results is that the point estimates of $|\alpha|$ are substantially larger than those obtained by Hansen and Singleton (1982) using the value-weighted return on stocks listed on the NYSE (VWSR) for the period February 1959 through December 1978. For comparison, we have estimated the model using the returns GNMA8 and VWSR and displayed the results in the last two rows of Table I. The estimates of the parameters are similar to those obtained for GNMA8 alone. These findings suggest that the postwar period may not be homogeneous with regard to the joint behavior of consumption and asset returns, a possibility that warrants further investigation.

Finally, we note that the estimated values of the discount factor are slightly larger than unity. The large values of $(\hat{\beta} - 1)$ relative to their standard errors provides some evidence against the time-separable CRRA parameterization of preferences.

[9] For the case of time-separable preferences, the matrix W_T^* is an estimate of the inverse of the matrix $E[(h(x_{t+n+1}, b_0) \otimes z_t)(h(x_{t+n+1}, b_0) \otimes z_t)']$.

Table I

Summary of Results for the Model with Time-Separable Preferences

Returns[a]	NLAG	$\hat{\alpha}^{b}$	$\hat{\beta}^{b}$	χ^{2c}	DF	Test[c] H_0: $\alpha = -1$
GNMA8	1	−3.662	1.0090	.700	3	1.617
		(2.086)	(.0047)	(.127)		(.796)
GNMA8	3	−3.682	1.0095	.937	7	3.118
		(1.518)	(.0039)	(.004)		(.923)
GNMA8-LTGB	0	−1.924	1.0066	8.531	6	.685
		(1.078)	(.0026)	(.797)		(.592)
GNMA8-LTGB	1	−1.910	1.0067	12.051	12	.407
		(.954)	(.0025)	(.558)		(.476)
GNMA8-VWSR	0	−3.755	1.0085	7.943	6	
		(1.850)	(.0045)	(.758)		
GNMA8-VWSR	1	−3.407	1.0089	10.537	12	
		(1.508)	(.0039)	(.431)		

Notes:

a. GNMA8 = one-month, value-weighted holding period return on eight-percent GNMA securities. LTGB = one-month, holding period return on long-term U.S. Treasury bonds. VWSR = one-month, value-weighted holding period return on stocks listed on the NYSE.

b. Standard errors are given in parentheses.

c. Probability values are given in parentheses.

5. Concluding Remarks

The empirical results suggest that the restrictions on the behavior of returns on GNMA securities implied by the consumption-based model of asset prices considered here are generally consistent with the data. Of equal interest is the fact that the cross-sectional restrictions on the co-movement of GNMA8 and LTGB are not rejected by the data. Hence, the evidence from our analysis of the first-order conditions of an investors' intertemporal optimum problem is not supportive of the view that GNMA pass-through securities are "incorrectly" priced relative to long-term U. S. Treasury bonds.

Another interesting feature of our results is that all of the point estimates of $|\alpha|$ are larger than unity. The imprecision with which α is estimated does not allow us to conclude with confidence that the degree of risk aversion exhibited by investors is larger than that implied by logarithmic preferences. Nevertheless, the findings should not be interpreted as supporting the assumption $\alpha = -1$, since the differences $|\hat{\alpha}| - 1$ are quite large. In view of the important implications of different values of α for modeling strategies (see, e.g., Cox, Ingersoll, and Ross (1978) and Breeden (1982)), further research that attempts to estimate α more precisely seems warranted.

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