Stock And Bond Market Linkage In The Empirical Study Of Interest Rate Sensitivity Of Bank Returns

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Abstract

The bank stock's equilibrium pricing relation is the traditional CAPM augmented by a second factor to account for the unexpected changes in the interest rates. This paper examines the methodological issue of constructing an interest rate variable that is orthogonal to the market index. We test a new approach in which the interest rate variable and the market return are treated as the components of a bivariate vector, a suitable vector ARMA model is determined, and then the appropriate whitened residuals are used as the interest rate factor in the two-factor model. Results are compared with the results from other models in which prevailing orthogonalization procedure is used. Our investigation indicates that the robustness of the result depends, to a limited extent, on the procedure employed to orthogonalize the two factors.

I. Introduction

Interest rate sensitivity of the commercial bank stock return has been the subject of considerable research. Stone (1974) proposed a two-factor model incorporating both the market return and interest rate variable as return generating factors. Studies conducted by Fama and Schwert (1977), Lynge and Zumwalt (1980), Christie (1981), Flannery and James (1984), and Booth and Officer (1985) have found the interest rate factor to be an important determinant of the bank stock returns. Others have found the bank stock returns to be insensitive

(Chance and Lane (1980)) or only marginally explained by the interest rate factor (Lloyd and Shick (1977)). Sweeny and Warga (1986) used the APT framework of analysis to conclude that interest rate risk-premium exists but vary over time. Unal and Kane (1988) provided a critical review of the earlier research on this topic. However, existing research has left some methodological questions unanswered. In this paper, we focus on the methodological issue of interest rate factor specification. How important is it to incorporate the stock-bond market linkage in constructing the interest rate factor? It is expected that the stock-bond market linkage plays an important role. Does the robustness of the re-

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sults depend critically on the procedure employed to construct an orthogonal interest rate factor?

The remainder of this paper is divided into five sections. In Section II, we describe the interest rate risk of bank stock returns. The stock and bond market linkage is explained in Section III. The data used for this analysis is described in Section IV. Section V presents empirical results and Section VI concludes the paper.

II. Interest Rate Risk

Changing economic conditions alter the default- and liquidity-risk of a financial intermediary's nominal assets and liabilities. Further, they changes the inflation expectation. These changes represent a significant shift in the future investment opportunities for commercial banks having a wide variety of nominal assets and liabilities. Investors, in equilibrium, require additional compensation for bearing the risk of such changes. To capture such changes, a second factor representing the additional risk premium is added to the traditional single-index market model. The basic equation for bank stock returns is

$$r_{jt} = \beta_{0j} + \beta_{1j}r_{mt} + \beta_{2j}r_{it} + \varepsilon_{jt} \quad (1)$$

where r_{jt} is the bank stock return, r_{mt} is the market return, and r_{it} is the interest rate variable. Coefficients β_{0j} and β_{1j} are analogous to the alpha and beta coefficients of the single-index market model, and β_{2j} measures the interest rate risk. While Stone (1974) and others did not place *a priori* restriction on the sign of β_{2j} , the nominal contracting hypothesis (see, e.g., French, Ruback and Schwert (1983), Flannery and James (1984)) implies that it should be positive.¹ According to this hypothesis, the behavior of stock returns is partly explained by the holdings of nominal assets that lead to redistribution in the events of unexpected changes in inflation. The unexpected change in inflation reduces the market value of nominal assets and liabilities with

greater losses for longer maturity. Consequently, the cross-sectional differences in the interest rate beta of bank returns are partly explained by the differences in the maturity composition of the nominal assets and liabilities. As the maturity of bank assets is typically longer than that of its liabilities, β_{2j} is expected to be positive. Support for the hypothesis was found by Flannery and James but not by French et al.

III. Stock Market and Bond Market Linkage

An important issue in the empirical investigation of the two-factor model is the specification of an appropriate interest rate factor. Theoretical consideration of Factor Analysis requires that two factors, r_{mt} and r_{it} , be orthogonal whereby choice of the second factor (r_{it}) would not influence the first factor loading (β_{1j}). The resolution of this constraint requires a robust technique for the determining the unexpected changes in the interest rate that is uncorrelated with the market return. In existing studies, there are two approaches to specify the interest rate factor. In the first approach, the expected change in the interest rate is estimated using the high correlation between the observed interest rate and the market rate. The residual -- difference between observed and estimated rates -- is used as the interest rate factor. The second approach is to identify and estimate a univariate ARMA model for the interest rate variable and use the residuals from the ARMA model as the second factor. These two have been extensively used in the existing research.

This paper tests a theoretically superior technique to construct the interest rate factor. Here, the interest rate variable and the market return are treated as the components of a bivariate vector, a vector ARMA model is specified, and the appropriate whitened residuals are used as the interest rate factor.

A. Orthogonalization Procedure

Economic factors producing changes in

the market return also induce term structure movements. This leads to a high correlation between the market factor and the interest rate factor. Hence, market return can be used as an instrument variable to forecast the expected changes in the interest rates. To find the unexpected component of interest rates, the expected interest rate is purged by regressing r_{it} on r_{mt} and using the residuals. The systematic interest rate risk equation is:

$$r_{it} = \delta_0 + \delta_1 r_{mt} + \varepsilon_{it} \quad (2)$$

The residuals, ε_{it} , are the unsystematic interest rates and are used to replace r_{it} in equation (1).² Giliberto (1985) has questioned the validity of this approach on methodological grounds and pointed out that this orthogonalization procedure produces biased estimates of coefficients (intercept and β_{1j} in equation 1), and that the efficiency of β_{2j} is not improved. On the other hand, use of an unorthogonal interest rate factor leads to the errors-in-variable problem, i.e., the estimated coefficient β_{2j} also captures some of the effects responsible for changing the market factor and hence, it is not a true measure of the interest rate risk. Another problem associated with the second approach stems from the fact that interest rate (r_{it}) is usually autoregressive (Flannery and James (1984)). Therefore, residuals, ε_{it} , from equation (2) are autocorrelated unless GLS parameter estimation procedure is employed. To use the GLS procedure, a variance-covariance matrix has to be specified, which is not an easy task.

B. Univariate ARMA model

The second approach is to identify and estimate an ARMA model for the interest rate variable, r_{it} . The unanticipated change in interest rate from the estimated model (i.e., residuals) is used to replace r_{it} in equation (1). In general, the ARMA model of order (p, q) for the univariate time series, r_{it} , is written as:

$$r_{it} = \phi_1 r_{i,t-1} + \phi_2 r_{i,t-2} + \dots + \phi_p r_{i,t-p} + \mu - \theta_1 \varepsilon_{i,t-1} -$$

$$\dots - \theta_q \varepsilon_{i,t-q} + \varepsilon_{it} \quad (3)$$

where ε_{it} , $\varepsilon_{i,t-1}$, ... are identically and independently distributed random errors with mean zero. The ARMA procedure for the modeling of time series data is outlined in Box and Jenkins (1976). The modeling is usually done in three steps. First, a tentative parsimonious model is identified. Second, the parameters are estimated, and diagnostic (Box-Pierce Q) statistics and residual auto correlation plots are examined. The model is acceptable if the time series of residuals is white noise and the Box-Pierce Q statistics are significant.

This approach leads to unbiased estimates of all the coefficients in equation (1). The shortcoming of the univariate ARMA approach is that valuable information contained in the stock and bond market linkage is ignored. Consequently, coefficient β_{2j} captures some of the effects of economic factors producing stock market changes.

C. Vector ARMA Model

In recent years vector autoregressive moving average (VARMA) models have proved to be useful tools to describe the dynamic relationship between economic variables (see Hsiao (1974), Hasbrouck (1991) and Campbell and Ammer (1993)). A vector autoregressive moving average model of order (p, q) for k -dimensional time series, $R_t = (r_{1t}, r_{2t}, \dots, r_{kt})^T$, is generated by the following equation:

$$\Phi(B)R_t = \Theta(B)\varepsilon_t \quad (4)$$

where $\Phi(B) = (I - \phi_1 B - \phi_2 B^2 - \dots - \phi_p B^p)$ and $\Theta(B) = (I - \theta_1 B - \theta_2 B^2 - \dots - \theta_q B^q)$ is a $k \times k$ matrix, B is the back shift operator, I is a unit matrix, and ε_t is a sequence of an independent k -dimensional vector with zero mean and positive definite covariance matrix.³ In this paper, the interest rate variable and the market return are treated as the components of a bivariate vector, which is modeled as a vector AR process. The

estimated model provides the unanticipated change in interest rate variable to be used as the second factor in the augmented CAPM.

The vector AR model for the vector $\{r_{it}, r_{mt}\}$ is written as:

$$\begin{bmatrix} \phi_{II}(B) & \phi_{Im}(B) \\ \phi_{mI}(B) & \phi_{mm}(B) \end{bmatrix} \begin{bmatrix} r_{it} \\ r_{mt} \end{bmatrix} = \begin{bmatrix} \varepsilon_{it} \\ \varepsilon_{mt} \end{bmatrix} \quad (5)$$

The bivariate autoregressive models for the vector $\{r_{it}, r_{mt}\}$ is the following system of two equations:

$$r_{it} = \mu_I + \phi_{II,1}r_{it-1} + \phi_{II,2}r_{it-2} + \dots + \phi_{Im,0}r_{mt} + \phi_{Im,1}r_{mt-1} + \dots + e_{it} \quad (6a)$$

$$r_{mt} = \mu_m + \phi_{mI,0}r_{it} + \phi_{mI,1}r_{it-1} + \dots + \phi_{mm,1}r_{mt-1} + \phi_{mm,2}r_{mt-2} + \dots + e_{mt} \quad (6b)$$

and the parameters are jointly estimated. For the sake of parsimony, the number of parameters in the general model, equation (6), is limited, and the time series is truncated after a few lags.

IV. Data

We test bank stock returns from 1979 to 1990. This period covers two contrasting economic and regulatory environments. In addition, most of the existing research has been done using data from this period. The monthly returns, from January 1979 to December 1990, for 3-month T-bills, 6-month T-bill, 1-year T-note, 7-year T-note, and BAA corporate bonds are calculated using the corresponding yield series obtained from Citibank's money market tape.⁴ Monthly bank stock returns for the corresponding period are calculated using the closing prices and dividends obtained from Compustat's Price Dividend and Earning (PDE) data tape. An equally weighted market return obtained from the CRSP tape is used as the proxy for the market portfolio return. A sample of 88 banks is selected to form an equally weighted portfolio. This portfolio is used for estimating the interest

rate beta for different specifications of the interest rate factor. Another 21-bank portfolio is constructed for an out-of-sample test of forecasting accuracy. None of the banks included in the in-sample portfolio is included in the out-of-sample portfolio. The observation period from January 1979 to December 1990 is divided into two contrasting economic and regulatory periods: (1) a high interest rate and high-volatility period from January 1979 to December 1984 and (2) a low interest rate and low-volatility period from January 1985 to December 1990. The descriptive statistics of the sample reported in Table 1 exhibit an interesting fact --that the average return of the bank portfolio for 1985-90 is lower than that for 1979-84, even though the market beta is higher.

V. RESULTS

A. Interest Rate Factor

Estimated coefficients of the systematic interest rate equation (2), using all five interest rate variables, are reported in Table 2. Coefficient δ_0 is statistically insignificant except for 1979-84 period with a BAA bond index as the second factor. Coefficient δ_1 changes substantially over the two sub-periods, but it is statistically insignificant during 1985-90 period except with a BAA bond index as the second factor.⁵ The very low R^2 is consistent with Campbell and Ammer (1993) observation of low correlation between excess stock and bond return. Further, the Durbin-Watson statistic is significantly less than two, exhibiting the existence of residual autocorrelation (Table 2). This demonstrates that the interest rate residual model--which has been used in several earlier studies--changes over time and its relevance depends on the choice of the interest rate index. The structural instability of the systematic interest rate equation (2) contributes, to some extent, toward the instability of the interest rate risk. It is expected that any risk-premia would change with economic conditions, but to be statistically significant in one period and not in the other has important

Table 1
Descriptive Statistics of the Sample

	1979-84		1985-90	
	Average Return	Market Beta	Average Return	Market Beta
88-Bank Portfolio ^a	22.28	0.7259	6.48	1.0102
21-Bank Portfolio ^b	23.42	0.6174	5.87	0.8482
Market Portfolio	22.05	1.0000	8.58	1.0000
3-month T-bill	10.71		6.92	
6-month T-bill	10.80		7.12	
1-year T-note	11.70		7.62	
7-year T-note	11.91		8.67	
BAA Bond Index	14.04		10.84	

a: equally-weighted portfolio return of 88 banks is used for model estimation.

b: equally-weighted portfolio return of 21 banks is used for out-of-sample error analysis.

The average returns are reported on annualized basis.

Return on NYSE equally-weighted index is used as the market return.

bank management implications.

indicated by smaller values of ϕ_1 and ϕ_2 .

In Table 3 we report the estimated coefficients of the univariate ARMA models for all five interest rate variables. For periods (1979-84 and 1985-90), all five interest rate variables are generated by an AR(2) process with coefficient ϕ_1 being positive and ϕ_2 being negative. However, the AR(2) model for period 1985-90 exhibits weaker autocorrelation in interest rates as

The estimated coefficients of the proposed vector auto-regressive model for interest rate dependent variable (equation 6a) are reported in Table 4.⁶ The contemporaneous cross-correlation coefficient, $\phi_{lm,0}$, is statistically significant (at $\alpha=.001$) for 1979-84 period but not for the 1985-90 period. The lagged cross-correlation coefficient, $\phi_{lm,1}$, is statistically sig-

Table 2
Coefficients of the Systematic Interest Rate Equation:

$$r_{it} = \delta_0 + \delta_1 r_{mt} + \varepsilon_{it}$$

	1979-84				1985-90			
	δ_0	δ_1	R^2	F	δ_0	δ_1	R^2	F
3-month T-bill	-.0020 (-.15)	.4720 (2.04)	.056	4.18	.0037 (0.89)	-.089 (-1.13)	.018	1.28
6-month T-bill	-.0040 (-.35)	.5350 (2.63)	.090	6.94	.0033 (0.72)	.0469 (0.55)	.004	0.30
1-year T-note	-.0053 (-.50)	.5663 (3.00)	.114	9.00	.0045 (0.90)	.0402 (0.43)	.003	0.19
7-year T-note	-.0084 (-1.38)	.3550 (3.27)	.132	10.69	.0047 (1.01)	.1491 (1.73)	.041	3.01
BAA Bond Index	-.0078 (-2.40)	.2230 (3.86)	.175	14.89	.0027 (1.11)	.1376 (2.99)	.114	8.97

Return on NYSE equally weighted index is used as the market return.

For all cases the Durbin-Watson statistics is about 1.50.

Table 3
Coefficients of the Interest Rate Univariate ARMA Model:

$$r_{it} = \phi_1 r_{i,t-1} + \phi_2 r_{i,t-2} + \dots + \phi_p r_{i,t-p} + \mu - \theta_1 e_{i,t-1} - \dots - \theta_q e_{i,t-q} + \varepsilon_{it}$$

	1979-84					1985-90				
	Model	μ	ϕ_1	ϕ_2	Q-stat	Model	μ	ϕ_1	ϕ_2	Q-stat
3-month T-bill	AR(2)	.0049 (0.46)	.5652 (5.06)	-.3882 (-3.46)	44.6	AR(2)	.0027 (0.73)	.5493 (4.69)	-.2519 (-2.15)	48.9
6-month T-bill	AR(2)	.0042 (0.43)	.5546 (4.93)	-.3611 (-3.18)	42.2	AR(2)	.0033 (0.81)	.4790 (4.13)	-.2910 (-2.51)	50.1
1-year T-note	AR(2)	.0036 (0.36)	.5438 (4.81)	-.3450 (-3.02)	48.0	AR(2)	.0042 (0.95)	.4744 (4.16)	-.3205 (-2.80)	48.4
7-year T-note	AR(2)	-.0019 (-.09)	.5176 (4.56)	-.3391 (-2.96)	35.9	AR(2)	.0051 (1.25)	.4815 (4.29)	-.3693 (-3.28)	40.5
BAA Bond Index	AR(2)	-.0024 (-.84)	.6738 (5.78)	-.2521 (-2.13)	25.8	AR(2)	.0029 (1.23)	.5085 (4.37)	-.2617 (-2.25)	29.3

t-statistics is reported in the parenthesis; Q-statistics is calculated at lag 36.

nificant (at $\alpha = .001$) during 1979-84 when using 6-month T-bill or 1-year T-note as the interest rate variable but not with other interest rate variables. For period 1985-90, the lagged cross-correlation coefficient, $\phi_{lm,1}$, is statistically insignificant with all interest rate variables. The moderate value of R^2 reported in Table 4 is much higher than that reported in Table 2. Further, the DW statistic indicates that residuals of equation (6a)--to be subsequently used as the interest rate factor in equation (1)--are not autocorrelated. Finally, Table 4 exhibits a weaker linkage between stock and bond market return for 1985-90 period than for the 1979-84 period.

The forecasting accuracy of the vector auto-regressive model is compared with that of the orthogonalization procedure and the univariate ARMA using two statistical measures: the mean absolute error (MAE) and the standard deviation of error (SDE). The forecasting accuracy measures, MAE and SDE, are reported in Table 5. These results clearly indicate the superiority of the vector ARMA approach.

B. Two-Factor Model

The estimated coefficients of the two-factor model (equation 1) for period 1979-84

are presented in Table 6. The statistical significance of the interest rate factor (β_{2j}) varies with the choice of the interest rate index. The size and significance of the interest rate risk, holding other model specifications constant increases with these test securities: 3-month T-bills, 1-year T-note and 7-year T-note.⁷

The estimated coefficients of the two-factor model (equation 1), for period 1985-90, is reported in Table 7. In general, the value of β_{2j} for this period is smaller than the corresponding value for the 1979-84 period reported in Table 6. Further, β_{2j} is statistically insignificant with the 3-month T-bill return as the second factor but is significant with 7-year T-note return as the second factor. The results are somewhat mixed with 1-year T-note or BAA bond return used as the second factor. Interest rate risk is significant when the second factor is constructed using univariate ARMA or bivariate ARMA approach, but insignificant when second factor is constructed using the orthogonalization procedure or an unorthogonalized interest rate variable is used.

The possible causes for the change in the interest risk from 1979-84 and 1985-90 are (1) changes in real returns as reported by Fama

Table 4
Coefficients of the Interest Rate Vector Auto-Regressive Model:

$$r_{it} = \mu_i + \phi_{i1,1}r_{i,t-1} + \phi_{i1,2}r_{i,t-2} + \dots + \phi_{im,0}r_{mt} + \phi_{im,1}r_{m,t-1} + \dots + \varepsilon_{it}$$

	μ_i	$\phi_{i1,1}$	$\phi_{i1,2}$	$\phi_{im,0}$	$\phi_{im,1}$	R^2	F
Time period: January 1979-December 1984							
3-month T-bill	.0024 (0.21)	.5677 (5.13)	-.4043 (-3.66)	.4995 (2.43)	-.3488 (-1.68)	.37	9.43
6-month T-bill	.0020 (0.19)	.5593 (5.00)	-.3621 (-3.31)	.5025 (2.74)	-.3802 (-2.02)	.38	9.88
1-year T-note	.0017 (0.17)	.5331 (4.65)	-.3181 (-2.89)	.4762 (2.71)	-.3785 (-2.09)	.37	9.61
7-year T-note	-.0032 (-.53)	.4710 (3.90)	-.2822 (-2.46)	.2649 (2.46)	-.1901 (-1.70)	.34	8.23
BAA Bond Index	-.0043 (-1.37)	.6118 (4.96)	-.2163 (-1.90)	.1614 (3.02)	-.0535 (-.94)	.43	11.95
Time period: January 1985-December 1990							
3-month T-bill	.0036 (0.99)	.5775 (4.90)	-.2053 (-1.78)	-.1403 (-1.96)	-.0002 (-.00)	.31	7.15
6-month T-bill	.0039 (0.92)	.4809 (4.03)	-.2507 (-2.11)	-.0022 (-.03)	-.0804 (-.96)	.23	4.78
1-year T-note	.0047 (1.02)	.4758 (4.00)	-.2872 (-2.41)	-.0147 (-.16)	-.0869 (-.72)	.23	4.95
7-year T-note	.0050 (1.18)	.4530 (3.86)	-.3568 (-3.05)	.1150 (1.35)	-.0613 (-.72)	.27	5.90
BAA Bond Index	.0025 (1.06)	.4244 (3.40)	-.2671 (-2.23)	.0940 (1.96)	.0138 (0.28)	.27	5.89

t-statistics is reported in the parentheses. Coefficients of the equation: $r_{mt} = \mu_m + \phi_{m1,0}r_{it} + \phi_{m1,1}r_{i,t-1} + \dots + \phi_{mm,1}r_{m,t-1} + \phi_{mm,2}r_{m,t-2} + \dots + \varepsilon_{mt}$, is available to interested readers.

and Gibbons (1982), (2) unexpected changes in short-term and long-term inflation expectation, (3) shift of focus from short-term to long-term inflation expectation, (4) unexpected changes in risk aversion, (5) unexpected changes in the default risk of banks' nominal contracts, and (6) structural instability of the systematic interest rate equation (2)⁸. Our investigation explicitly tested the last two reasons and found some evidence for both. Further, we found that the interest rate risk is a phenomenon associated with relatively volatile interest rates and the strength of stock and bond market linkage.

The estimated value of β_{2j} using an unwhitened interest rate factor shows that the whitening of interest rate factors has no major effect on interest rate sensitivity. This fact was also observed by Flannery and James (1984), and Unal and Kane (1988). Using orthogonal factors reduces the errors-in-variable problem eluded earlier. Further, using an unwhitened interest rate factor, the model underestimates (4% to 6%) market betas compared with the estimates of market betas from the single-index model.

To test the robustness of our approach, the mean absolute error (MAE) and the standard

Table 5
Accuracy of Interest Rate Models to
Extract a Whiten Interest Rate Factor

	Orthogonalization Procedure		Univariate ARMA		Bivariate ARMA	
	MAE	SDE	MAE	SDE	MAE	SDE
Period: 1979-84						
3-month T-bill	.0700	.1041	.0627	.0903	.0617	.0863
6-month T-bill	.0636	.0916	.0566	.0818	.0563	.0768
1-year T-note	.0612	.0851	.0543	.0776	.0542	.0727
7-year T-note	.0375	.0489	.0341	.0456	.0341	.0434
BAA Bond Index	.0208	.0260	.0185	.0234	.0183	.0220
Period: 1985-90						
3-month T-bill	.0273	.0353	.0247	.0311	.0231	.0292
6-month T-bill	.0305	.0385	.0267	.0343	.0261	.0338
1-year T-note	.0334	.0416	.0299	.0368	.0296	.0367
7-year T-note	.0304	.0386	.0268	.0343	.0269	.0342
BAA Bond Index	.0155	.0206	.0149	.0193	.0146	.0190

MAE: Mean absolute error; SDE: Standard deviation of error.

deviation of error (SDE) of equation (1) for the out-of-sample 21-bank portfolio is calculated using unbiased estimates of β_{1j} and β_{2j} . Market beta, β_{1j} , is estimated using the single index model:

$$r_{jt} = \alpha_{0j} + \beta_{1j}r_{mt} + \varepsilon_{jt} \quad (7)$$

The estimated values of market beta, for periods 1979-84 and 1985-90, are 0.6134 and 0.8482 respectively. The interest rate beta, β_{2j} , is estimated using a reduced form equation:

$$(r_{jt} - \hat{b}_{1j}r_{mt}) = \beta_{0j} + \beta_{2j}r_{it} + \varepsilon_{jt} \quad (8)$$

The unwhitened 3-month T-bill return, 1-year T-note return and 7-year T-note return is used as the interest rate variable, r_{it} , to obtain three estimates of β_{2j} for each period. For period 1979-84, the estimated values of β_{2j} --with 3-month T-bill, 1-year T-note, and 7-year T-note returns as the interest rate variable-- are 0.0729, 0.1190 and 0.2450 respectively. For period 1985-90, the corresponding values are 0.0580,

0.0992 and 0.1300. Estimated values of β_{1j} , β_{2j} , and appropriate dependent variables (r_{mt} and whitened r_{it}) are used to calculate errors, ε_{jt} , and mean absolute error (MAE) and standard deviation of error (SDE) for out-of-sample 21-bank portfolio. MAE and SDE for 88-bank in-sample and 21-bank out-of-sample portfolios are reported in Table 8. The in-sample and out-of-sample error statistics (MAE and SDE) are compar-

able in magnitude.

VI. Conclusions

This paper compares three different approaches of specifying the interest factor in the empirical investigation of interest rate sensitivity of bank stock returns. The orthogonalization and univariate ARMA approach of whitening the interest rate variable are extensively used in the literature. The third, a theoretically superior vector ARMA approach was proposed in this paper. The vector ARMA approach provides better forecasting accuracy. However, there are no significant differences in the estimated values of the interest rate beta.

Suggestions For Future Research

Several opportunities exist for future research using vector ARMA approach in place of multiple regression. Finance literature is replete with work on asset pricing models using multiple regression. These models express asset returns

Table 6
Estimated Coefficients of the Two-Factor Model
with Different Interest Rate Factors (Time Period: 1979-84)

$$r_{jt} = \beta_{0j} + \beta_{1j}r_{mt} + \beta_{2j}r_{lt} + \varepsilon_{jt}$$

	β_0	β_1	β_2	R^2	F
3-month T-bill					
Unwhitened	.0055 (1.56)	0.673 (10.57)	0.111 (3.47)	.682	74.8
Orthogonalization Procedure	.0052 (1.49)	0.726 (11.73)	0.111 (3.47)	.684	74.8
Univariate ARMA	.0062 (1.75)	0.763 (10.45)	0.127 (3.30)	.684	73.2
Bivariate ARMA	.0059 (1.63)	0.732 (11.41)	0.123 (3.09)	.684	69.8
1-year T-note					
Unwhitened	.0061 (1.84)	0.629 (10.09)	0.171 (4.61)	.721	87.2
Orthogonalization Procedure	.0052 (1.57)	0.726 (12.37)	0.171 (4.41)	.716	87.2
Univariate ARMA	.0066 (1.95)	0.651 (10.52)	0.187 (4.35)	.711	84.1
Bivariate ARMA	.0059 (1.72)	0.732 (12.04)	0.192 (4.27)	.712	81.6
7-year T-note					
Unwhitened	.0083 (2.64)	0.599 (10.24)	0.358 (5.15)	.764	106.6
Orthogonalization Procedure	.0052 (1.70)	0.726 (13.33)	0.358 (5.97)	.755	106.6
Univariate ARMA	.0066 (2.04)	0.649 (11.00)	0.358 (5.13)	.732	94.1
Bivariate ARMA	.0059 (1.81)	0.732 (12.66)	0.374 (5.23)	.743	93.8

t-statistics is reported in the parentheses. Market beta, β_1 , using single-index model is 0.7259. In all cases the Durbin-Watson statistics is about 2.00.

as a function of only the contemporaneous value of independent variables. Often, the independent variables used in the model are known to have autoregressive properties. Unfortunately, autoregressive properties are not incorporated in the model. A vector ARMA approach would rectify that shortcoming without disturbing the underlying theory of the model. In particular, we may take a step further with the Arbitrage Pricing Model where asset returns are expressed as a

linear function of innovations in market-wise factors such as GNP, Inflation, Interest Rate, and Securities Market Returns. A vector ARMA model of the asset return and common factors will capture the autoregressive behavior of common factors without destroying the underlying rationale of APT.

Endnotes

1. β_{2j} is negative when change in bond yields and not the bond rate of return is used as the interest rate factor (as in Sweeney and Warga (1986)).

2. An equivalent orthogonalization procedure is to write the auxiliary equation as: $r_{mt} = \delta_0 + \delta_1 r_{lt} + \varepsilon_{mt}$ and substitute residuals, ε_{mt} , as the market rate factor, r_{mt} , in equation (1).

3. See Judge et al. (1985), Tiao and Tsay (1989), and Akaike (1973) for a discussion of multivariate time series models and parameter estimation.

4. The rate of return on a bond index is calculated from the yield series as: $r_{lt} = -(Y_{lt} - Y_{l,t-1})/Y_{lt}$, where Y_{lt} is the bond index yield at time t. Some investigators use: $r_{lt} = -(Y_{lt} - Y_{l,t-1})/Y_{l,t-1}$.

5. The accepted practice is to use the return

Table 7
Estimated Coefficients of the Two-Factor Model
with Different Interest Rate Factors (Time Period: 1985-90)

$$r_{jt} = \beta_{0j} + \beta_{1j}r_{mt} + \beta_{2j}r_{it} + \varepsilon_{jt}$$

	β_0	β_1	β_2	R^2	F
3-month T-bill					
Unwhitened	-.0020 (-.57)	1.010 (15.24)	0.051 (0.51)	.774	117.3
Orthogonalization Procedure	-.0018 (-.51)	1.010 (15.31)	0.051 (0.51)	.773	117.3
Univariate ARMA	-.0019 (-.53)	1.023 (15.21)	0.105 (0.91)	.775	118.6
Bivariate ARMA	-.0015 (-.40)	1.025 (15.00)	0.129 (1.05)	.768	113.1
1-year T-note					
Unwhitened	-.0023 (-.65)	1.010 (15.36)	0.103 (1.22)	.778	120.0
Orthogonalization Procedure	-.0018 (-.52)	1.010 (15.45)	0.103 (1.22)	.777	120.0
Univariate ARMA	-.0018 (-.52)	1.015 (15.78)	0.187 (2.00)	.784	125.5
Bivariate ARMA	-.0015 (-.41)	1.025 (15.35)	0.199 (2.08)	.780	120.0
7-year T-note					
Unwhitened	-.0026 (-.76)	0.984 (14.97)	0.175 (1.95)	.779	125.1
Orthogonalization Procedure	-.0018 (-.53)	1.010 (15.70)	0.175 (1.95)	.784	125.1
Univariate ARMA	-.0016 (-.48)	0.986 (15.52)	0.268 (2.70)	.794	132.7
Bivariate ARMA	-.0015 (-.42)	1.025 (15.64)	0.268 (2.65)	.795	125.8

t-statistics in the parentheses. Market beta, β_1 , using single-index model is 1.0102. For all cases the Durbin-Watson statistics is about 2.00.

- on default-free government bond as the interest rate factor. BAA bond return was used to test the existence of default risk-premia as a part of the interest rate risk-premia.
- The coefficients of the second equation in the system (6b) was estimated but is not being reported because it is not used in testing the two-factor model.
 - Results using 6-month T-bill return or BAA-bond return as the interest rate fac-

tor exhibit similar characteristics.

- It is possible that the first four factors are responsible the structural instability of the systematic interest rate equation (2).

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Table 8
Error Analysis of the Two-Factor Model with Different Interest Rate Factors

$$r_{jt} = \beta_{0j} + \beta_{1j}r_{mt} + \beta_{2j}r_{it} + \varepsilon_{jt}$$

	In-sample		Out-of-sample		In-sample		Out-of-sample	
	MAE	SDE	MAE	SDE	MAE	SDE	MAE	SDE
3-month T-bill								
Unwhitened	.0221	.0277	.0194	.0250	.0239	.0294	.0250	.0308
Orthogonalization Procedure	.0221	.0276	.0197	.0249	.0239	.0293	.0268	.0332
Univariate ARMA	.0283	.0279	.0200	.0249	.0237	.0293	.0267	.0332
Bivariate ARMA	.0223	.0282	.0202	.0250	.0239	.0295	.0271	.0335
1-year T-note								
Unwhitened	.0202	.0263	.0183	.0238	.0236	.0291	.0249	.0306
Orthogonalization Procedure	.0219	.0262	.0186	.0237	.0236	.0291	.0267	.0330
Univariate ARMA	.0202	.0266	.0188	.0237	.0231	.0286	.0264	.0326
Bivariate ARMA	.0204	.0267	.0190	.0235	.0232	.0288	.0269	.0330
7-year T-note								
Unwhitened	.0182	.0244	.0171	.0228	.0229	.0297	.0245	.0304
Orthogonalization Procedure	.0182	.0243	.0179	.0223	.0229	.0287	.0264	.0328
Univariate ARMA	.0191	.0255	.0188	.0231	.0224	.0280	.0258	.0321
Bivariate ARMA	.0191	.0254	.0187	.0227	.0225	.0283	.0265	.0328

MAE and SDE are mean absolute error and standard deviation of error, respectively; 88-bank portfolio is used for in-sample and an entirely different 21-bank portfolio is used for out-of-sample error analysis.

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