Co-Movements between Daily Returns on Global Bonds and Equities: A First Look

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1. Introduction

In this paper, we present the results of a preliminary analysis of the relation between daily returns on U.S. equities and U.S. Treasury securities across the maturity spectrum. This analysis is part of a larger agenda to construct a conditional factor model for global equity and global term structure movements at a daily frequency.

We find that the co-movement itself displays substantial “jump” behavior. Two different types of market environment seem to be associated with these jumps or outliers: One is a “flight to quality” or “flight to liquidity” environment; the other seems to be one in which substantial surprise revisions in expected inflation or macro conditions occur. While jumps in the co-movement of equity returns and bond returns in both cases are loosely associated with “volatile” market conditions, our analysis suggests that those conditions are not well modeled by a simple symmetric volatility measure.

We don’t find significant persistence in jumps in equity-bond co-movements across adjacent days, and it doesn’t seem useful to condition the co-movements on prior days’ stock and/or bond returns, i.e. there is no obvious “GARCH effect” at a daily frequency. At the same time, however, we do see evidence of a longer-term persistence or “memory” in the co-movements. We provide some results that show that it may be possible to describe this longer 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-60s, when the term structure environment (“regime”) bore an uncanny resemblance to that of today’s.

We also investigate the trend in the correlation between U.S. equity returns and Treasury returns over the last decade. That correlation declined from about 50% in the mid-1990s to a low of –40% in 2002, and it is now around zero. It is widely acknowledged that this last decade has been a “signature” one in terms of Federal Reserve impact on the markets, e.g. giving rise to the term “the Fed put.” We find that the changes in interaction between equity and bond markets seem to have occurred primarily via 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.

The rest of the paper proceeds as follows: In Section 2, we discuss the changes in the co-movement between equity and bonds over the period January 9, 1996 – July 1, 2005. We look at these co-movements between bond and equity index returns for different economic sectors, size, and style (value-growth). In Section 2, we also look at the correlation between equity returns and the two dominant term structure factors, i.e. the level and slope factors. In Section 3, we explore possible determinants of the equity-bond return co-movements, in particular whether volatility can explain changes in the co-movement between equity and bond returns as other authors have suggested. In Sections 4 and 5, we focus on the sharp outliers that occur in the daily equity-bond return correlation – under what market conditions do they occur, and do they seem to persist from one day to the next. In Section 6, we look at the possible long-term dependency in co-movements between equity and bond returns, and we conclude in Section 7.

2. The Relation between Equity and Bond Returns: Stylized Facts

We use daily returns on U.S. 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 3,276 stocks over the period.[1]

Figure 1 shows the realized correlation between returns on the 500 largest capitalization[2] U.S. stocks and an equally weighted index of the returns on Treasuries with maturities of

[1] The number of stocks in the universe increases from 2,150 at the beginning of the sample, peaks at 3,839 around the end of 2001, then declines to 3,511 by the end of our sample period.

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

6 months, 1 year, 2 years, 3 years, 5 years, 7 years, 10 years, and 20 years.[3] The realized monthly correlation is calculated for non-overlapping months and can be thought of as a joint moment rendition 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 the figure – the "jaggedness" *per se* will be discussed later. As can be seen from Figure 1, the time-series of realized 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 was roughly zero in mid-2005. This trend in the behavior of realized correlation agrees with the results reported in Li (2002, Figure 3)[4] over his sample period 1996 to 2002.

Table 1 reports mean correlation between daily 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 since, as shown in Figure 1, the correlation is significantly different between these two sub-periods. In the first five 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 ten-year period has been "unusual", both in the sense that sustained negative correlation has not been seen 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-90s, peaking in the positive 20% to 50% range. Li shows that

[3] 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.

[4] 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 (U.S.) universe (i.e. the broad market index) differs little from that shown in Figure 1, and we don't show it there. However, the correlation numbers for the broad market index are reported in Table 1.

this behavior of realized correlation is also similar across countries with the exception of Japan.

To investigate further, 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, along with that 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 and Timmermann (2004) also report a similar result over the longer sample period 1954:01 – 1999:12[5] that ends one 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, i.e. both small and large stocks have had roughly the same correlation with bonds in the last five years -- the correlation 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 examine whether these observed changes in those co-movements seem to be driven more by changes in the level, or in the slope, of the term structure. We 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 yield 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

[5] 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.

fitting principal components to yield changes, along the lines of say Litterman and Scheinkman (1991).[6]

Figure 3.1 shows the time series correlation between returns on the 500 stock-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 yields to facilitate the comparison with other figures where bond returns are used). Figure 3.1 shows that equity returns co-vary over time with the level of the term structure in a similar fashion to that of the bond returns themselves; this is not surprising, since the equally weighted bond index proxies for a (non-linear) 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 didn't respond to changes in term structure slope and they increased when the level of the term structure increased.

The picture presented in Figure 3.1 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 3.1.

It is interesting that in the regression of equity returns on changes in term structure level and orthogonalized slope, the slope coefficient is relatively constant and stable – an increase or decrease in term structure slope over and above that implied by a change in

[6] The Appendix describes the fixed income factor model as in Litterman and Scheinkman (1991).
[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.

term structure level is associated with roughly a 2 basis point move in equity returns in the opposite direction. A qualification is that, 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 3.1).

Next, we fit term structure level and slope factors implicitly by fitting principal components to yield changes, i.e. by using definition (iii) above. 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 confirmed by looking at Figure 3.2 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) above, where the level of the term structure is defined as the 6 month yield, and the slope is orthogonalized with respect to the 6 month yield. Figure 3.3 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 have

[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 sub-period 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.

been 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 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.

As an adjunct to the figures, average correlations between bond returns and equity sector returns are given in Table 3 for the two sub-periods 1996.01.09 to 2000.12.29 and 2001.01.03 to 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 that prior-2001, i.e. a decrease in slope of the yield curve was associated with a decrease in equity prices. Moreover, this inversion of the 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 post-2000 appears to defy conventional wisdom as to how different sector stocks "should" typically behave. We now turn to a closer examination of what characteristics of the market environment may have been associated with the realized correlation differences pre-2000 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 models to joint equity-bond returns, both of which use a variant of a multivariate GARCH model, are 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 capitalization and small capitalization stocks versus 10-year T-Bond Returns as 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, 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, Stivers, and Sun (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) depiction of "crash" and "volatility" as characteristics of their fitted regimes. We fit the Connolly, Stivers, and Sun model:

$$B_t = a_0 + [a_1 + a_2 \ln(VIX_{t-1})]S_t + \nu_t \tag{1}$$

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 January 9, 1996 to December 31, 2000:

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

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

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

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 don't precisely match, the results in (2) and (3) reasonably replicate those of Connolly, Stivers, and Sun then.

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

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, i.e. a "symmetric volatility" in bond returns on that day. If possible, we'd like to differentiate condition the correlation estimates on market environments such as "crash," "high stock market uncertainty," "flight to quality," "liquidity crunch," or "dramatic shift in investor risk aversion."

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 doesn't *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% to 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" model. But the fall in equities was quite uneven across the market — 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

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

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 in the latter half of our sample period — January 3 2001, July 29 2002, and October 15 2002 — the market displayed "reverse flight to quality" behavior, i.e. the market was up in the 4% to 6% range, and bond prices fell substantially. One might conceivably argue that investors' perception of stock market uncertainty and/or risk aversion had fell 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 that was apparent in Figure 1. We begin with an exploratory analysis that imposes as little parameterization on the data as possible. Figure 6.1 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, AND 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 AND 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 AND 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 AND the 6-month bond return is *negative* and greater than a "one sigma" event (Quadrant 4). The black dot on the figure 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 the figure, 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 that investors don't perceive significant differences in liquidity between short-term and long-term U.S. Government bonds.

The other event days that are significant in Figure 6.1 are those on which stock prices are up significantly, but bond prices are down, i.e. 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 6.2 and 6.3, which parallel Figure 6.1 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 the sharp variations in equity-bond correlation are unusual events that do not persist beyond a day, and they can't 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, Switzer, and Vezina (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 4.1, 4.2, and 4.3 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 realized covariance between equity return and bond return (in Table 4.1); (ii) "large" prior-day realized bond return (in Table 4.2); and (iii) "large" prior-day realized equity return (in Table 4.3). 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 the first table, and only four columns in Tables 4.2 and 4.3 (note that the information in Table 4.2 and 4.3 can be inferred from Table 4.1, but those tables are included for convenience). Going down the rows in the Tables, 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." Thus, for example, in Table 4.1 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 conclusion 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 on day *t*, i.e. return movements in equities and bonds on the day following are less than one sigma events.

6. Longer Term Regimes in Equity-Bond Correlation

In this section, we investigate whether there is identifiable longer-run dependency and/or a longer-term "regime" in the daily stock-bond-return relation. 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 $(\frac{\Delta B_t}{B_{t-1}} \frac{\Delta S_t}{S_{t-1}})$; 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 1,000 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 day-to-day suggests that there is a longer-term memory in the events. We are currently exploring the nature of this longer-run dependence and whether it is useful to model it in a regime-switching model.

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[12] Note that it is the covariance of bond and equity returns, rather than correlation, which is being plotted, one of the indications 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.

The most substantial long-term dependency seems to occur post-2000 when 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 to support the Fed-regime hypothesis comes from the early-to-mid 1960s. The realized correlation between equity returns and U.S. bond returns was negative then, just as it has been from the year 2000 until recently. Bullard (2005) recently points out: "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 longer-term bond yield remained anchored near 4 percent."

7. Conclusion

In the exploratory analysis here, we've 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 five years when we follow the common approach and define level in terms of a short-term yield and slope as the difference between long-term yield and short-term yield; (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 longer-term (and thus "less Fed-managed) yield seems preferable; (iv) substantial "jumps" occurred in equity and Treasury return co-movements over our sample period, and these largely 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 longer-run serial dependency in co-movements that we believe to be associated with Fed rate management post-2001. We are currently researching ways in which we can best model this longer-term dependence.

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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 year, 2 years, 3 years, 5 years, 7 years, 10 years, 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.

Sample Period: 1996.01.09 - 20050613

	Top 500	Top 2000	Top10%	Bottom10%
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

	Top 500	Top 2000	Top10%	Bottom10%
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

	Top 500	Top 2000	Top10%	Bottom10%
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

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.

Sample Period:1996.01.09-2005.07.01

	Const	Level	Slope
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

	Const	Level	Slope
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

	Const	Level	Slope
Coeff	0.000	-0.063	0.031
t-stat	0.025	-12.231	3.232
R^2	0.122		

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 10Year are returns on 6 month and 10 year bonds. Bond index is an equally weighted index of returns on bonds including 6 months, 1 year, 2 years, 3 years, 5 years, 7 years, 10 years, 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.

Sample Period: 1996.01.09 – 2005.06.13

	BSC	CYC	ENE	FIN	HCR	IDU	NCY	TEC	TLS	UTI
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

	BSC	CYC	ENE	FIN	HCR	IDU	NCY	TEC	TLS	UTI
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

	BSC	CYC	ENE	FIN	HCR	IDU	NCY	TEC	TLS	UTI
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

Table 4.1

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)

Sample Period: 1996.01.09-2005.07.01

	Unconditional	$RS_{t-1}>=s$; $RB_{t-1}>=b$	$RS_{t-1}<-s$; $RB_{t-1}>=b$	$RS_{t-1}<-s$; $RB_{t-1}<-b$	$RS_{t-1}>=s$; $RB_{t-1}<-b$	$0<=RS_{t-1}<s$; $0<=RB_{t-1}<b$	$-s<=RS_{t-1}<0$; $0<=RB_{t-1}<b$	$-s<=RS_{t-1}<0$; $-b<=RB_{t-1}<0$	$0<=RS_{t-1}<s$; $-b<=RB_{t-1}<0$
1. $RS_t>=s$; $RB_t>=b$	0.018	0.047	0.014	0	0.032	0.024	0.014	0.011	0.019
2. $RS_t<-s$; $RB_t>=b$	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. $RS_t>=s$; $RB_t<-b$	0.026	0.023	0.027	0.043	0.081**	0.02	0.032	0.016	0.03
5. $0<=RS_t<s$; $0<=RB_t<b$	0.281	0.302	0.297	0.34	0.226	0.271	0.281	0.316*	0.261
6. $-s<=RS_t<0$; $0<=RB_t<b$	0.239	0.186	0.257	0.106**	0.274	0.247	0.235	0.227	0.254
7. $-s<=RS_t<0$; $-b<=RB_t<0$	0.184	0.163	0.095*	0.362**	0.177	0.182	0.154**	0.197	0.212
8. $0<=RS_t<s$; $-b<=RB_t<0$	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

	Unconditional	$RS_{t-1}>=s$; $RB_{t-1}>=b$	$RS_{t-1}<-s$; $RB_{t-1}>=b$	$RS_{t-1}<-s$; $RB_{t-1}<-b$	$RS_{t-1}>=s$; $RB_{t-1}<-b$	$0<=RS_{t-1}<s$; $0<=RB_{t-1}<b$	$-s<=RS_{t-1}<0$; $0<=RB_{t-1}<b$	$-s<=RS_{t-1}<0$; $-b<=RB_{t-1}<0$	$0<=RS_{t-1}<s$; $-b<=RB_{t-1}<0$
1. $RS_t>=s$; $RB_t>=b$	0.031	0.053	0	0	0.133	0.043	0.023	0.019	0.029
2. $RS_t<-s$; $RB_t>=b$	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. $RS_t>=s$; $RB_t<-b$	0.012	0	0.034	0.031	0	0.011	0.012	0.012	0.012
5. $0<=RS_t<s$; $0<=RB_t<b$	0.297	0.316	0.345	0.313	0.267	0.276	0.301	0.318	0.292
6. $-s<=RS_t<0$; $0<=RB_t<b$	0.208	0.184	0.241	0.094	0.267	0.203	0.216	0.205	0.222
7. $-s<=RS_t<0$; $-b<=RB_t<0$	0.207	0.184	0.069*	0.406**	0.2	0.198	0.166	0.244*	0.218
8. $0<=RS_t<s$; $-b<=RB_t<0$	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

	Unconditional	$RS_{t-1}>=s$; $RB_{t-1}>=b$	$RS_{t-1}<-s$; $RB_{t-1}>=b$	$RS_{t-1}<-s$; $RB_{t-1}<-b$	$RS_{t-1}>=s$; $RB_{t-1}<-b$	$0<=RS_{t-1}<s$; $0<=RB_{t-1}<b$	$-s<=RS_{t-1}<0$; $0<=RB_{t-1}<b$	$-s<=RS_{t-1}<0$; $-b<=RB_{t-1}<0$	$0<=RS_{t-1}<s$; $-b<=RB_{t-1}<0$
1. $RS_t>=s$; $RB_t>=b$	0.006	0	0.022	0	0	0.003	0.003	0.011	0.009
2. $RS_t<-s$; $RB_t>=b$	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. $RS_t>=s$; $RB_t<-b$	0.043	0.143	0.022	0.063	0.104	0.031*	0.052	0.022	0.048
5. $0<=RS_t<s$; $0<=RB_t<b$	0.262	0.429	0.261	0.375	0.208	0.255	0.269	0.303	0.229
6. $-s<=RS_t<0$; $0<=RB_t<b$	0.271	0.286	0.261	0.188	0.271	0.299	0.249	0.253	0.286
7. $-s<=RS_t<0$; $-b<=RB_t<0$	0.159	0	0.13	0.25	0.167	0.163	0.138	0.129	0.207**
8. $0<=RS_t<s$; $-b<=RB_t<0$	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 4.2

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)

Sample Period: 1996.01.09-2005.07.01					
	Unconditional	$RB_{t-1}>=b$	$RB_{t-1}<-b$	$0<=RB_{t-1}<b$	$-b<=RB_{t-1}<0$
1. $RS_t>=s$; $RB_t>=b$	0.018	0.018	0.022	0.021	0.013
2. $RS_t<-s$; $RB_t>=b$	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. $RS_t>=s$; $RB_t<-b$	0.026	0.021	0.032	0.027	0.025
5. $0<=RS_t<s$; $0<=RB_t<b$	0.281	0.281	0.276	0.276	0.29
6. $–s<=RS_t<0$; $0<=RB_t<b$	0.239	0.24	0.196**	0.241	0.255
7. $–s<=RS_t<0$; $-b<=RB_t<0$	0.184	0.156	0.26**	0.168*	0.188
8. $0<=RS_t<s$; $-b<=RB_t<0$	0.2	0.243*	0.17	0.213	0.174*

Sub-Sample Period: 1996.01.09-2000.12.29					
	Unconditional	$RB_{t-1}>=b$	$RB_{t-1}<-b$	$0<=RB_{t-1}<b$	$-b<=RB_{t-1}<0$
1. $RS_t>=s$; $RB_t>=b$	0.031	0.031	0.041	0.036	0.02
2. $RS_t<-s$; $RB_t>=b$	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. $RS_t>=s$; $RB_t<-b$	0.012	0.012	0.02	0.011	0.01
5. $0<=RS_t<s$; $0<=RB_t<b$	0.297	0.282	0.272	0.293	0.316
6. $–s<=RS_t<0$; $0<=RB_t<b$	0.209	0.215	0.177	0.207	0.221
7. $–s<=RS_t<0$; $-b<=RB_t<0$	0.207	0.141**	0.286**	0.192	0.224
8. $0<=RS_t<s$; $-b<=RB_t<0$	0.196	0.27**	0.143*	0.216	0.159**

Sub-Sample Period: 2001.01.03-2005.07.01					
	Unconditional	$RB_{t-1}>=b$	$RB_{t-1}<-b$	$0<=RB_{t-1}<b$	$-b<=RB_{t-1}<0$
1. $RS_t>=s$; $RB_t>=b$	0.006	0.006	0.018	0.004	0.003
2. $RS_t<-s$; $RB_t>=b$	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. $RS_t>=s$; $RB_t<-b$	0.042	0.029	0.042	0.044	0.046
5. $0<=RS_t<s$; $0<=RB_t<b$	0.263	0.281	0.267	0.258	0.257
6. $–s<=RS_t<0$; $0<=RB_t<b$	0.271	0.257	0.212*	0.279	0.299
7. $–s<=RS_t<0$; $-b<=RB_t<0$	0.159	0.17	0.236**	0.14	0.141
8. $0<=RS_t<s$; $-b<=RB_t<0$	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 4.3

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)

Sample Period: 1996.01.09-2005.07.01					
	Unconditional	$RS_{t-1}>=s$	$RS_{t-1}<-s$	$0<=RS_{t-1}<s$	$-s<=RS_{t-1}<0$
1. $RS_t>=s$; $RB_t>=b$	0.018	0.03	0.003*	0.021	0.016
2. $RS_t<-s$; $RB_t>=b$	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. $RS_t>=s$; $RB_t<-b$	0.026	0.04	0.052**	0.022	0.016**
5. $0<=RS_t<s$; $0<=RB_t<b$	0.281	0.234*	0.305	0.276	0.296
6. $-s<=RS_t<0$; $0<=RB_t<b$	0.239	0.244	0.227	0.25	0.228
7. $-s<=RS_t<0$; $-b<=RB_t<0$	0.184	0.175	0.169	0.198	0.178
8. $0<=RS_t<s$; $-b<=RB_t<0$	0.2	0.224	0.182	0.187	0.212

Sub-Sample Period: 1996.01.09-2000.12.29					
	Unconditional	$RS_{t-1}>=s$	$RS_{t-1}<-s$	$0<=RS_{t-1}<s$	$-s<=RS_{t-1}<0$
1. $RS_t>=s$; $RB_t>=b$	0.031	0.053	0**	0.036	0.026
2. $RS_t<-s$; $RB_t>=b$	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. $RS_t>=s$; $RB_t<-b$	0.012	0.012	0.026	0.01	0.009
5. $0<=RS_t<s$; $0<=RB_t<b$	0.297	0.247	0.329	0.296	0.305
6. $-s<=RS_t<0$; $0<=RB_t<b$	0.209	0.212	0.194	0.212	0.21
7. $-s<=RS_t<0$; $-b<=RB_t<0$	0.207	0.194	0.2	0.208	0.213
8. $0<=RS_t<s$; $-b<=RB_t<0$	0.196	0.229	0.187	0.2	0.182

Sub-Sample Period: 2001.01.03-2005.07.01					
	Unconditional	$RS_{t-1}>=s$	$RS_{t-1}<-s$	$0<=RS_{t-1}<s$	$-s<=RS_{t-1}<0$
1. $RS_t>=s$; $RB_t>=b$	0.006	0	0.006	0.007	0.008
2. $RS_t<-s$; $RB_t>=b$	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. $RS_t>=s$; $RB_t<-b$	0.042	0.073	0.078**	0.036	0.023**
5. $0<=RS_t<s$; $0<=RB_t<b$	0.263	0.226	0.279	0.248	0.285
6. $-s<=RS_t<0$; $0<=RB_t<b$	0.271	0.292	0.26	0.292	0.246
7. $-s<=RS_t<0$; $-b<=RB_t<0$	0.159	0.146	0.149	0.189**	0.133*
8. $0<=RS_t<s$; $-b<=RB_t<0$	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 1
Realized Correlation between U.S. 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 U.S., rebalanced daily. Bond Index is an equally weighted index of implied zero-coupon returns on Treasuries with maturities of 6 months, 1 year, 2 years, 3 years, 5 years, 7 years, 10 years, and 20 years. The smoothed curve of the realized correlation is calculated with the Hodrick-Prescott filter (smoothing parameter 14400).

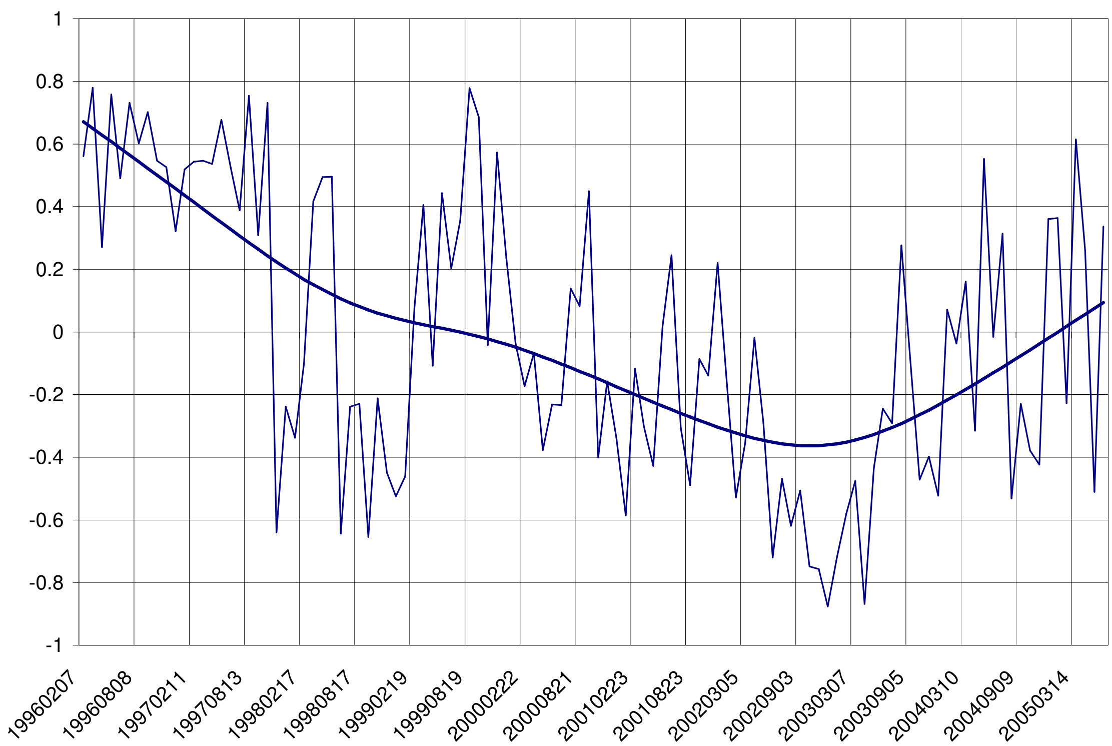


Figure 2
Realized Correlation between Bond Index and Large/Small Cap Index Returns

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 14400).

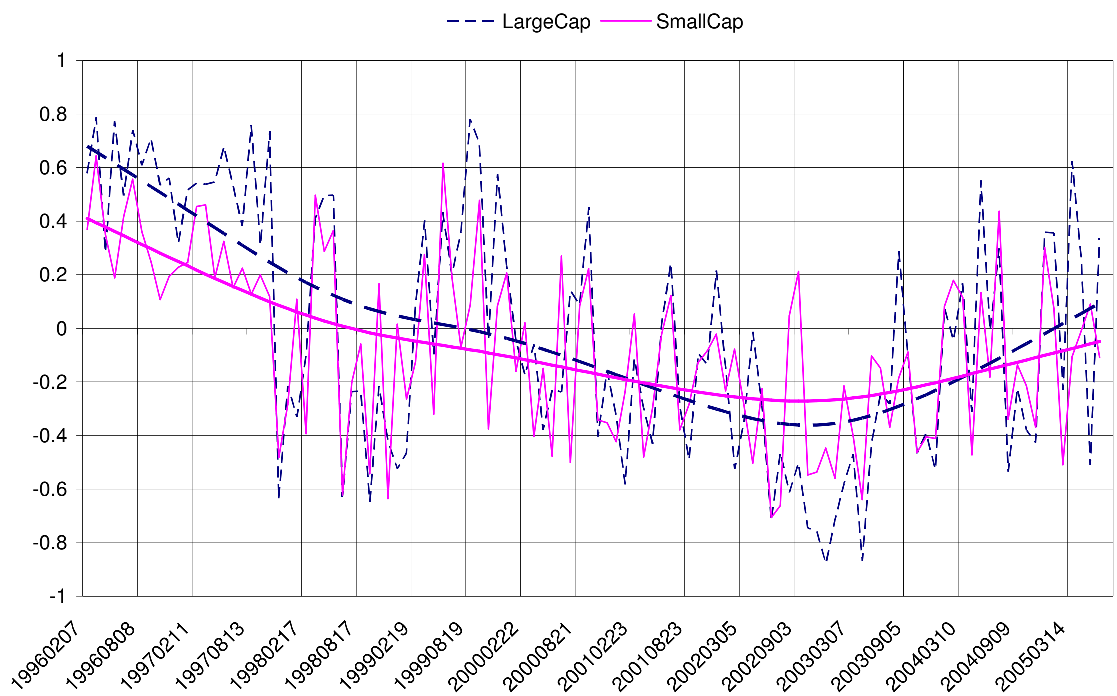


Figure 3.1
Correlation between Explicit Fixed Income Factors and Top 500 Equity Index

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 14400).

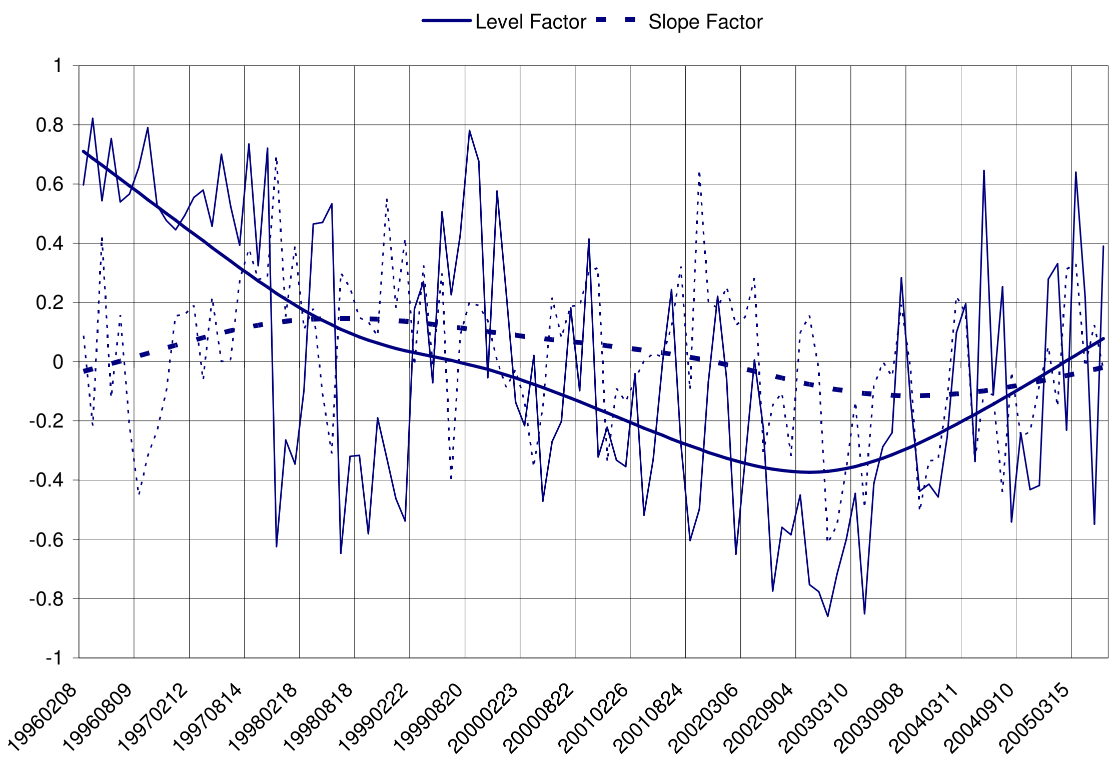


Figure 3.2
Correlation between Fixed Income Factors and Top 500 Equity Index

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-year 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 14400), are shown below.

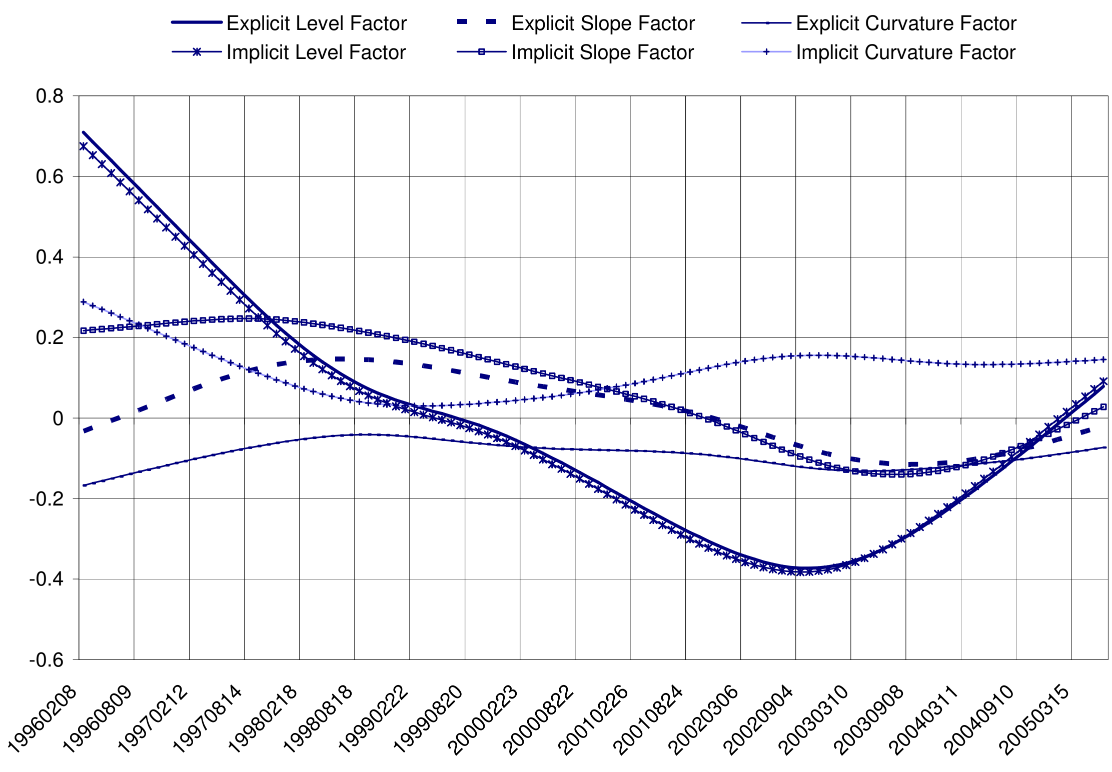


Figure 3.3
Correlation between Explicit Fixed Income Factors and Top 500 Equity Index

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 14400).

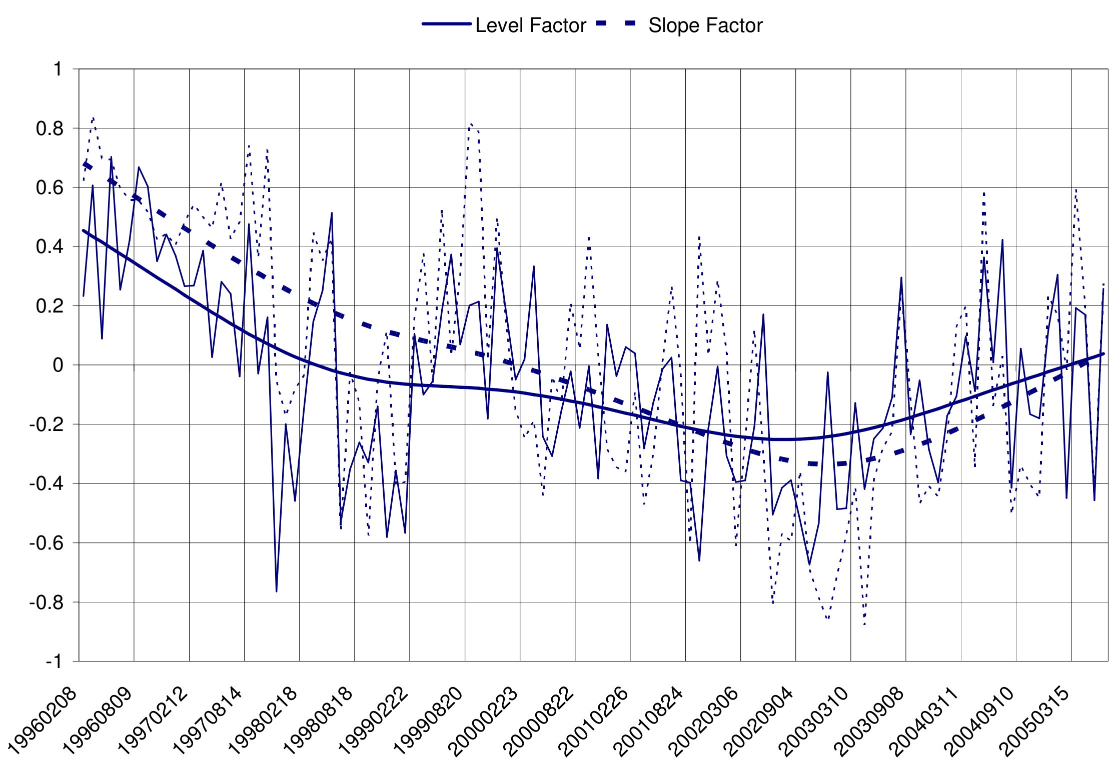


Figure 4
Correlation between Bond Index and Equity Sector Indices

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 14400), are shown below.

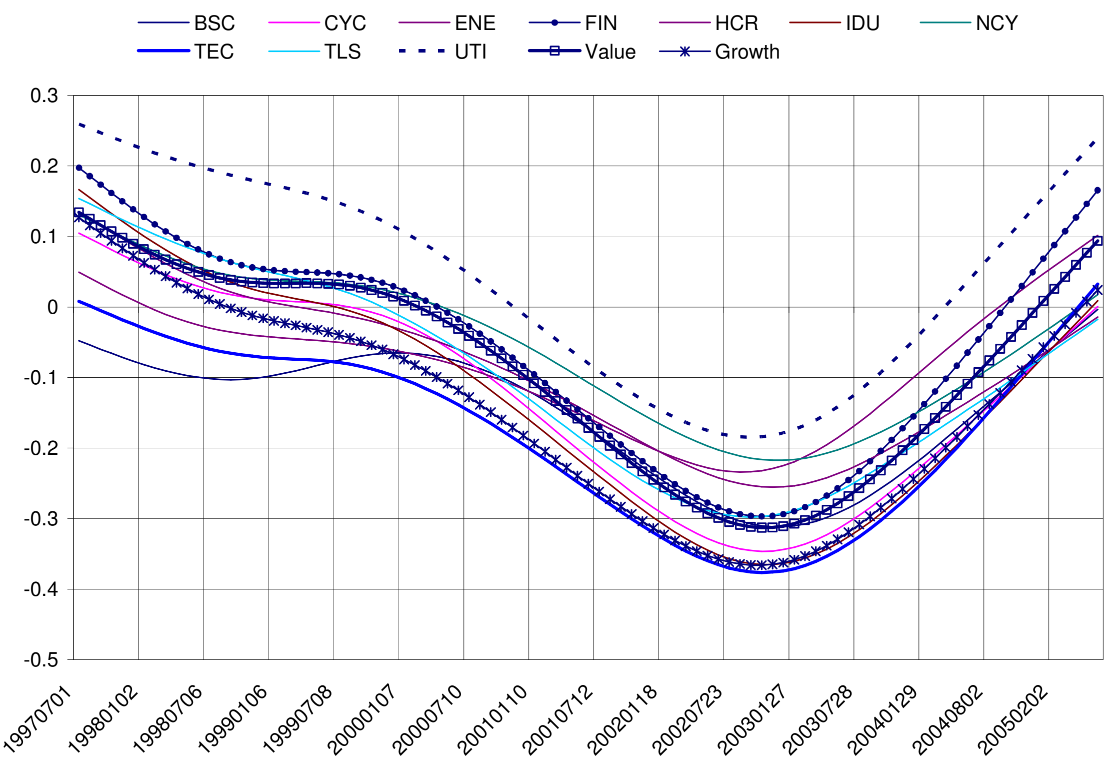


Figure 5
Scatter Plot of Daily Equity Index Return
and (Equity Index Return * Bond Index Return)

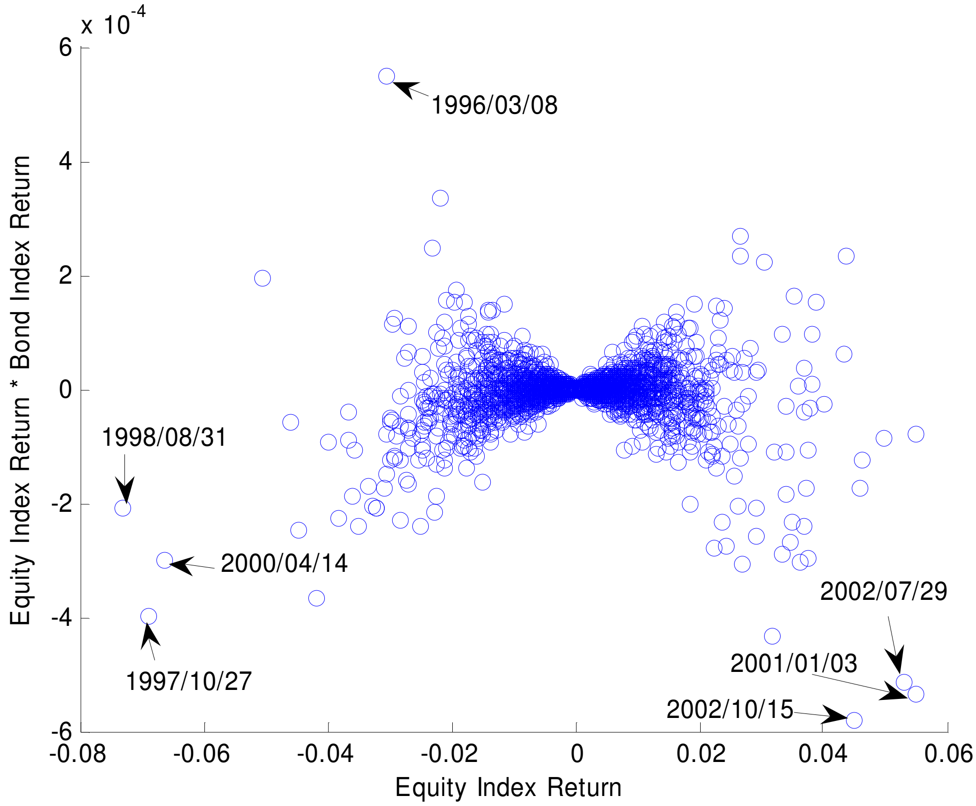


Figure 6.1
Non-Parametric Analysis of Events
Sample Period: 1996.01.09-2005.07.01

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>=s; RB_t>=b}; Quadrant 2 event = {RS_t<-s; RB_t>=b}; Quadrant 3 event = { RS_t<-s; RB_t<-b}; Quadrant 4 event = { RS_t>=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.

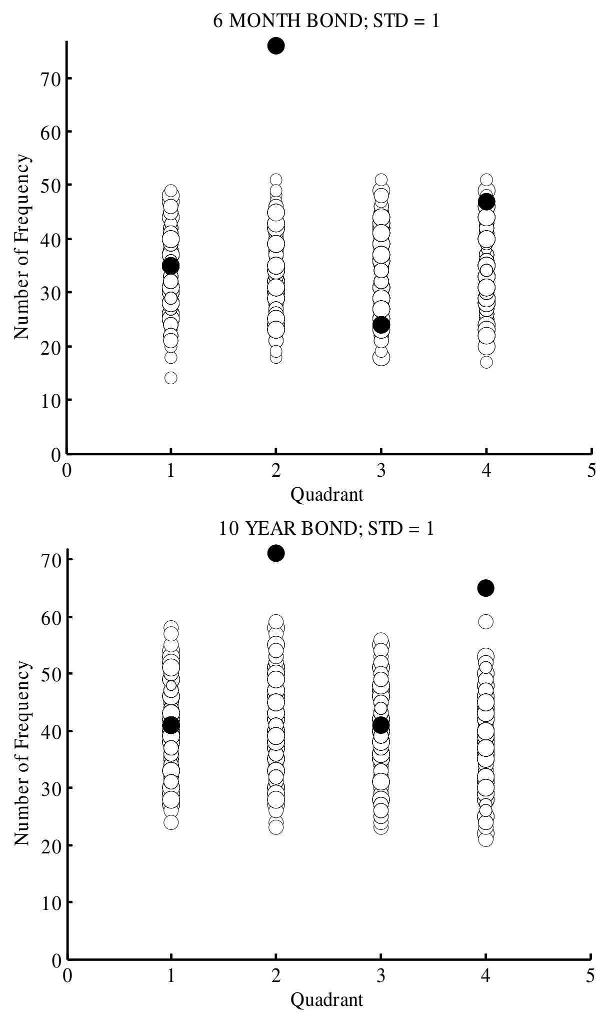


Figure 6.2
Non-Parametric Analysis of Events
Sub-Sample Period: 1996.01.09-2000.12.29

Black dots in the following plots show the number of events occurring in the sample period. Events are defined as follows: Quadrant 1 event = $\{RS_t >= s; RB_t >= b\}$; Quadrant 2 event = $\{RS_t < -s; RB_t >= b\}$; Quadrant 3 event = $\{RS_t < -s; RB_t < -b\}$; Quadrant 4 event = $\{RS_t >= s; RB_t < -b\}$, 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.

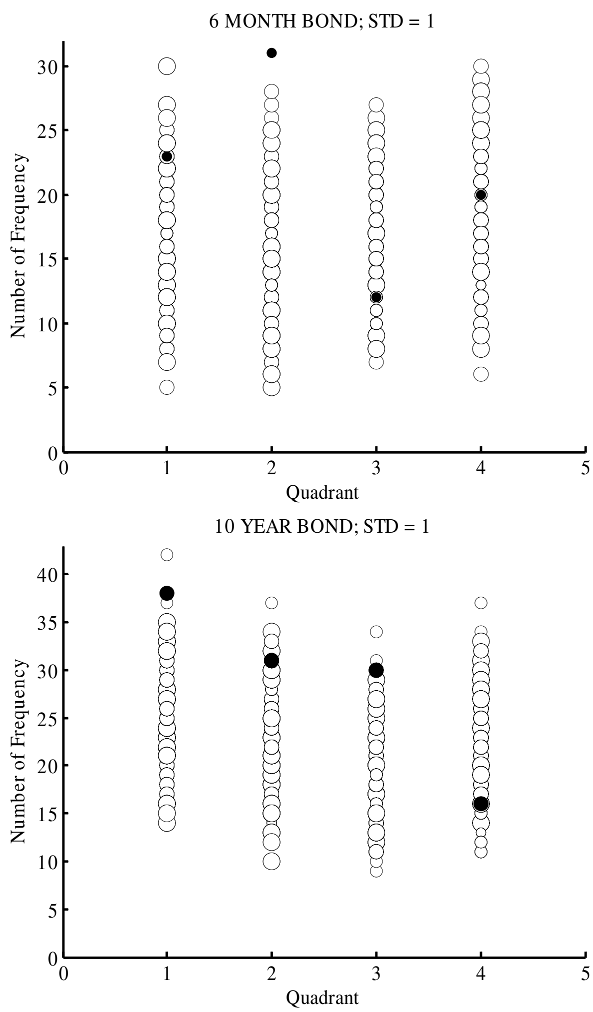


Figure 6.3
Non-Parametric Analysis of Events
Sub-Sample Period: 2001.01.03-2005.07.01

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>=s; RB_t>=b}; Quadrant 2 event = {RS_t<-s; RB_t>=b}; Quadrant 3 event = { RS_t<-s; RB_t<-b}; Quadrant 4 event = { RS_t>=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.

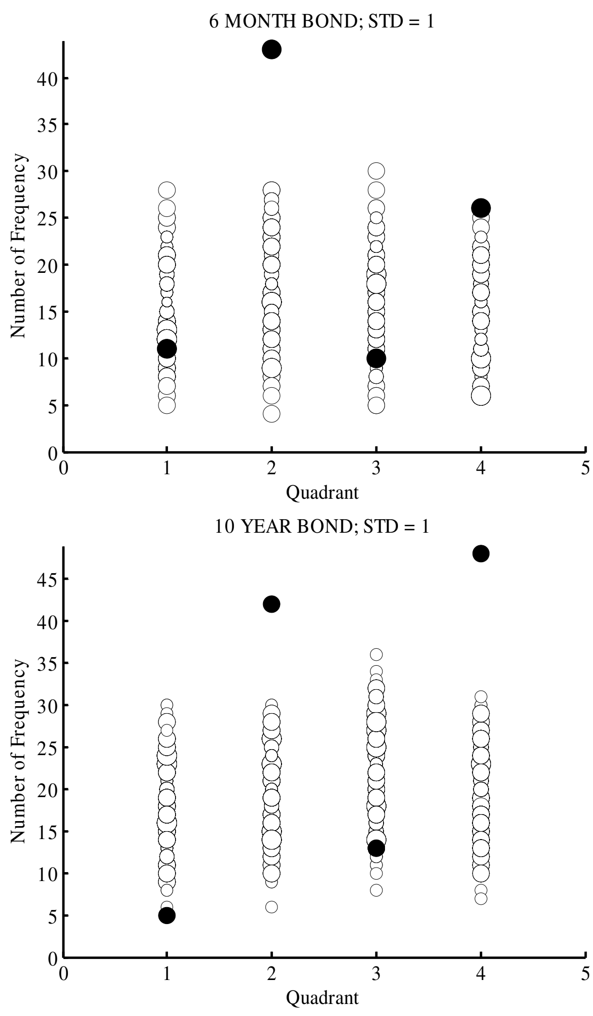
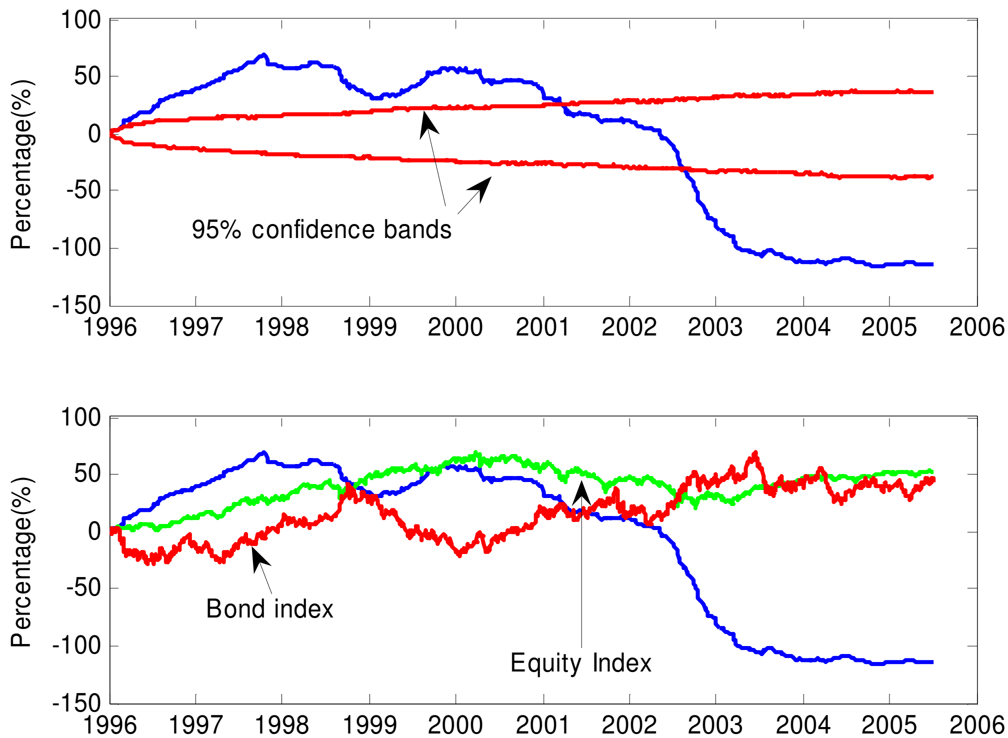


Figure 7
Cumulative Returns of (Bond Index * Equity Index)
1000 simulations



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 year, 2 year, 3year, 5 year, 7 year, 10 year, 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 longer term maturities; and the third factor, the so-called "curvature" factor, characterizes the curvature of the yield curve.

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

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 year, 2 years, 3 years, 5 years, 7 years, 10 years, and 20 years.