Journal Of Investment Management, Vol. 4, No. 4, (2006), pp. 52–72

www.joim.com

THE RELATION BETWEEN FIXED INCOME AND EQUITY RETURN FACTORS*

Jaime Lee[a], *Terry Marsh*[a,b], *Robert Maxim*[a] *and Paul Pfleiderer*[a,c]

This paper provides an analysis of the relation between equity and fixed income returns over time. As measured by realized correlation, this relation has changed substantially over the last decade, from positive to negative through the market collapse and is currently around zero. We find "jumps" in the co-movements of equity and bond returns at a daily frequency; these jumps can at times be attributed to "flight to liquidity" phenomena in the markets, and at other times, to apparent surprise announcements in expected inflation or related macro conditions. We find no evidence of short-run persistence in the jumps in daily co-movement of bond and equity returns, but there does seem to be a "regime-like" longer-run persistence in them, perhaps associated with Federal Reserve "management over the last decade.

1 Introduction

In this article, we study the relation between equity and fixed income returns where individual equity returns and the returns on fixed income (Treasury) securities across the maturity spectrum are modeled with a factor structure. The relation is of practical importance for at least three related reasons: (i) managers of portfolios of equity securities are often concerned with the "interest rate exposure" of the portfolios they construct; (ii) investors or managers who allocate their investments across both equities and fixed income securities will generally have strategies that depend quite strongly on the predicted relation between equity and bond returns; and (iii) credit risk managers who want to understand and model the interaction between movements in the Treasury yield curve and credit risk when the credit risk model is partly "driven" by equity price variation.[1] In all three cases, it is necessary that the modeling be done at the individual stock and Treasury maturity level. As will be discussed later, our modeling procedure allows us to examine such things as the validity of the common wisdom that a portfolio tilted toward financial stocks or building and construction sector stocks will be more "interest rate sensitive" than would a broadly diversified portfolio of stocks. We will also be able to determine whether some of these

*We owe special thanks to our colleague Indro Fedrigo who, in the process of inciting us to protest the thousand ways in which he must surely be wrong, helped us see things that we might never have seen otherwise.

[a]Quantal International Inc.

[b]University of California at Berkeley, Berkeley, CA, USA

[c]Stanford University, Stanford, CA, USA

"interest rate sensitive" stocks have more exposure to changes in the slope of the term structure than to its level.

Over the long run, we would expect broad equity market returns and bond returns to be positively correlated (equities and bonds are both vehicles for substituting current and future consumption). In the "short-run," however, realized correlation defined in almost any reasonable way has varied considerably. Over the last decade, the correlation has declined from about 50% in the mid-1990s to a low of –40% in 2002, and it is now around zero. We conclude that this variation is primarily associated with changes in the level of the term structure; changes in the slope of the yield curve have a steadier, albeit weaker, impact on equity returns.

We examine co-movements in equity and bond returns at a daily frequency. We find that the co-movement itself displays substantial "jump" behavior. In particular, we find that two different types of market conditions seem to be associated with these jumps. One is a "flight-to-quality" or "flight-to-liquidity" condition; the other seems to be associated with surprise revisions in expected inflation or macro conditions. Moreover, while jumps in the co-movement of equity and bond returns are loosely associated with "volatile" market conditions, our analysis suggests that those conditions are not well modeled by a simple symmetric volatility measure.

Our finding to date is that there is no persistence in jumps in equity–bond co-movements across adjacent days, and it does not seem useful to condition the co-movements on prior days' stock and/or bond returns, that is, there is no obvious "GARCH effect" at a daily frequency. At the same time, however, we do see evidence of a long-term persistence, that is, there is a long-term "memory" in the co-movements. It appears that it may be possible to describe this long-term persistence in co-movement in terms of a "regime" involving Federal Reserve "management" of interest rates. Interestingly, the post-2000 negative realized correlation in equity and bond returns was last seen in the early to mid-1960s, when the term structure environment looked quite similar to that seen today.

The rest of the paper proceeds as follows: Section 2 discusses stylized facts on the relation between equity and bonds over the period January 9, 1996 to July 1, 2005. We look at co-movements between bond and equity index returns for different economic sectors, size, and style (value-growth). We also discuss correlation between equity returns and term structure factors, that is, the level and slope factors. In Section 3, we explore possible determinants of the equity–bond return co-movements, especially whether volatility can explain changes in the co-movement between equity and bond returns. Sections 4 and 5 deal jumps in daily equity–bond return correlation. We look more closely at the large events in the daily equity and bond co-movements to investigate whether these events are persistent and if so, whether they can be conditioned on the prior events. Section 6 explores long-term dependency in co-movements between equity and bond returns, and Section 7 concludes.

2 The relation between equity and bond returns: Stylized facts

We use daily returns on US equities and fixed income securities over the period January 9, 1996 to July 1, 2005 from Quantal's database. The universe includes both non-survivor and new companies over this period and is screened for illiquidity and other considerations. There are on average 3276 stocks over the period.[2]

Figure 1 shows the realized correlation between returns on the 500 largest capitalization[3] US stocks and an equally weighted index of the returns on Treasuries with maturities of 6 months, 1, 2, 3, 5, 7,

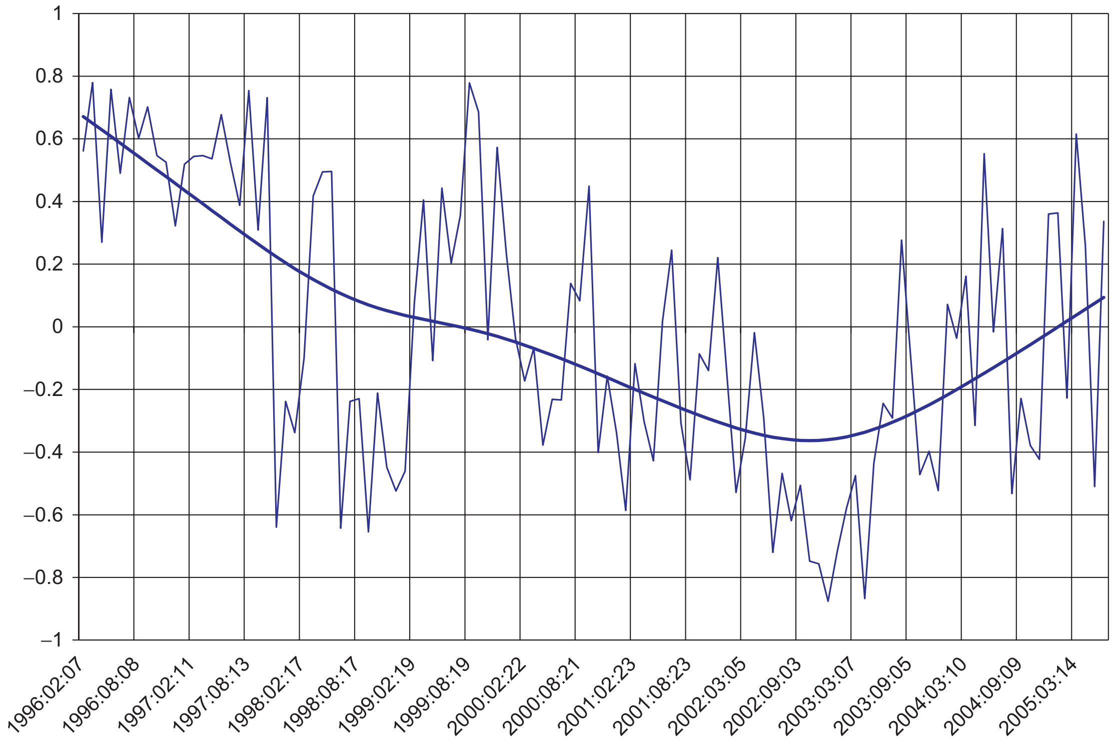

Figure 1 Realized correlation between US equity and bond index returns January 9, 1996–June 13, 2005. Realized correlation is calculated for non-overlapping months by taking the average intra-month daily correlation. Equity index is a value weighted index of the largest (by market capitalization) stocks in the US, rebalanced daily. Bond index is an equally weighted index of implied zero-coupon returns on treasuries with maturities of 6 months, 1, 2, 3, 5, 7, 10, and 20 years. The smoothed curve of the realized correlation is calculated with the Hodrick–Prescott filter (smoothing parameter 14,400).

10, and 20 years.[4] The realized monthly correlation is calculated for non-overlapping months and can be thought of as a joint moment version of the "Merton volatility estimator." A smoothed curve fitted to the realized correlation with a Hodrick–Prescott filter is superimposed on the "jagged" realized correlation series in Figure 1—the "jaggedness" *per se* will be discussed later. Figure 1 time-series behavior of realized correlation is consistent with the results reported in Li (2002, Figure 3)[5] over his sample period 1996–2002: it shows that the correlation between large cap stock returns and the bond returns decreased from a high in the 50% range at the beginning of the sample period, to an *ex post* minimum around −40% in 2002, and then has increased again to where it is roughly zero in mid-2005.

Table 1 reports mean correlation between bond and equity index returns for the full sample period as well as for the two sub-sample periods, 1996.01.09–2000.12.29 and 2001.01.03–2005.07.01—as shown in Figure 1, the correlation changes significantly between these two sub-periods: In the first 5 year sub-period, the mean correlation between the equity and bond index returns is 0.18 (t-stat = 3.23), whereas in the second sub-period it is −0.25 (t-stat = −5.19).

The negative realized correlation between equity and fixed income returns over the latter part of this 10-year period has been "unusual", both in the sense that negative correlation has not been seen

Table 1 Average correlation between equity index and bond returns. All equity indices, top 500, top 2000, top 10%, and bottom 10%, are value weighted index returns. 6 month and 10 year are returns on 6-month and 10-year bonds. Bond index is an equally weighted index of returns on bonds with maturities of 6 months, 1, 2, 3, 5, 7, 10, and 20 years. Level factor is (a negative of) changes in the 6-month yield and the slope factor is (a negative of) changes in the difference between 10-year and 6-month yields. Correlations are calculated using non-overlapping 21 days of data.

	Top 500	Top 2000	Top 10%	Bottom 10%
Sample period: 1996.01.09–2005.06.13				
6 month	−0.05	−0.06	−0.05	−0.02
10 year	−0.02	−0.03	−0.02	−0.07*
Bond index	−0.02	−0.02	−0.01	−0.07*
Level factor	−0.05	−0.05	−0.05	−0.02
Slope factor	0.01	0.01	0.02	−0.06*
Sub-sample period: 1996.01.09–2000.12.29				
6 month	0.05	0.05	0.05	0.02
10 year	0.18**	0.18**	0.19**	0.04
Bond index	0.18**	0.18**	0.19**	0.04
Level factor	0.06	0.06	0.06	0.03
Slope factor	0.22**	0.22**	0.23**	0.06
Sub-sample period: 2001.01.03–2005.06.13				
6 month	−0.18**	−0.19**	−0.18**	−0.12**
10 year	−0.26**	−0.27**	−0.26**	−0.23**
Bond index	−0.25**	−0.26**	−0.25**	−0.23**
Level factor	−0.19**	−0.20**	−0.19**	−0.12**
Slope factor	−0.23**	−0.24**	−0.23**	−0.22**

*Significant at the 5% level; **Significant at the 1% level.

since the early to mid-1960s, and in that most models would suggest a positive steady-state correlation. As Li (2002), Scruggs and Glabadanidis (2001) and others have also found, realized correlation tended to increase steadily from the late 1960s to the mid-1990s, peaking in the positive 20%–50% range. Li shows that this behavior of realized correlation is also similar across countries, with the notable exception of Japan. Baur and Lucey (2006) also report a similar time series pattern of realized correlation between U.K. and E.U. Stock and Bond indices, and that Germany seems to be the European exception.

For further descriptive analysis, we look at the realized correlation between returns on different subsets of stocks and the returns on the bond index, and also with term structure factors. Figure 2 shows the realized correlation between the returns on the largest capitalization decile of stocks and bond index returns, and does the same for the lowest capitalization stock returns. The large cap realized correlation is higher than that for small caps at the beginning of the sample period. The mean correlation in the first sub-sample period is 0.19 (t-stat $= 3.27$) for the large cap stocks and 0.04 (t-stat $= 1.03$) for the small cap stocks; Guidolin

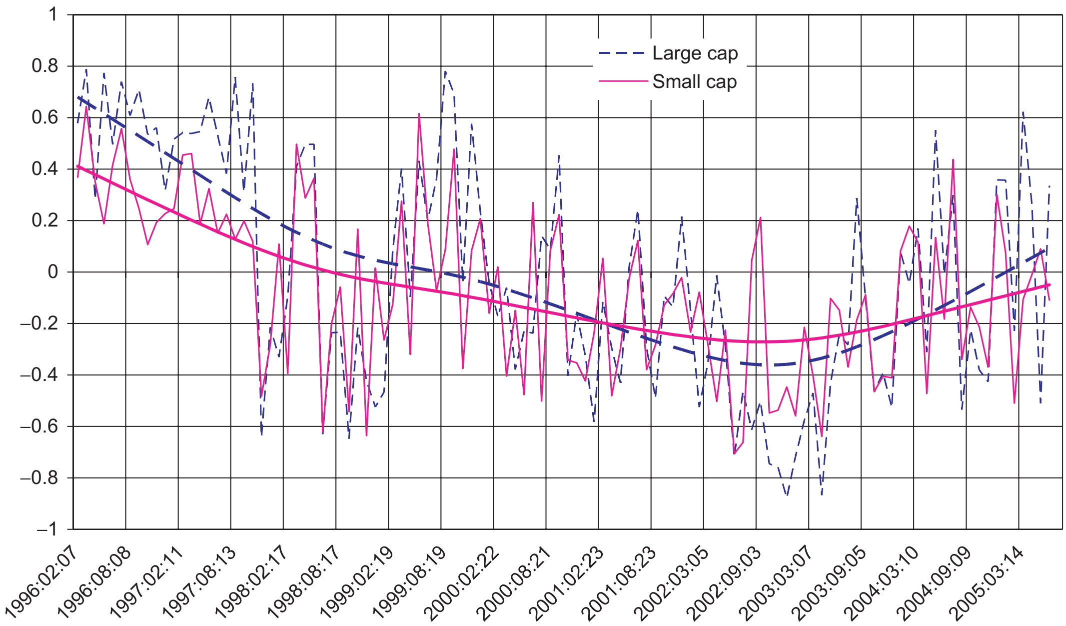

Figure 2 Realized correlation between bond index and large/small cap index returns. Large (small) cap index is a value weighted index of stocks in the top (bottom) 10 percentiles. The smoothed curve of the realized correlation is calculated with the Hodrick–Prescott filter (smoothing parameter 14,400).

and Timmermann (2004) also report a similar result over the longer sample period 1954:01–1999:12[6] that ends 1 year earlier than our first sub-period. However, in the second sub-sample period, the mean correlation is −0.25 (t-stat = −5.17) and −0.23 (t-stat = −6.42) for the large cap and small cap stocks respectively, that is, both small and large stocks have had roughly the same correlation with bonds in the last 5 years, and the point estimation of the correlation increased in absolute magnitude of small cap stock returns with bond returns has increased.

So far, we have examined co-movements between equity returns and an equally weighted index of bond returns. We now look more microscopically at whether the observed changes in those co-movements are due to changes in the level or in the slope of the term structure. We will define "level" and "slope" of the term structure in three ways: (i) the level of the term structure is the 10-year yield, and the slope is the *orthogonalized* difference between 10-year and 6-month yields, where orthogonalization is performed by regressing changes in the differences between the 10-year and 6-month yields on changes in the level variable, the 10-year yield in this case; (ii) the level of the term structure is defined as the 6-month yield, and the slope as in (i) but orthogonalized with respect to the 6-month yield; and (iii) term structure level and slope factors are defined implicitly by fitting principal components to yield changes, along the lines of say Litterman and Scheinkman (1991).

Figure 3a shows the time series correlation between returns on the 500-large cap index and the negative of changes in the term structure level and slope as defined in (i) we use the negative of the term structure variables to facilitate the comparison with other figures where with involving. Figure 3a shows that equity returns co-vary over time with the level of the term structure in a similar fashion to bond returns themselves; this is not surprising, since the equally weighted bond index is quite close to a (non-linear)

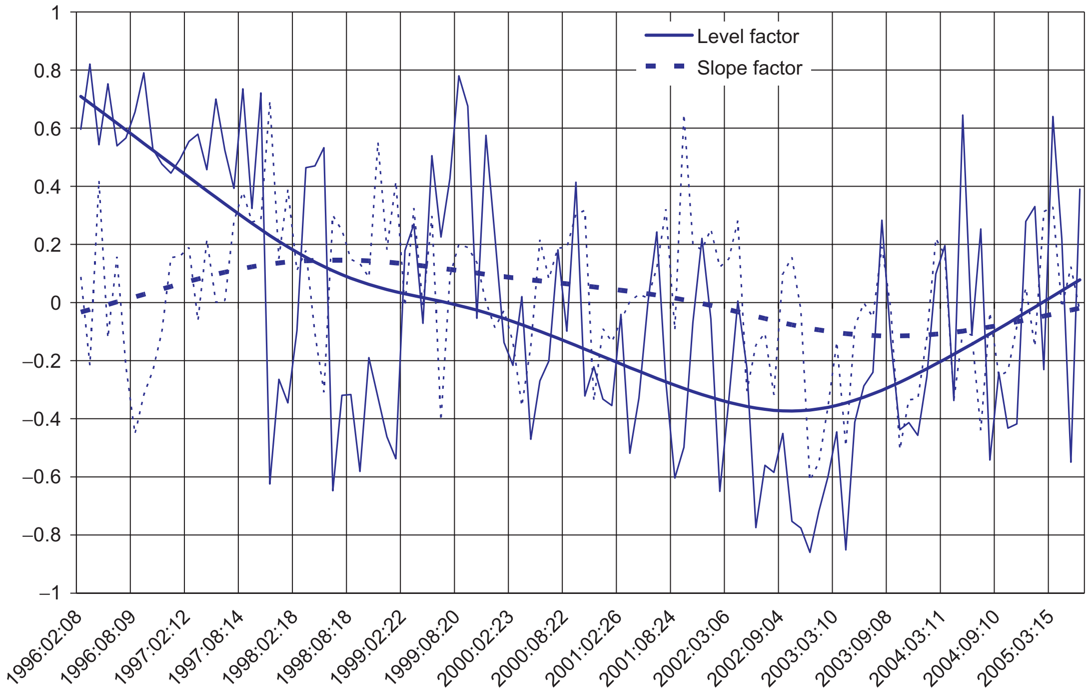

Figure 3a Correlation between explicit fixed income factors and top 500 equity index. The level factor is the 10-year yield and (the negative of) its daily change is used to calculate the correlation. The slope factor is the difference between the 6-month and 10-year yields, orthogonalized with respect to the daily change in the 10-year yield (the "level factor"). We use the (negative of the) daily change of the slope factor to calculate the correlation. The correlation is calculated using non-overlapping 21 days of daily data. The top 500 equity index is a value weighted index of the 500 stocks with the largest market capitalization. The smoothed curve of the realized correlation is calculated with the Hodrick–Prescott filter (smoothing parameter 14,400).

transform of the 10-year yield. The interesting feature is the co-movement of equity returns and (orthogonalized) slope: prior to 2001, when the orthogonalized slope of the term structure decreased and/or the level of 10-year yields decreased, equity prices increased on average. Post-2000, equity returns essentially did not respond to changes in term structure slope and they increased when the level of the term structure increased.

The picture presented in Figure 3a is confirmed by a regression of equity returns on the level and orthogonal slope variables.[7] The regression results are presented in Table 2. Over the full sample period, the coefficients on the two variables are –0.024 and 0.020 respectively, where both coefficients are significant at conventional levels. The full period result reflects primarily the second sub-period from January 3, 2001 to July 1, 2005—for that sub-period, the level coefficient is −0.063 and significant, while it is positive 0.019 and significant in the first sub-period—the switch in sign between positive correlation of equity returns with the level of yields in the first sub-period to negative post-2000 is consistent with the realized correlation in the negative region in Figure 3a.

Interestingly, in the regression of equity returns on changes in term structure level and orthogonalized slope, the slope coefficient is relatively constant and

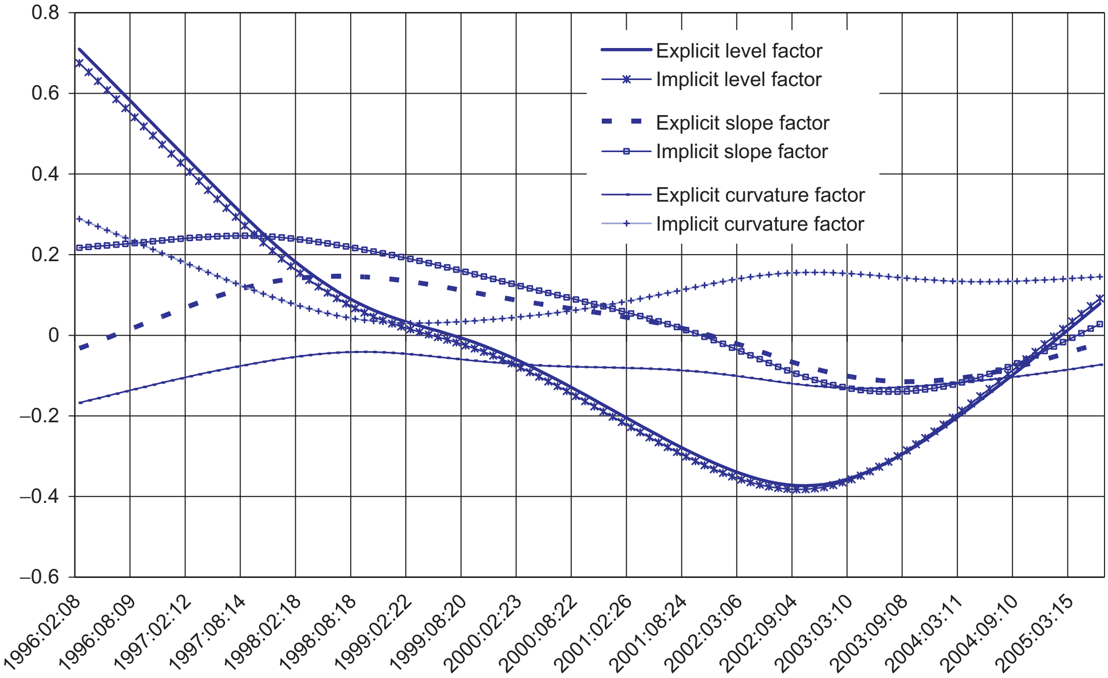

Figure 3b Correlation between fixed income factors and top 500 equity index. The explicit level factor is the 10-year yield and (the negative of) its daily change is used to calculate the correlation. The explicit slope factor is the difference between the 6-month and 10-year yields, orthogonalized with respect to the daily change in the 10-year yield (the "level factor"). The explicit curvature factor is changes in the difference between the 5-year yield and the average of the 10- and 1-year yields, orthogonalized with respect to the level and slope factors. The implicit factors are the first three factors from the principal component analysis on yield changes. The smoothed curves of the realized correlations, calculated with the Hodrick–Prescott filter (smoothing parameter 14,400), are shown above.

stable—an increase or decrease in term structure slope over and above that implied by a change in term structure level is associated with roughly a 2 basis point basis intern, approximately 0 in the opposite direction. In the second sub-period, the coefficient on the orthogonal slope variable is somewhat sensitive to outliers—if outliers are excluded,[8] the coefficient is insignificantly different from zero (as suggested by Figure 3a).

When we fit term structure level and slope factors implicitly by fitting principal components to yield changes, that is, definition (iii), we find that the correlation of equity returns with these level and slope factors looks very similar to that estimated using the explicit definition (i), as just described. This can be seen in Figure 3b where the correlations are shown both for the explicit definition (i) of level and slope, and the implicit definition (iii). The result itself is not surprising—the implicit level factor gives roughly equal arithmetic weight to the yields at different maturities, while the 10-year yield is roughly a geometric average of shorter-maturity (equivalent zero-coupon) yields.[9]

It is common to identify the "level" of the term structure with the short-term rate of interest. That is done in definition (ii), where the level of the term structure is defined as the 6-month yield, and

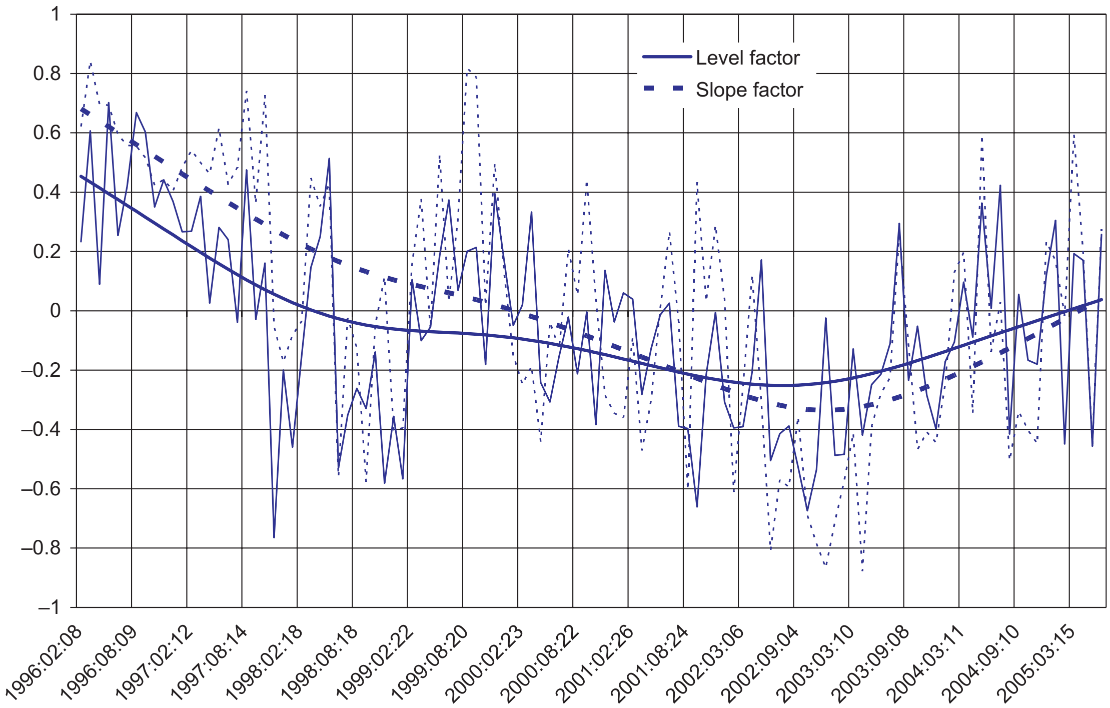

Figure 3c Correlation between explicit fixed income factors and top 500 equity index. The level factor is the 6-month yield and (the negative of) its daily change is used to calculate the correlation. The slope factor is the difference between the 6-month and 10-year yields, orthogonalized with respect to the daily change in the 6-month yield (the "level factor"). We use the (negative of the) daily change of the slope factor to calculate the correlation. The correlation is calculated using non-overlapping 21 days of daily data. The Top 500 equity index is a value weighted index of the 500 stocks with the largest market capitalization. The smoothed curve of the realized correlation is calculated with the Hodrick–Prescott filter (smoothing parameter 14,400).

the slope is orthogonalized with respect to the 6-month yield. Figure 3c shows the equity-level and equity-slope correlation when the 6-month yield ("short rate") is used to define term structure level. The results look quite different from those using the previous two definitions of term structure level and slope—indeed, the graph suggests that the co-movement between equity returns and changes in level and slope are more or less equal and shift in a parallel fashion over time. One interpretation is that the 6-month yield is a poor measure of the "market level" of the term structure when short-term interest rates are "managed" by the Fed, which most observers agree to be the case over much of our sample period, particularly post-2000. We will return to this point later.

Next, we look at differences in bond–equity return correlation across different equity sectors and a value-growth categorization for equities. The degree of difference gives us one indication of how important it might be to model that correlation at the stock rather than index level. The time series of correlations between returns for equity sectors defined using the ICB classifications, and the Dow Jones US Value and Growth Indexes, are shown in Figure 4. Per conventional wisdom, utility stocks are most correlated with bond price

Table 2 Regression of equity index returns on the level and slope factors. The level factor is changes in the 10-year yield, and the slope factor is changes in the difference between 10-year and 6-month yields. Here the negative of the factors are used for regression.

	Const	Level	Slope
Sample period: 1996.01.09–2005.07.01			
Coeff	0.000	−0.024	0.020
t-stat	1.437	−5.983	2.983
R^2	0.019		
Sub-sample period: 1996.01.09–2000.12.29			
Coeff	0.001	0.019	0.020
t-stat	1.983	3.145	2.151
R^2	0.011		
Sub-sample period: 2001.01.03–2005.07.01			
Coeff	0.000	−0.063	0.031
t-stat	0.025	−12.231	3.232
R^2	0.122		

changes, technology the least. Correlations with growth stocks behave most like correlations with tech stocks—no surprise there—but value stock return correlations with bond returns behave more like those of financial stocks than utility stocks. The other salient feature of Figure 4 is that the variation over time in the co-movement between equity and bond returns is quite uniform across all classifications; the uniformity suggests that the transition to negative correlation post-2000 is not driven, for example, by changes in expected inflation that have a differential impact on the cash flows across economic sectors.

Average correlations between bond returns and equity sector returns are given in Table 3 for the two sub-periods 1996.01.09–2000.12.29 and 2001.01.03–2005.06.13. A couple of additional features stand out: Pre-2001, the sectors whose stock returns are most correlated with term structure changes are utilities and financial—decreases in both the level and in the slope of the yield curve were associated with increases in equity prices in these sectors; this is consistent with the plot of correlation between equity returns and bond returns in Figure 4. The fact that financial stock returns increase with decreases in the slope of the yield curve is one confirmation of the perhaps obvious fact that the financial sector as a whole has developed beyond a "borrow short and lend long" business.

Post-2001, there is little consistent interaction between changes in the level of the yield curve and equity returns in any sector. Interestingly, equity returns still co-varied with the slope of the yield curve across most sectors, but in the opposite direction to prior-2001, that is, a decrease in slope of the yield curve was associated with a decrease in equity prices. Moreover, this inverted pattern of co-variation with the slope of the yield curve was significant for sectors like health care, technology, and industrial—the two notable exceptions were financials and utilities, where there was a disconnect between what happened to equity returns and term structure movements. In short, the co-movement between equity returns and term structure movements post-2000 appears to defy conventional wisdom as to how different sector stocks "should" typically behave. Given this conclusion, we turn to a closer examination of what might have been driving regime differences pre- and post-2000.

3 Determinants of the relation between equity and bond returns

The substantial change in the equity–bond return correlation—certainly from the 1960s and even over our decade-long sample period—suggests that there may be distinct "regimes" or states defining different joint behavior of equity and fixed income returns. Two applications of regime-switching

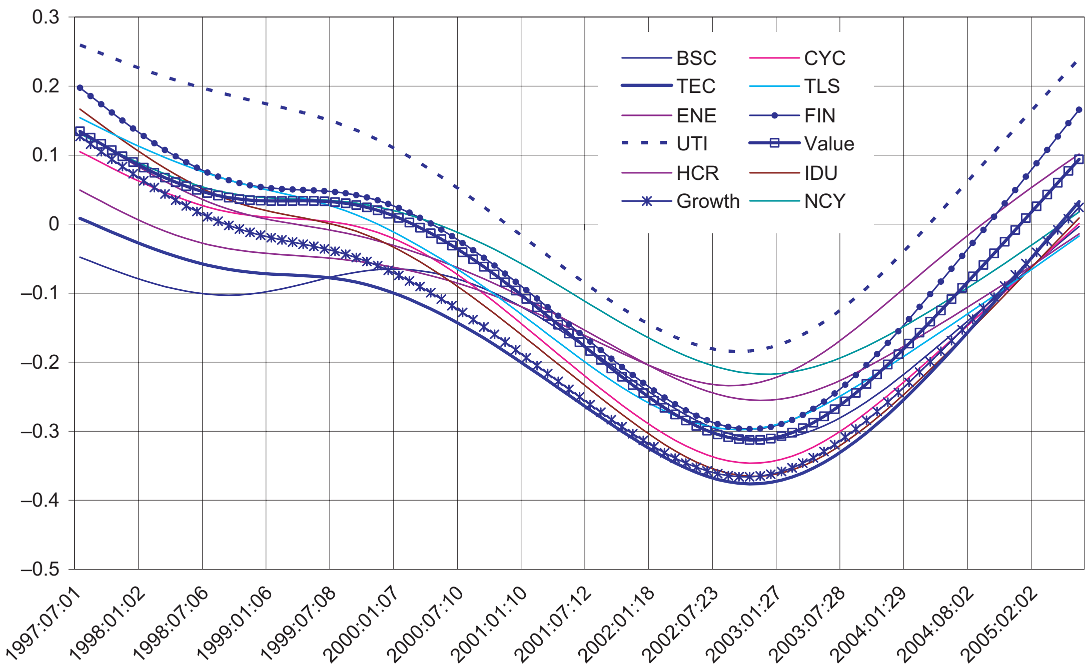

Figure 4 Correlation between bond index and equity sector indices. The 10 Dow Jones economic sectors are used to define the sector indices. The Dow Jones US value and Dow Jones US growth indexes are used. The sample period is 1997.06.02–2005.06.30. The smoothed curves of the realized correlations, calculated with the Hodrick–Prescott filter (smoothing parameter 14,400), are shown here.

models to joint equity–bond returns, both of which use a variant of a multivariate GARCH model, can be found in Scruggs and Glabadanidis (2001) and Guidolin and Timmerman (2004). Scruggs and Glabadanidis fit asymmetric dynamic GARCH covariance models to returns for the value weighted index of NYSE–AMEX stocks and the long-term government bond index, while Guidolin and Timmerman (2004) model the returns on large and small capitalization stocks versus 10-year T-Bond Returns as following a regime-dependent multivariate GARCH process. Guidolin and Timmerman's preferred model, for the period January 1954 through December 1999, contains four states: a "crash" state with regime a "low growth" regime, a "sustained bull market regime," and a "bounce-back" regime.

Li (2001) investigates various macro-business cycle variables that may affect the equity–bond return correlation and concludes that uncertainty about expected inflation is the most dominant. Connolly *et al.* (2004) propose making the co-movement of equity and bond returns a function of stock return uncertainty, which they measure by the VIX index.[10] The intuition behind the inclusion of stock market uncertainty in their regression model is broadly consistent with Guidolin and Timmermann's (2004) reasonably heavy use of "crash" and "volatility" in characterizing their fitted regimes. We fit the Connolly, Stivers, and Sun model:

$$B_t = a_0 + [a_1 + a_2 \ln(\text{VIX}_{t-1})]S_t + \nu_t \qquad (1)$$

where B_t is the day-t 10-year T-bond return, VIX_{t-1} is the day $t-1$ VIX, and S_t is the day-t value-weighted NYSE–AMEX–NASDAQ CRSP equity index return. Over the sample period

Table 3 Average correlation between equity sector indices and bond returns. The 10 Dow Jones economic sectors are used to define sectors and all equity indices are value weighted. 6 month and 10 year are returns on 6-month and 10-year bonds. Bond index is an equally weighted index of returns on bonds including 6 months, 1, 2, 3, 5, 7, 10, and 20 years. Level factor is (a negative of) changes in the 6-month yield and the slope factor is (a negative of) changes in the difference between 10-year and 6-month yields. Correlations are calculated using non-overlapping 21 days of data.

	BSC	CYC	ENE	FIN	HCR	IDU	NCY	TEC	TLS	UTI
Sample period: 1996.01.09–2005.06.13										
6 month	−0.08**	−0.05	−0.03	0.00	−0.02	−0.06*	−0.03	−0.09**	−0.07**	0.05
10 year	−0.08*	−0.03	−0.03	0.05	0.00	−0.03	0.05	−0.12**	−0.01	0.12**
Bond index	−0.08*	−0.03	−0.02	0.06	0.01	−0.03	0.05	−0.12**	−0.01	0.12**
Level factor	−0.08**	−0.05	−0.03	0.00	−0.02	−0.06*	−0.03	−0.09**	−0.07*	0.05
Slope factor	−0.05	0.00	−0.02	0.07	0.02	0.00	0.08*	−0.09**	0.03	0.13**
Sub-sample period: 1996.01.09–2000.12.29										
6 month	−0.02	0.05	0.05	0.11*	0.07	0.04	0.06	−0.02	0.00	0.15**
10 year	0.05	0.17**	0.07	0.25**	0.17**	0.17**	0.20**	0.02	0.17**	0.30**
Bond index	0.05	0.17**	0.09*	0.26**	0.17**	0.17**	0.21**	0.01	0.17**	0.30**
Level factor	−0.02	0.06	0.04	0.12*	0.07	0.05	0.07	−0.02	0.01	0.16**
Slope factor	0.10*	0.20**	0.08	0.27**	0.19**	0.20**	0.23**	0.06	0.23**	0.30**
Sub-sample period: 2001.01.03–2005.06.13										
6 month	0.00	0.02	0.00	0.02	0.01	0.00	0.04	0.01	0.04	0.03
10 year	−0.07*	−0.04	−0.05	−0.03	−0.06*	−0.06**	−0.04	−0.06	−0.02	−0.02
Bond index	−0.06*	−0.04	−0.04	−0.02	−0.05	−0.05	−0.03	−0.04	−0.01	−0.01
Level factor	0.00	0.01	0.00	0.01	0.01	−0.01	0.03	0.01	0.04	0.03
Slope factor	−0.09**	−0.06	−0.06*	−0.04	−0.09**	−0.08**	−0.07*	−0.09**	−0.05	−0.05

* Significant at the 5% level; ** significant at the 1% level.

January 9, 1996 to December 31, 2000, we get:

$$\hat{B}_t = \underset{(0.269)}{0.004} + [\underset{(11.244)}{1.866} - \underset{(-11.056)}{0.568} \ln(\text{VIX}_{t-1})]S_t \quad (2)$$

with an R^2 of 0.09. If we use Quantal's conditional variance–covariance forecast for equity returns, based on historical daily equity returns, to forecast the daily volatility for the large-cap equity index, we obtain:

$$\hat{B}_t = \underset{(0.80)}{0.01} + [\underset{(8.46)}{1.13} - \underset{(-8.33)}{0.38} \ln(\text{QV}_{t-1})]S_t \quad (3)$$

with an R^2 of 0.06, where QV_{t-1} is the day $t-1$ Quantal volatility forecast for the large-cap equity index, and the sample period is January 9, 1996 to December 31, 2000. This period most closely matches the Connolly, Stivers and Sun sub-period July 1993 to December 2000 for which they report $\hat{a}_2 = -0.513$ (t-stat $= -10.48$, $R^2 = 0.15$). Taking into account that our respective sample periods do not precisely match, the results in (2) reasonably replicate those of Connolly *et al.* then.

We now investigate this apparent relationship between equity–bond return co-movement and volatility. It seems very important to distinguish whether there are asymmetries in the equity–bond co-movements, and whether these co-movement changes over time are a function of potential conditioning information like volatility. For example, a short-term investor who could predict that bonds will appreciate in price on a day when stock prices fall sharply—the "crash" scenario—will make a quite different allocation between equities and bonds than an otherwise identical investor who believes that there is a 50–50 chance of bonds going up or down in a crash scenario, that is, a "symmetric volatility" in bond returns on that day. If possible, we'd like to differentiate among regimes such as "crash," "high stock market uncertainty," "flight to quality," "liquidity crunch," or "dramatic shift in investor risk aversion."

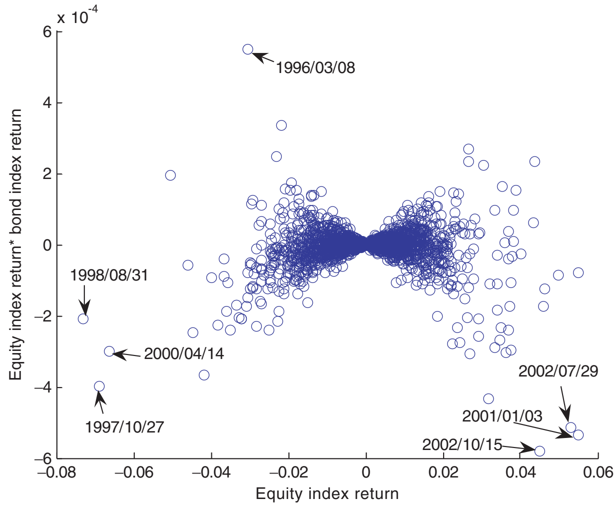

Figure 5 Scatter plot of daily equity index return and (equity index return ∗ bond index return).

To begin, we plotted the day-to-day cross-product between the daily value-weighted large cap index return and the same-day bond index return, $(\Delta B_t \Delta S_t)/(B_{t-1}S_{t-1})$, against the equity index return,$(\Delta S_t)/(S_{t-1})$, over the full sample period January 9, 1996 to July 1, 2005. The scatter plot is shown in Figure 5. The "hour glass on its side" heteroscedasticity is simply a result of plotting $(\Delta B_t \Delta S_t)/(B_{t-1}S_{t-1})$ against $(\Delta S_t)/(S_{t-1})$. Although this scatter plot does not *per se* condition on lagged volatility, it is interesting that the co-movement between bond returns and stock returns appears reasonably symmetric, and that most of the "action" over the decade-long period occurs on the small number of outlier days noted. On three of these outlier days—October 27, 1997, August 31, 1998, and April 14, 2000—there were drops in equity market prices in the 6–8% range, and bond prices increased. These three observations are consistent with a "flight-to-quality" or "flight-to-liquidity." Only one of the outliers—March 8, 1996—where the Dow fell by around 7% and bond prices fell sharply ("…with the 30-year treasury falling a heart-stopping 3 points")[11] would possibly fit a "contagion" pattern. But the fall in equities was quite uneven across the market on March 8, 1996 the S&P 500 fell by approximately 85 basis points and the NASDAQ by only 124 basis points—which is counter to what we'd expect in a contagion scenario. Moreover, news reports that day alluded to a surprisingly strong unemployment report as the catalyst, which would be more consistent with a surprise to inflation expectations that adversely affected not only bonds, but also stocks—quite unevenly, as might plausibly be the case if inflation has differential effects across companies.

On three days, which are in the latter half of our sample period—January 3, 2001, July 29, 2002, and October 15, 2002—the market was consistent with a "reverse flight to quality," that is, the stock market was up in the 4–6% range, and bond prices fell substantially. One might conceivably argue that investors' perception of stock market uncertainty and/or risk aversion had fallen substantially on those days, but it seems likely that other events were also at work, notably bond market "events" like Fed announcements and surprises to market expectations of inflation. Further evidence below suggests that Fed action seems to be a more important determinant of stock–bond return correlation than shifts in market uncertainty, at least over the last decade.

4 Jumps in daily equity–bond return correlation

In this section, we turn to the "jaggedness" in the time series of equity–bond return correlations. We begin with an exploratory analysis that imposes as little parameterization on the data as possible. Figure 6a classifies "outlier" events over the full sample period January 9, 1996 to July 1, 2005 as follows: (i) days on which the large cap equity return is *positive* and greater than a "one sigma" event plus the 6-month bond return is *positive* and greater than a "one sigma" event (Quadrant 1); (ii) days on which the large cap equity return is *negative* and greater than a "one sigma" event plus the 6-month bond return is *positive* and greater than a "one sigma" event (Quadrant 2); (iii) days on which the large cap equity return is *negative* and greater than a "one sigma" event plus the 6-month bond return is *negative* and greater than a "one sigma" event (Quadrant 3); and (iv) days on which the large cap equity return is *positive* and greater than a "one sigma" event plus the 6-month bond return is *negative* and greater than a "one sigma" event (Quadrant 4). The black dot on Figure 6a shows the frequency with which the events (i)–(iv) actually occur in each of the four respective quadrants, while the string of white dots shows the range of frequencies we observe when the series of daily stock returns are randomly paired (1000 times) with the series of daily 6-month bond returns. The white dots, in other words, show the range of outcomes one would expect to see if daily stock and bond returns were unrelated.

As can be seen from Figure 6a, there are more instances of the event {"large" negative equity return, "large" positive 6-month bond return} than we would expect to see given the empirical marginal distributions of the stock and bond returns and an assumption that the stock and bond returns are independent. As can be seen in the lower half of the figure, large positive equity returns and large negative 10-year bond returns are also observed more frequently than would be expected. The fact that both 6-month and 10-year bond prices increase significantly on days when there is a (one-day) "crash" in stock prices suggests that a "flight-to-quality" is taking place on those days rather than a "flight-to-liquidity," or at least

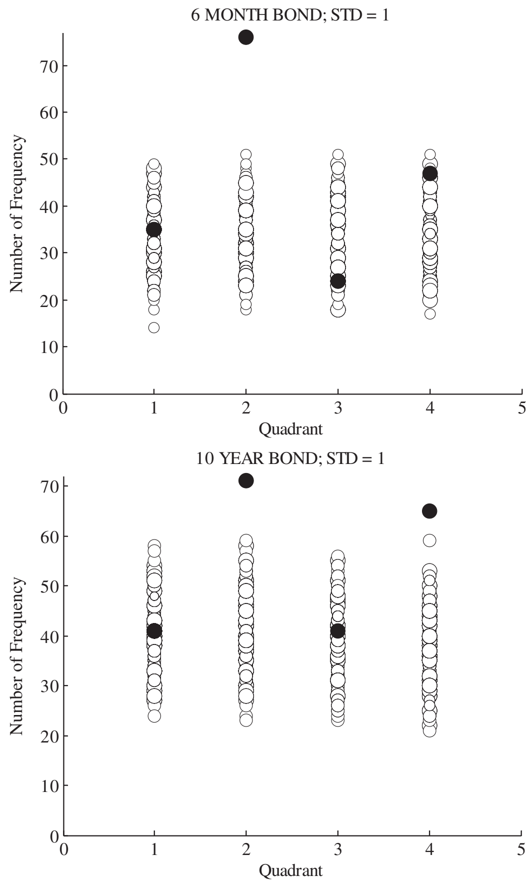

Figure 6a Non-parametric analysis of events; sample period: 1996.01.09–2005.07.01. Black dots in the following plots show the number of events occurring in the sample period. Events are defined as follows: Quadrant 1 event = $\{RS_t \geq s; RB_t \geq b\}$; Quadrant 2 event = $\{RS_t < -s; RB_t \geq b\}$; Quadrant 3 event = $\{RS_t < -s; RB_t < -b\}$; Quadrant 4 event = $\{RS_t \geq s; RB_t < -b\}$, where RS = equity index return; s = std(RS); RB = return on the given bond; b = std(RB). White circles show the number of events that are observed when the series of daily stock is randomly paired (1000 times) with the series of the given bond returns.

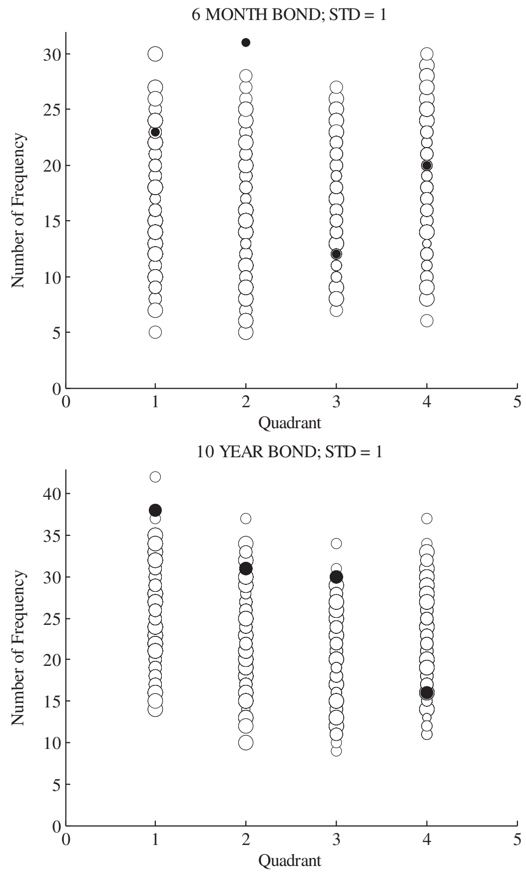

Figure 6b Non-parametric analysis of events; subsample period: 1996.01.09–2000.12.29. Black dots in the following plots show the number of events occurring in the sample period. Events are defined as follows: Quadrant 1 event = $\{RS_t \geq s; RB_t \geq b\}$; Quadrant 2 event = $\{RS_t < -s; RB_t \geq b\}$; Quadrant 3 event = $\{RS_t < -s; RB_t < -b\}$; Quadrant 4 event = $\{RS_t \geq s; RB_t < -b\}$, where RS = equity index return; $s = \text{std(RS)}$; RB = return on the given bond; $b = \text{std(RB)}$. White circles show the number of events that are observed when the series of daily stock is randomly paired (1000 times) with the series of the given bond returns.

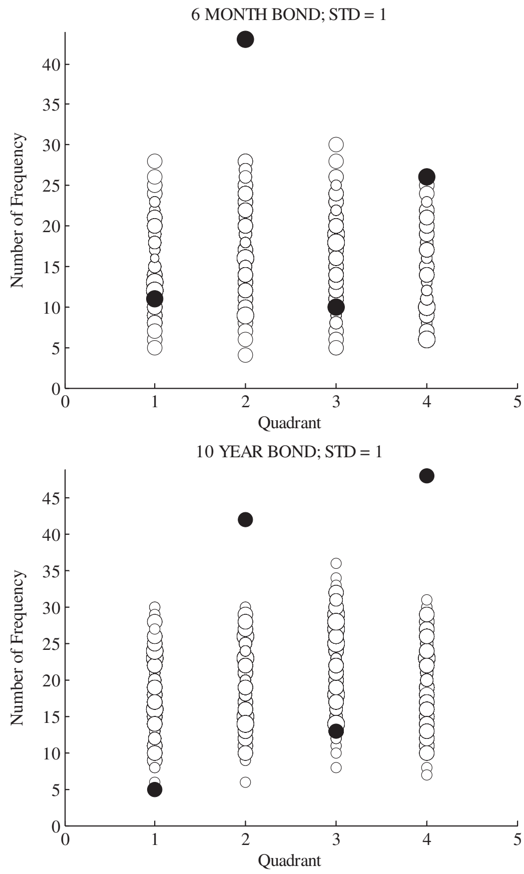

Figure 6c Non-parametric analysis of events; subsample period: 2001.01.03–2005.07.01. Black dots in the following plots show the number of events occurring in the sample period. Events are defined as follows: Quadrant 1 event = $\{RS_t \geq s; RB_t \geq b\}$; Quadrant 2 event = $\{RS_t < -s; RB_t \geq b\}$; Quadrant 3 event = $\{RS_t < -s; RB_t < -b\}$; Quadrant 4 event = $\{RS_t \geq s; RB_t < -b\}$, where RS = equity index return; $s = \text{std(RS)}$; RB = return on the given bond; $b = \text{std(RB)}$. White circles show the number of events that are observed when the series of daily stock is randomly paired (1000 times) with the series of the given bond returns.

that investors do not perceive significant differences in liquidity between short- and long-term US Government bonds.

The other event days that are significant in Figure 6a are those on which stock prices are up significantly, but bond prices are down, that is, days that are "good" for stocks and "bad" for bonds. It is reasonable to surmise that "macro" surprises occur on such days; for example, regarding expected inflation or, more generally, expected future spot interest rates. Surprises in expected inflation (expected future nominal spot rates) that are interpreted by the market as good for corporate revenues and/or depreciate the value of fixed-rate corporate debt obligations would explain increases in equity prices concomitant with decreases in bond prices. Figures 6b and 6c, which parallel Figure 6a but are for the sub-periods January 9, 1996 through December 29, 2000 and January 3, 2001 through July 1, 2005 respectively, support this conjecture: only in the second sub-period, when the general consensus is that the Fed has been managing short-term rates more than usual, do these hypothesized "macro" effects occur.

5 Conditioning and persistence of jumps in daily equity–bond return correlation

If these "jumps" in equity–bond correlation are unusual events that do not persist beyond a day, and they cannot be conditioned on events in the preceding days, then they would be best treated as outliers or reduced form "noise" and thus tapered in structuring the factor models that underpin a forecast of equity–bond return correlation. There is some evidence of persistence. Arshanapalli *et al.* (2003) conclude that there is persistence in the conditional covariance between S&P 500 returns and 10-year Treasury returns in a multivariate GARCH-m model that they fit over the period October 1, 1979 to July 5, 2000. Scruggs and Glabadanidis (2001) conclude that an asymmetric dynamic covariance model best fits the second-moments of monthly time series of stock–bond returns.

Tables 4a–4c provide results for a simple non-parametric test of conditioning/persistence for the "jumps" in daily bond–stock return covariance as a function of three prior-day events: (i) "large" prior day's realized covariance between equity return and bond return (in Table 4a); (ii) "large" prior day realized bond return (in Table 4b); and (iii) "large" prior day realized equity return (in Table 4c). In these tables, the prior day ($t-1$) event is across the columns, with the first column labeled "Unconditional" providing the marginal frequency of the day t event in each row; there are eight columns for joint stock return—bond return events in Table 4a, and only four columns in Tables 4b and 4c (note that the information in Tables 4b and 4c can be inferred from Table 4a, but those tables are included for convenience). Going down the rows in Tables 4a–4c, the first four rows are the events with a "large" equity and bond return on day t, and the last four rows in the tables complete the space of possible outcomes on day t by adding "non-events," for example, in Table 4a, the first row is the event {"large" positive equity return on day t, "large" positive bond return on day t}, while row five is the complement of that event (thus, the columns add to unity). The cells (joint frequencies) with an asterisk are significantly different from the marginal frequency, (assessed from the empirical distribution) at a 90% level, and with a double asterisk, at a 95% level.

The general impression that emerges from the tables is that "large" joint events in equity and bond markets on any given day are not foreshadowed by "large" events on the previous day. The corollary is that large events do not seem to persist into the following day's market behavior. For example, in the only instance where a large co-movement in equity returns and bond returns on day $t-1$ significantly foreshadows a particular scenario on the following day, that scenario seems to be a "quiet" day, that is, return movements in equities and bonds on the day following are less than one sigma events.

6 Long-term regimes in equity-bond correlation

In this section, we investigate whether there is identifiable long-run dependency and/or a long-term "regime" in the stock–bond return relation.

Table 4a Non-parametric test of persistence in stock–bond Return correlation on adjacent days [RS = equity index return; $s = \text{std(RS)}$; RB = bond index return; $b = \text{std(RB)}$].

	Unconditional	$RS_{t-1} \geq s$; $RB_{t-1} \geq b$	$RS_{t-1} < -s$; $RB_{t-1} \geq b$	$RS_{t-1} < -s$; $RB_{t-1} < -b$	$RS_{t-1} \geq s$; $RB_{t-1} < -b$	$0 \leq RS_{t-1} < s$; $0 \leq RB_{t-1} < b$	$-s \leq RS_{t-1} < 0$; $0 \leq RB_{t-1} < b$	$-s \leq RS_{t-1} < 0$; $-b \leq RB_{t-1} < 0$	$0 \leq RS_{t-1} < s$; $-b \leq RB_{t-1} < 0$
Sample period: 1996.01.09–2005.07.01									
1. $RS_t \geq s$; $RB_t \geq b$	0.018	0.047	0.014	0	0.032	0.024	0.014	0.011	0.019
2. $RS_t < -s$; $RB_t \geq b$	0.031	0.023	0.054	0.021	0.065	0.026	0.046**	0.021	0.025
3. $RS_t < -s$; $RB_t < -b$	0.02	0.023	0.014	0.043	0	0.014	0.018	0.023	0.03
4. $RS_t \geq s$; $RB_t < -b$	0.026	0.023	0.027	0.043	0.081**	0.02	0.032	0.016	0.03
5. $0 \leq RS_t < s$; $0 \leq RB_t < b$	0.281	0.302	0.297	0.34	0.226	0.271	0.281	0.316*	0.261
6. $-s \leq RS_t < 0$; $0 \leq RB_t < b$	0.239	0.186	0.257	0.106**	0.274	0.247	0.235	0.227	0.254
7. $-s \leq RS_t < 0$; $-b \leq RB_t < 0$	0.184	0.163	0.095*	0.362**	0.177	0.182	0.154**	0.197	0.212
8. $0 \leq RS_t < s$; $-b \leq RB_t < 0$	0.2	0.233	0.243	0.085*	0.145	0.218	0.219	0.19	0.169*
Sub-sample period: 1996.01.09–2000.12.29									
1. $RS_t \geq s$; $RB_t \geq b$	0.031	0.053	0	0	0.133	0.043	0.023	0.019	0.029
2. $RS_t < -s$; $RB_t \geq b$	0.023	0.026	0.069	0	0.067	0.019	0.039	0.019	0.012
3. $RS_t < -s$; $RB_t < -b$	0.026	0.026	0	0.063	0	0.014*	0.023	0.031	0.041
4. $RS_t \geq s$; $RB_t < -b$	0.012	0	0.034	0.031	0	0.011	0.012	0.012	0.012
5. $0 \leq RS_t < s$; $0 \leq RB_t < b$	0.297	0.316	0.345	0.313	0.267	0.276	0.301	0.318	0.292
6. $-s \leq RS_t < 0$; $0 \leq RB_t < b$	0.208	0.184	0.241	0.094	0.267	0.203	0.216	0.205	0.222
7. $-s \leq RS_t < 0$; $-b \leq RB_t < 0$	0.207	0.184	0.069*	0.406**	0.2	0.198	0.166	0.244*	0.218
8. $0 \leq RS_t < s$; $-b \leq RB_t < 0$	0.196	0.211	0.241	0.094	0.067	0.236**	0.22	0.151**	0.173
Sub-sample period: 2001.01.03–2005.07.01									
1. $RS_t \geq s$; $RB_t \geq b$	0.006	0	0.022	0	0	0.003	0.003	0.011	0.009
2. $RS_t < -s$; $RB_t \geq b$	0.041	0	0.043	0.063	0.063	0.034	0.056	0.022	0.04
3. $RS_t < -s$; $RB_t < -b$	0.014	0	0.022	0	0	0.014	0.016	0.011	0.018
4. $RS_t \geq s$; $RB_t < -b$	0.043	0.143	0.022	0.063	0.104	0.031*	0.052	0.022	0.048
5. $0 \leq RS_t < s$; $0 \leq RB_t < b$	0.262	0.429	0.261	0.375	0.208	0.255	0.269	0.303	0.229
6. $-s \leq RS_t < 0$; $0 \leq RB_t < b$	0.271	0.286	0.261	0.188	0.271	0.299	0.249	0.253	0.286
7. $-s \leq RS_t < 0$; $-b \leq RB_t < 0$	0.159	0	0.13	0.25	0.167	0.163	0.138	0.129	0.207**
8. $0 \leq RS_t < s$; $-b \leq RB_t < 0$	0.203	0.143	0.239	0.063	0.188	0.201	0.216	0.247	0.163

*Significantly different from the unconditional distribution at the 10% level; **Significantly different from the unconditional distribution at the 5% level.

Table 4b Non-parametric test of persistence in stock–bond return correlation on adjacent days [RS = equity index return; s = std(RS); RB = bond index return; b = std(RB)].

	Unconditional	$RB_{t-1} \geq b$	$RB_{t-1} < -b$	$0 \leq RB_{t-1} < b$	$-b \leq RB_{t-1} < 0$
Sample period: 1996.01.09–2005.07.01					
1. $RS_t \geq s$; $RB_t \geq b$	0.018	0.018	0.022	0.021	0.013
2. $RS_t < -s$; $RB_t \geq b$	0.031	0.027	0.026	0.038	0.025
3. $RS_t < -s$; $RB_t < -b$	0.02	0.015	0.019	0.016	0.028
4. $RS_t \geq s$; $RB_t < -b$	0.026	0.021	0.032	0.027	0.025
5. $0 \leq RS_t < s$; $0 \leq RB_t < b$	0.281	0.281	0.276	0.276	0.29
6. $-s \leq RS_t < 0$; $0 \leq RB_t < b$	0.239	0.24	0.196**	0.241	0.255
7. $-s \leq RS_t < 0$; $-b \leq RB_t < 0$	0.184	0.156	0.26**	0.168*	0.188
8. $0 \leq RS_t < s$; $-b \leq RB_t < 0$	0.2	0.243*	0.17	0.213	0.174*
Sub-sample period: 1996.01.09–2000.12.29					
1. $RS_t \geq s$; $RB_t \geq b$	0.031	0.031	0.041	0.036	0.02
2. $RS_t < -s$; $RB_t \geq b$	0.023	0.037	0.02	0.026	0.015
3. $RS_t < -s$; $RB_t < -b$	0.026	0.012	0.041	0.019	0.035
4. $RS_t \geq s$; $RB_t < -b$	0.012	0.012	0.02	0.011	0.01
5. $0 \leq RS_t < s$; $0 \leq RB_t < b$	0.297	0.282	0.272	0.293	0.316
6. $-s \leq RS_t < 0$; $0 \leq RB_t < b$	0.209	0.215	0.177	0.207	0.221
7. $-s \leq RS_t < 0$; $-b \leq RB_t < 0$	0.207	0.141**	0.286**	0.192	0.224
8. $0 \leq RS_t < s$; $-b \leq RB_t < 0$	0.196	0.27**	0.143*	0.216	0.159**
Sub-sample period: 2001.01.03–2005.07.01					
1. $RS_t \geq s$; $RB_t \geq b$	0.006	0.006	0.018	0.004	0.003
2. $RS_t < -s$; $RB_t \geq b$	0.041	0.023	0.03	0.052	0.039
3. $RS_t < -s$; $RB_t < -b$	0.014	0.018	0	0.015	0.02
4. $RS_t \geq s$; $RB_t < -b$	0.042	0.029	0.042	0.044	0.046
5. $0 \leq RS_t < s$; $0 \leq RB_t < b$	0.263	0.281	0.267	0.258	0.257
6. $-s \leq RS_t < 0$; $0 \leq RB_t < b$	0.271	0.257	0.212*	0.279	0.299
7. $-s \leq RS_t < 0$; $-b \leq RB_t < 0$	0.159	0.17	0.236**	0.14	0.141
8. $0 \leq RS_t < s$; $-b \leq RB_t < 0$	0.204	0.216	0.194	0.208	0.194

* Significantly different from the unconditional distribution at the 10% level; ** Significantly different from the unconditional distribution at the 5% level.

Table 4c Non-parametric test of persistence in stock–bond return correlation on adjacent days [RS = equity index return; $s = \text{std}(RS)$; RB = bond index return; $b = \text{std}(RB)$].

	Unconditional	$RS_{t-1} \geq s$	$RS_{t-1} < -s$	$0 \leq RS_{t-1} < s$	$-s \leq RS_{t-1} < 0$
Sample period: 1996.01.09–2005.07.01					
1. $RS_t \geq s$; $RB_t \geq b$	0.018	0.03	0.003*	0.021	0.016
2. $RS_t < -s$; $RB_t \geq b$	0.031	0.036	0.042	0.024	0.033
3. $RS_t < -s$; $RB_t < -b$	0.02	0.017	0.019	0.02	0.021
4. $RS_t \geq s$; $RB_t < -b$	0.026	0.04	0.052**	0.022	0.016**
5. $0 \leq RS_t < s$; $0 \leq RB_t < b$	0.281	0.234*	0.305	0.276	0.296
6. $-s \leq RS_t < 0$; $0 \leq RB_t < b$	0.239	0.244	0.227	0.25	0.228
7. $-s \leq RS_t < 0$; $-b \leq RB_t < 0$	0.184	0.175	0.169	0.198	0.178
8. $0 \leq RS_t < s$; $-b \leq RB_t < 0$	0.2	0.224	0.182	0.187	0.212
Sub-sample period: 1996.01.09–2000.12.29					
1. $RS_t \geq s$; $RB_t \geq b$	0.031	0.053	0**	0.036	0.026
2. $RS_t < -s$; $RB_t \geq b$	0.023	0.024	0.039	0.016	0.026
3. $RS_t < -s$; $RB_t < -b$	0.026	0.029	0.026	0.022	0.028
4. $RS_t \geq s$; $RB_t < -b$	0.012	0.012	0.026	0.01	0.009
5. $0 \leq RS_t < s$; $0<=RB_t < b$	0.297	0.247	0.329	0.296	0.305
6. $-s \leq RS_t < 0$; $0\leq RB_t < b$	0.209	0.212	0.194	0.212	0.21
7. $-s \leq RS_t < 0$; $-b \leq RB_t < 0$	0.207	0.194	0.2	0.208	0.213
8. $0 \leq RS_t < s$; $-b \leq RB_t < 0$	0.196	0.229	0.187	0.2	0.182
Sub-sample period: 2001.01.03–2005.07.01					
1. $RS_t \geq s$; $RB_t \geq b$	0.006	0	0.006	0.007	0.008
2. $RS_t < -s$; $RB_t \geq b$	0.041	0.051	0.045	0.034	0.044
3. $RS_t < -s$; $RB_t < -b$	0.014	0	0.013	0.018	0.015
4. $RS_t \geq s$; $RB_t < -b$	0.042	0.073	0.078**	0.036	0.023**
5. $0 \leq RS_t < s$; $0\leq RB_t < b$	0.263	0.226	0.279	0.248	0.285
6. $-s \leq RS_t < 0$; $0 \leq RB_t < b$	0.271	0.292	0.26	0.292	0.246
7. $-s \leq RS_t < 0$; $-b \leq RB_t < 0$	0.159	0.146	0.149	0.189**	0.133*
8. $0 \leq RS_t < s$; $-b \leq RB_t < 0$	0.204	0.212	0.169	0.175*	0.246**

* Significantly different from the unconditional distribution at the 10% level; ** Significantly different from the unconditional distribution at the 5% level.

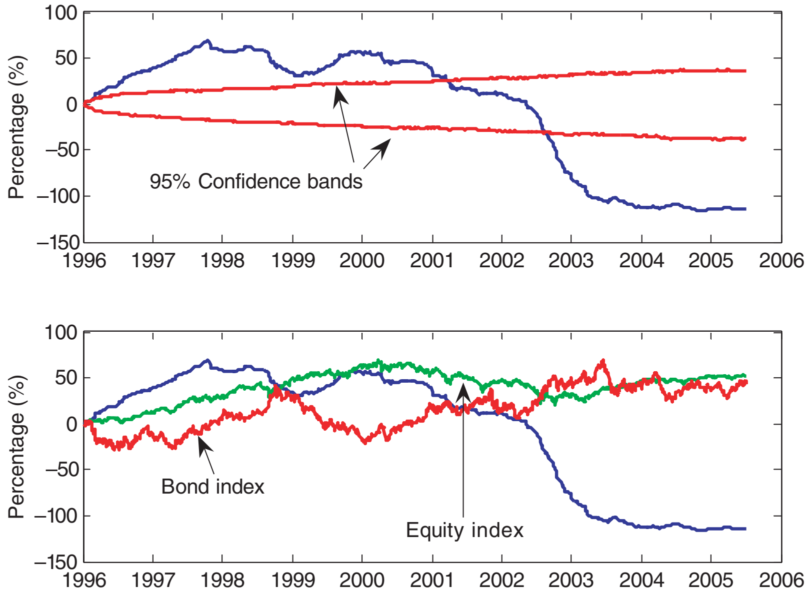

Figure 7 Cumulative returns of (bond index ∗ equity index) 1000 simulations.

As a first look at whether such regimes might exist, we computed a cumulative time series of the cross-product of realized daily stock and bond returns $\left(\frac{\Delta B_t}{B_{t-1}} \frac{\Delta S_t}{S_{t-1}}\right)$; the statistic plotted is an analog to the familiar CUSUM statistic. This series is graphed in Figure 7. In the top panel of the figure, the time series is shown versus 95% confidence intervals derived from 1000 simulations of the cumulative cross-product based on the empirical returns.

As can be seen, the cumulative cross-product appears significant.[12] The fact that the cumulative co-movement appears significantly non-random while there seems to be little evidence of serial dependence little evidence of day-to-day implies that there is a long-term memory in the events. We are currently exploring the nature of this long-run dependence and whether it is useful to model it in a regime-switching model.

The most substantial long-term dependency seems to occur post-2000 as the Fed began to actively manage short-term interest rates. Moreover, the time series behavior appears linked to movements in the short rate of interest, so it seems plausible—some might say obvious—that there is a link between the co-movement and Fed action. One item of evidence that would support the hypothesis comes from the early-to-mid-1960s. The realized correlation between equity returns and US bond returns was negative then, just as it has been from the year 2000 until recently. Bullard (2005) recently wrote: "the low level of inflation and high level of Fed credibility characteristic of the early 1960s returned in the early 2000s. Thus, the early 1960s may give a better indication of the nature of today's financial markets than most of the intervening years…in both eras, once the federal funds rate began rising following the recession, the long-term bond yield remained anchored near 4 percent."

7 Conclusion

In the exploratory analysis so far in this paper, we have found: (i) there has been a substantial shift over the last decade in realized correlation between equity returns and Treasury returns; (ii) while both term structure level and slope factors co-varied with equity returns across sectors and value-growth categories in "conventional" ways pre-2001, only changes in yield curve slope (orthogonal to level) have co-varied with equity returns in the last 5 years when we follow the common approach and define level in terms of a short-term yield and slope as the difference between long- and short-term yields; (iii) the common approach defining term structure level in terms of the short-term yield appears not to be useful for understanding equity return-fixed income interaction in our sample period—an approach using implicit term structure factors or defining the level in terms of a long-term (and thus "less Fed-managed") yield seems preferable; (iv) on some days, there are "jumps" in equity and Treasury return co-movements that fit the pattern of "flight-to-quality" and surprise reactions to macro-inflation expectations; (iv) there seems to be little persistence in these jumps in co-movement on adjacent days; and (v) there appears to be a long-run serial dependency in co-movements that are probably associated with Fed rate management post-2001. We are currently researching ways in which we can best model this long-term dependence.

Appendix: Modeling the fixed income factors

The factor model that we use for the returns on the eight maturities of Treasury securities in our sample is similar to that described in Litterman and Scheinkman (1991). They find that the first three principal components of weekly changes in the Treasury spot curve[13] explain over 95% of the variation in returns on all fixed income securities over the period February 22, 1984 to August 17, 1988.

In this paper, we similarly fit principal components to the yield changes of the eight Treasury securities with maturities of 6 month, 1, 2, 3, 5, 7, 10, and 20 year. If we follow Litterman and Scheinkman's approach, we get roughly the same results that they report. Our results are plotted in Figure A.1. Three factors explain 97% of the variation in yields for the full sample period January 9, 1996 to July 1, 2005. The first factor can be characterized as a "level" factor as in Litterman and Scheinkman (1991), generating parallel change in yields; the second factor is very close to their "steepness" factor, affecting the slope of the yield curve—it lowers the yields of zeros up to 4 years and increases the yields for zeroes with long-term maturities; and the third factor, the so-called "curvature" factor, characterizes the curvature of the yield curve.

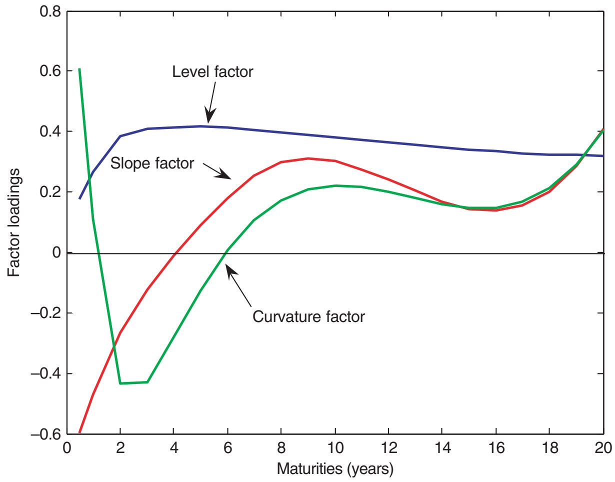

Figure A.1 Fixed income factors. The principal component analysis is done on the covariance of the yield changes of eight Treasury securities with maturities of 6 months, 1, 2, 3, 5, 7, 10, and 20 years.

Notes

1 In credit risk measurement using the Merton model, for example, that of Moody's—KMV. We thank Jeff Bohn for discussion on this application.

2 The number of stocks in the universe increases from 2150 at the beginning of the sample, peaks at 3839 around the end of 2001, then declines to 3511 by the end of our sample period.

3 The portfolio ("index") of stocks is rebalanced each day to contain the largest 500 market capitalization companies at the previous day's close price.

[4] The bond returns are constructed from implied zero-coupon yield series. Using the constant maturity yield data on the Treasury securities, obtained from the Federal Reserve, we construct the implied zero-yield curve, and calculate the returns of the Treasury securities.

[5] Li looks at correlation between the broad market equity index and long-term bond index returns. We find that the time series of realized correlation between the long-term bond returns and the return on the value-weighted index of all stocks in the (US) universe (i.e. the broad market index) differs little from that shown in Figure 1, and we do not show it there. However, the correlation numbers for the broad market index are reported in Table 1.

[6] They find that the correlation between long-term bond and small cap stocks ranges from -0.26 to 0.12, while the large cap stocks' correlation with long-term bond return ranges from −0.41 to 0.37.

[7] Again, to make the comparison with other analysis where bond returns are used, we use the negative of changes in the explicit factors to run the regression.

[8] The outliers are worrisome insofar as a major portion of the change in slope might not be "subtracted out" in estimating the orthogonalized slope on days where there were large changes in either level or slope. We excluded days on which either the absolute change in the 10-year yield or the slope was greater than 20 basis points. (The days excluded were 1996.03.08, 1998.10.08, 1998.10.09, 1998.10.16, 1999.07.06, 2001.12.26, 2001.01.03, 2001.01.04, 2001.01.05, 2001.04.18, 2001.09.17, 2001.09.19, 2001.12.07, 2002.11.07, 2003.01.02, 2003.08.13, 2004.04.02.) The results in the second subperiod with the outliers excluded are −0.064 (t-stat: −12.118) for the level factor and 0.017(t-stat: 1.864) for the slope factor.

[9] The implicit level factor is calculated from a vector of maturities including the 20-year bond; however, the term structure between 10 and 20 years is quite flat, so the rough reasoning remains correct.

[10] They look at adding a second conditioning variable (lagged correlation, dummy for Asian crisis, stock turnover); we do not do that here.

[11] D. Brancaccio, "Marketplace" *NPR*, Monday March 11, 1996.

[12] Note that it is the covariance of bond and equity returns, rather than correlation, which is being plotted, suggesting that the time series behavior of the realized correlation analyzed in previous sections is not induced when covariance is scaled by a shifting variance of equity returns.

[13] The maturities that Litterman and Scheinkman use to define the curve are: 6 months, 1, 2, 5, 8, 10, 14, and 18 years.

References

Arshanapalli, B., Switzer, L., and Vezina, A. (2003). "Sources of Time-Varying Risk and Risk Premia in U.S. Stock and Bond Markets." January, Concordia University.

Baur, D. and Lucey, B. (2006). "Flight-to-quality or Contagion? An Empirical Analysis of Stock-bond correlations," Working paper, School of Business Studies, Trinity College, Dublin, February.

Bullard, J. B. (2005). "Twist and Shout, or Back to the Sixties." *National Economic Trends*, Federal Reserve Bank of St. Louis, March 2005.

Connolly, R., Stivers, C., and Sun, L. (2004). "Stock Market Uncertainty and the Stock–Bond Return Relation," Working Paper, Kenan–Flagler Business School, University of North Carolina at Chapel Hill, February 5.

Guidolin, M. and Timmermann, A. (2004). "An Econometric Model of Nonlinear Dynamics in the Joint Distribution of Stock and Bond Returns." University of Virginia and University of San Diego, Working Paper, July.

Henry, O. T., Olekams, N., and Suardi, S. (2004). "Modeling Comovements in Equity Returns and Short Term Interest Rates: Level Effects and Asymmetric Volatility Dynamics." Working Paper, October 26, Department of Economics, University of Melbourne.

Li, L. (2002). "Macroeconomic Factors and the Correlation of Stock and Bond Returns." Working Paper, November, Department of Economics, International Center for Finance, Yale University.

Litterman, R. and Scheinkman, J. (1991). "Common Factors affecting Bond Returns." Journal of Fixed Income, June, 54–61.

Scruggs, J. T. and Glabadanidis, P. (2001). "Risk Premia and the Dynamic Covariance between Stock and Bond Returns." Working Paper, John M. Olin School of Business, Washington University in St. Louis, March 21.

Keywords: Equity-bond return correlation; equity and fixed income factors; flight-to-quality; flight-to-liquidity; contagion; regimes in equity-bond return correlation; cumulative co-movement in equity and bond returns; Fed management of bond yields