Stock-Bond Correlation and Duration Risk Allocation

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ABSTRACT

Using weekly stock-bond correlations estimated with high-frequency data, the authors find that a lower (more negative) stock-bond correlation forecasts falling 10 -year interest rates over the coming weeks, and it also forecasts a falling 1-year interest rates over the next year. The reverse is true when the stock-bond correlation is higher (more positive). Therefore, investors, in particular those with long-term bond-like liabilities, should take greater duration risk when the recent stock-bond correlations are lower. The authors propose two possible explanations of such predictive power: (1) the markets and/or policymakers' under-reaction to the changing economic conditions implied by the stock-bond correlation; and (2) the markets' initial under-reaction to the long-term bonds' safe-haven status.

At the end of the article, we update the information until end of March/2017, and we also provide an URL in the article for live update.

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Using weekly stock-bond correlations estimated with high-frequency (HF) data, we find that a lower (more negative) stock-bond correlation (SB-Correl henceforth) forecasts falling US 10-year Treasury yield over the coming weeks, and falling 1-year bond yield over the next year. For brevity, we refer to such predictive power of the SB-Correl as the correlation effect. Investors should take greater duration risk when the recent SB-Correl is lower. The empirical results are obtained using a simple decile portfolio that is based on a ranking of the weekly HF SB-Correl on its historical values.

The contribution of our findings is threefold: (1) we document a strong predictive power of HF SB-Correl over Treasury bond (bond henceforth) returns; (2) we document an inverse relationship between the 10-year bond's time-varying equity betas and returns, and; (3) we provide possible explanations for the correlation effect, such as policymakers/markets' under-reactions to the changing economic conditions, and markets' initial under-reaction to the changing safe-haven status of the long-term bond.

DATA AND METHODOLOGY

To study both short-term and cyclical dynamics of SB-Correls, we reduce information latency by using HF futures price data. From Jan/11/1985 to Sep/06/2013, we obtain one correlation estimate per week with no overlapping window, totaling 1,496 weekly observations. The realized weekly correlations are obtained using S&P 500 futures and 10-year Treasury bond futures price data with 10-minute frequency from tickdata.com. A frequency of 10-minutes is still of a low enough frequency to avoid microstructure noise. To ensure good liquidity of the futures, we use electronic futures contracts when they are liquid enough (Exhibit 1).

EXHIBIT 1
Futures Contacts Used

Date		Futures contract used	Futures contract used
from	to	for S&P 500	for US 10-year Treasury
Jan/04/1985	Jan/02/2004	SP futures open outcry; CME	TY futures open outcry; CBOT
Jan/05/2004	Sep/06/2013	E-mini futures elec; CME Globex	ZN futures elec; CME Globex

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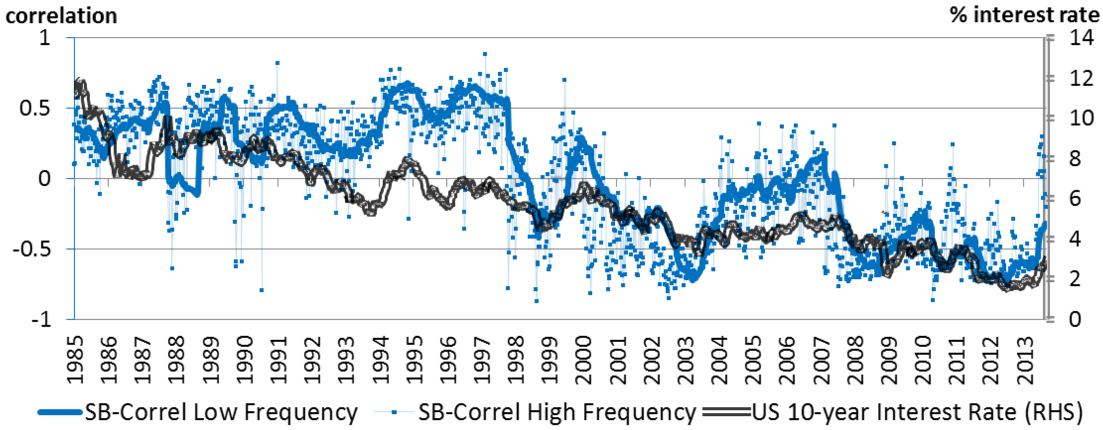
As shown in Exhibit 2, both HF and low-frequency (LF) SB-Correls exhibit a secular downward trend. HF SB-Correls are also highly persistent in the short- and medium-term.

EXHIBIT 2

Stock-Bond Correlations Using High- and Low-Frequency Data



Note: low-frequency SB-Correls use daily data with a 1-year rolling-window.

We also obtain 3-month, 1-year, 2-year, 5-year and 10-year constant-maturity Treasury yields from the FRED database. Forward rates and zero coupon bond log returns are estimated by linearly interpolating the zero-coupon yield curves. We obtain equity log returns using S&P 500 Total Return Index (SPTR[1]) and 3-month Treasury yields.

Let n=20 weeks for illustrative purpose. At the end of each week (t), we rank the last 20 weeks' HF SB-Correls ($HF\_Correl_T, T = t\text{-}19, t\text{-}18, \cdots, t$), and determine the decile of $HF\ SB\_Correl_t$, or $Decile20_t$ accordingly. For convenience, we also refer to week (t) as week 0 and week $(t+1)$ as week 1. A simple HF SB-Correl-sorted portfolio allocates greater weight to bond on week 1 when the decile is lower on week 0:

$$weight20_{t+1} = 1 - 2(Decile20_t - 1)/(10-1). \tag{1}$$

To show a more representative result, we use different sampling windows and use the averages of their deciles. As HF SB-Correls are highly persistent, we may also use

[1] From 1985 to 1987, SPTR is not available and the S&P 500 Index is used as the proxy.

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equally weighted moving averages of the lagged deciles. A portfolio is hence defined by its underlying asset, the object used for ranking, the sampling windows and corresponding lag terms. For example:

[Asset=*Bond10Yr*; RankObj=*HF_Correl*; n=20,40; Lag=1, 4] means

$$
\begin{aligned}
&R_t = Weight_t * Return_t\left(10YrBond\right) \\
&Weight_t = 1-2\left(Decile_{t-1}-1\right)\Big/\left(10-1\right) \\
&Decile_{t-1} = Round\left(\frac{1}{2}\left(MA\left(1,\ Decile20_{t-1}\right)+MA\left(4,\ Decile40_{t-1}\right)\right)\right) \\
&MA\left(\mathrm{K},\ Decile20_{t-1}\right) = averaege\left(Decile20_{t-K},\cdots,Decile20_{t-1}\right)
\end{aligned}
\tag{2}
$$

For the resulting time series of returns, we calculate averages, standard deviations, and Sharpe ratios. To test for the statistical significance of the Sharpe ratios and decile differences, we use a bootstrap to estimate the *t*-values. For a given strategy, suppose we have a sample of T weekly observations of SB-Correl, the associated contemporary return and the date. To estimate the *P*-value, we draw $N = 10,000$ samples of T observations (with replacement) from the empirical distribution. For each boostrap sample, we sort the observations sequentially according to their new date. We then use the defined SB-Correl-sorted decile strategy, re-established a new portfolio and calculate the average return for each decile. The *P*-values of Shape ratio is:

$$
P(\text{Sharpe ratio}) = \frac{\#\,means(\text{Sharpe ratio}-0) <= 0}{N}. \tag{3}
$$

And the *t*-values are given by: $t = N^{-1}\left(1-p\right)$, where N is the *cdf* of the normal distribution with zero mean and unit variance.

We also use a simple regression to disentangle the correlation effect from other factors. The factor portfolios are constructed in a similar manner to the SB-Correl-sorted portfolio. We define curve spread as the difference between 10-year and 1-year interest rates. In Equation (2), instead of letting RankObj=*HF_Correl*, we let RankObj=*Yield*, RankObj= –*Curve_Spread* and RankObj= –*VIX* respectively. And the resulting time series of returns $R_{Yield\_Momentum}$, R_{Curve_Spread} and R_{VIX} are used as the factors. By regressing the returns of the HF SB-Correl-sorted portfolio to the underlying bond returns, the equity returns as well as these factors, we control for possible systematic exposures:

$$\begin{aligned} R = \alpha + \beta_{Bond} R_{Bond} + \beta_{Yield\_Momentum} R_{Yield\_Momentum} \\ + \beta_{Curve\_Spread} R_{Curve\_Spread} + \beta_{VIX} R_{VIX} + \beta_{Equity} R_{Equity} + \varepsilon \end{aligned} \tag{4}$$

where R is the returns of the HF SB-Correl-sorted portfolio; α is the adjusted alpha; and $\beta_{Yield\_Momentum}$, β_{Curve_Spread} and β_{VIX} are the estimated factor exposures[2].

Following Ilmanen [2003], Campbell et al. [2013a] and Johnson et al. [2013, we consider a potential structural break in Jan/1997. We also consider another potential structural break in Dec/2008, when the fed funds rate is essentially zero.

EMPIRICAL RESULTS

Exhibit 3 shows the correlation effect over the 10-year bond from 1997 to 2013. We choose a geometric series: [20, 40, 80, 160] weeks as the sampling windows[3]. We use no lag terms. The 10-year bond underperforms exceptionally in the bottom-deciles. On week 1, D10 underperform D1 by 32% on week one and by 13% per week on average from week 2 to week 8 (returns are annualized). But such decile dispersion is absent from week 9 to week 52. The excess return and volatility of the simple strategy are 3.9% and 5.9% respectively. The Sharpe ratio is 0.66 and statistically significant.

E X H I B I T 3

Decile Dispersion for the 10-Year Bond

[Asset=Bond10Yr; n=20,40,80,160; Lag=1,1,1,1], from Jan/1997 to Sep/2013

Deciles		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
No of Observations		80	98	84	85	95	83	83	84	99	79
High-Frequency SB Correls mean		-0.49	-0.4	-0.36	-0.32	-0.3	-0.24	-0.31	-0.22	-0.17	-0.07
Bond Return Per Week, Annualized	week 1	19%	9%	-1%	3%	10%	11%	14%	6%	-10%	-13%
	week 2 to 8	11%	9%	7%	9%	8%	4%	7%	4%	-8%	-2%
	week 9 to 52	6%	6%	5%	5%	4%	5%	4%	4%	3%	5%
Curve Spread	week 0	1.04	1.3	1.28	1.59	1.32	1.45	1.6	1.77	1.65	1.04

2 The t-value of the alpha and betas are estimated using the closed form formula for OLS instead of simulation.

3 We find that the empirical results would be much weaker if we use only past-week Stock-Bond correlations or other shorter windows. This is because there is too much noise with short windows. The exhibit will be available online.

(10Yr-1Yr)	week 52	1.65	1.61	1.7	1.67	1.53	1.48	1.53	1.46	1.31	1.65
Equity beta	week 1	-0.14	-0.18	-0.11	-0.02	-0.25	-0.09	-0.26	-0.26	-0.02	-0.05

Note: Assuming a hypothesized structural change in 1997, Exhibit 3 shows the result with the time series starting from 1997 instead of 1985.

The outperformance of the long-term (10-year) bond in D1 is related to a "flight-to-safety" phenomenon. Gulko [2002] finds that during stock market crashes the correlation between the returns of U.S. stocks and bonds switches sign from positive to negative. Connolly et al. [2005] ascribes the negative SB-Correls since 1997 to "flight-to-safety", where increased stock market uncertainty induces investors to flee stocks in favor of the long-term bond, and realized SB-Correls drop sharply.

On the flip side of "flight-*to*-safety", we ascribe the short-lived underperformance of bond in D10 to "restore-to-normality" phenomenon, where investors bid down the price of the "safe" long-term bond, in times of increased SB-Correls, inducing corresponding negative returns of the long-term bond.

For each decile in Exhibit 3, we estimate the equity market beta by regressing the excess bond returns on week 1 to their contemporary equity returns. For D1 and D10, the stock betas are -0.14 and -0.05, while the excess bond returns are 19% and -13% respectively. A plot of the results reported in Exhibit 3 would show that there is an inverse relationship between the 10-year bond's equity betas and returns. Hence, the 10-year bond has higher return when it is less risky, if risk is measured by its time-varying equity betas.

As warned by Dopfel [2003], for investors, a low SB-Correl is beneficial in an asset-only context, but detrimental when there is a bond-like liability as a lower SB-Correl increases surplus risk. Our empirical findings suggest that lower SB-Correl (D1) is beneficial for an asset-only investor: not only does a lower SB-Correl indicate lower risk for a stock-bond portfolio, it also forecasts higher bond returns in the short run. On the other hand, a lower SB-Correl hurts equity investors with a long-term bond-like liability: not only does a lower SB-Correl increase surplus risk, but it also forecasts an increased liability. Therefore, investors should take greater duration risk when the recent SB-Correls are lower, either with cash bond or with derivatives.

How about bonds with shorter maturity? We study the different persistence and magnitude of the correlation effect over the entire forward curve from 1985 to 2013. There are three sub-periods divided by the two potential structural breaks (Jan/1997 and Dec/2008). D10–D1 is less significant pre-1997, especially at the long end of the forward curve. Before Dec/2008, D10 and D1 forecast rising and falling interest rates respectively at the short end of the forward curve persistently for about 52 weeks. The results are available online.

Therefore, in addition to the “restore-to-normality”, our strategy is also against the yield curve carry. As shown in Exhibit 3 on the curve spread (10Yr-1Yr), because of the highly persistent short-term interest rate movements over the following 52 weeks, in D1, the curve spread (10Yr-1Yr) steepens from 1.04% to 1.65% on average in 52 weeks, while in D10, it flattens from 1.80% to 1.19%.

Compared to previous research, our findings have a few distinct features. First, instead of the transmission from stock market uncertainty to SB-Correls, we document the transmission from SB-Correls to the bond returns. Second, we document a pronounced “restore-to-normality” phenomenon in parallel to the “flight-to-safety” phenomenon. Third, we document an inverse relationship between the 10-year bond’s time-varying equity betas and returns. And finally, we document that a low SB-Correl forecasts a more steepened yield curve over the next year and our strategy is against yield curve carry (10Yr-1Yr).

CONTROLLING FOR OTHER EFFECTS

How does the correlation effect relate to other? Could it be that the correlation effect simply captures the yield momentum, curve spread and stock market uncertainties?

To answer the question, we construct a few factor (yield, curve spread, VIX) portfolios constructed using the same decile-based strategy. Similarly to Equation (2), the HF SB-Correl-sorted strategy and a factor portfolio are defined as:

[Asset=*Bond10Yr*; RankObj=*SB_Correl* or *Factor*; n=20,40,80,160; Lag=1,2, 4,8]

From the sub-sample from Jan/1997 to Sep/2013, after correcting for these factors, the alpha for the HF SB-Correl-sorted strategy remains significant and the weekly alpha is 0.066%:

$$\begin{aligned} R_{HF\_Correl} &= 0.066\% - 0.013 R_{Bond10Yr} + 0.085 R_{Yield\_Momentum} - 0.19 R_{Curve\_Spread} \\ t-value \quad & \quad [3.5] \qquad [-0.8] \qquad\qquad [3.0] \qquad\qquad\qquad [-9.0] \\ & \quad + 0.35 R_{VIX} - 0.011 R_{Equity} + \varepsilon \\ & \qquad [13.1] \qquad [-1.5] \end{aligned} \tag{5}$$

which translates to an annualized alpha of 3.4%. The yield momentum and VIX factor loadings are positive. The equity risk factor loading is also negative. The curve spread factor loading is negative -- because our strategy is against yield curve carry. The signs of these factor loadings are robust and consistent when using other plausible sampling windows and lag terms. The factor loadings of the curve spread and equity returns are negative, which are valuable. In practice, the HF SB-Correl-sorted strategy can be used as an overlay for a conventional equity and bond portfolio.

For the 10-year bond, we find that the correlation effect is robust by using different sample window and quantiles. HF SB-Correls also have consistently greater predictive power over the low-frequency SB-Correls. The exhibit is available online.

Given this analysis, we conclude that for the 10-year bond, the correlation effect holds up well after controlling for other classic factors.

For the 1-year bond, much of the excess returns of the HF SB-Correl-sorted strategy have been explained by the yield momentum, curve spread and stock market uncertainties factors, and the adjusted alpha diminishes. In addition, for the 1-year bond, the predictive power of HF SB-Correls is similar to those of low-frequency SB-Correls. This is not surprising, as the predictive power of HF SB-Correls over the short-term interest rate is moderate but long-lasting, and using the most recent data is not an advantage. The exhibits of the tests are available online.

POSSIBLE EXPLANATIONS

We first provide a possible explanation for the 1-year bond by assuming negligible bond risk premia (BRP), then we provide a possible explanation for the 10-year bond.

We assume that bond and stock prices are driven by two economic drivers — expected growth and inflation. Then SB-Correls are driven by the following:

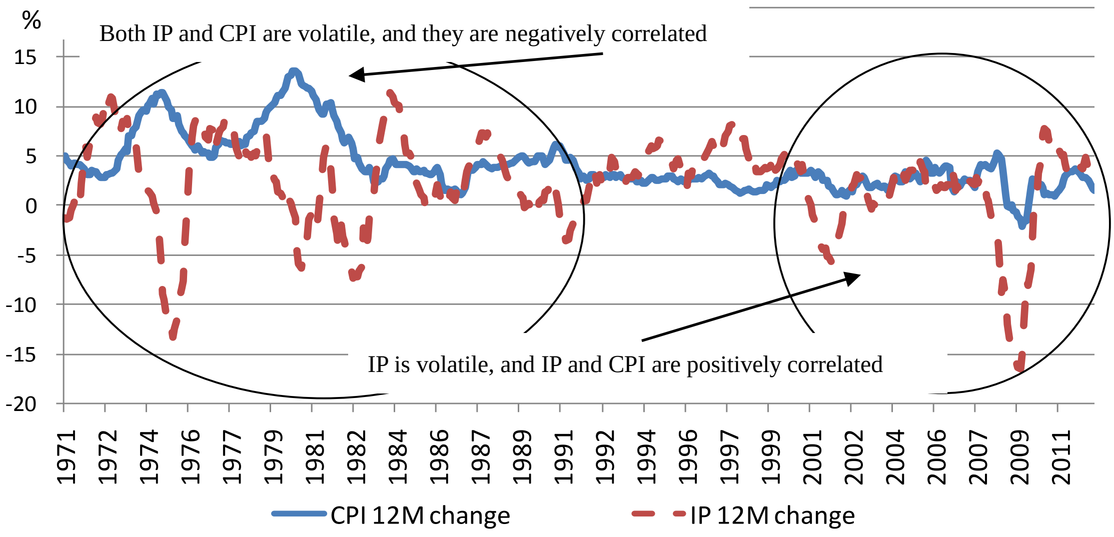
a) Sensitivities to economic drivers. Higher expected inflation drives both bond and stock prices down; higher expected economic growth drives bond price down but drives stock price up.

b) The relative volatility of the expected inflation and growth. SB-Correl is low when the uncertainty of growth dominates the inflation uncertainty. As shown in Exhibit 4, while growth is volatile for both the pre-1997 and post-1997 periods, the level dependent inflation volatility has subsided since the 1990s. Post-1997, SB-Correls are low as growth uncertainties drive stock and bond in the opposite directions while the impact of inflation uncertainties is relatively muted.

c) Growth-inflation correlation. SB-Correl is low when growth and inflation is positively correlated. As shown in Exhibit 4, in the 1970s and 1980s, supply shocks move inflation and growth in different directions, making bond returns pro-cyclical. But lately, demand shocks make bond returns countercyclical.

EXHIBIT 4

Historical Inflation and Growth, proxied by 12-Month Changes in CPI and IP



How is that related to the predictive power of the SB-Correl over the 1-year bond? A lower SB-Correl implies higher impact of growth uncertainties relative to inflation uncertainties. This is valid for the entire period. Therefore, a lower SB-Correl implies that the central bank may ease the policy rate, because resisting a recession becomes the paramount policy priority instead of resisting higher inflation. More importantly, for the period after 1997, a lower SB-Correl implies positive growth-inflation correlation and possible deflationary recession risk. Therefore, a lower SB-Correl implies that the central bank may ease the policy rate as both growth and inflation outlook requires lower interest rates, especially since the 1990s.

In practice, a central bank moves short rates in small steps so it can observe the consequences of its actions and assess the sequential incremental rate changes. The bond markets may forecast that further cuts is likely to follow the latest cut of the policy rate. In theory, such expectation will be built immediately into the short-term term structure. However, this term structure may not "immediately" reflect the economic conditions implied by the SB-Correl, but probably *with a lag*. It is either because the policy rate reacts to the implied economic conditions with *a lag*, or the markets react to the future policy rates with *a lag*. Such under-reaction may be more persistent since 1997 because of the positive growth-inflation correlation and hence "easier" policy rate directional decision, and because of the increased persistence of monetary policy since 1997 [Campbell et al. 2013a].

The above is a possible explanation on the correlation effect on the 1-year bond. How about the 10-year bond? Differently from the 1-year bond, the BRP is pivotal for the 10-year bond. Following Ilmanen [2011, Chapter 9] and in the spirit of Campbell et al. [2013b], we let $BRP(\text{safe haven})$ be an important component of the overall BRP. Such safe-haven premium refers to long-term bonds' equity and/or recession-hedging ability. If a lower SB-Correl reflects a greater ability for long-term bonds to hedge equity/recession risk, then it is possible that markets initially under-react to the bonds' changing safe-haven premia, such that long-term bonds' price lags behind the SB-Correls.

Traditional "efficient markets" thinking suggests that asset prices should completely and instantaneously reflect movements in underlying fundamentals. But such thinking needs not conform to the reality. We use the performance of the 10-year bond in 2013 as an example. As of Apr/19/2013, the 10-year interest rate is 1.73%. Consider a 60/40 stock-bond portfolio as the market portfolio, and let the stock/bond weight, correlation and volatility be:

$$\boldsymbol{\omega} = \begin{bmatrix} 0.6 \\ 0.4 \end{bmatrix}, \ \mathbf{C} = \begin{bmatrix} 1 & -0.6 \\ -0.6 & 1 \end{bmatrix}, \ \boldsymbol{\Omega} = \begin{bmatrix} 12 & 0 \\ 0 & 6 \end{bmatrix}.$$

Then the marginal contribution to portfolio risk is

$$\mathbf{MCTR} = \frac{\partial \sigma_{portfolio}}{\partial \boldsymbol{\omega}} = \boldsymbol{\beta} \sigma_{portfolio} = \frac{\boldsymbol{\Omega}\mathbf{C}\boldsymbol{\Omega}\boldsymbol{\omega}}{\left(\boldsymbol{\omega}'\boldsymbol{\Omega}\mathbf{C}\boldsymbol{\Omega}\boldsymbol{\omega}\right)^{1/2}} = \begin{bmatrix} 11.4 \\ -1.9 \end{bmatrix}.$$

If the portfolio is the tangency portfolio whose Sharpe ratio is maximized, then

$$\frac{\text{Exp Return of Equity}}{\text{MCTR of Equity}} = \frac{\text{Exp Return of Bond}}{\text{MCTR of Bond}} = \text{Portfolio's Sharpe}.$$

Let $\text{Exp Return of Equity} = 5\%$, then $\text{Exp Return of Bond} = -0.83\%$. Given the same volatility, and same equity expected return, Exhibit 5 shows the mapping from SB-Correls to the bond's expected returns.

EXHIBIT 5

Stock-Bond Correlations and Expected Bond Excess Returns

Stock-Bond Correl	-0.8	-0.6	-0.4	-0.2	0	0.2	0.4	0.6	0.8
Expected Bond Ret	-1.59%	**-0.83%**	-0.19%	0.36%	**0.83%**	1.25%	1.62%	1.94%	2.24%

As of Jun/21/2013, the 10-year interest rate is 2.52%, and the realized HF SB-Correl has increased to 0.12. For simplicity, let $\rho = 0$, and let other inputs be the same, then according to Exhibit 5, $\text{Exp Return of Bond} = 0.83\%$, which is about 1.66% higher than when $\rho = -0.6$. In this case, the bond yield has to be 1.66% higher instantaneously (without considering roll-down), which translates to an immediate and substantial bond price depreciation. But empirically, the yield only increases by (2.52% – 1.73% = 0.79%) from Apr/19/2013 to Jun/21/2013, much less than 1.66%. Subsequently, the 10-year interest rate climbs to 2.73% two weeks later and to 2.94% eleven weeks later, while the realized HF SB-Correls remain close to zero. It is possible that the markets learn about the evolving riskiness and safe-haven status of bonds and incorporate them into bond prices and expected returns *with a lag*.

The above is a hypothetical example for illustrative purpose only, because the real correlations, volatilities and the expected returns of equity are unknown.

Why is the high-frequency SB-Correl a stronger and more persistent predictor of the price of long-term bonds after 1997? We provide two additional arguments.

First, quantitatively, the 10-year bond's expected returns are more sensitive to SB-Correls when SB-Correls are already low. As shown in Exhibit 5, the bond's expected return increases by 1.85% when ρ increases from -0.8 to -0.2, but it increases by only 1% when ρ increases from 0.2 to 0.8. The average HF SB-Correl is 0.35 pre-1997 and is −0.30 post-1997, which is a substantial difference. On the other hand, the standard deviation of HF SB-Correl is similar. Therefore, post-1997, the changing SB-Correl is a greater driver of the bond's theoretical expected returns. If the markets' initial under-reaction is roughly proportional to the changing bond's theoretical expected returns, then post-1997, the changing SB-Correl is also a greater driver of the bond's subsequent returns.

Second, qualitatively, post-1997, bond's safe-haven status matters more to the investors. We follow Kim et al. [2005] that explicitly incorporates investors' expectations[4]. There is a secular downward trend of BRP, and it dips further into the negative territory in 2011 and 2012. It suggests that investors expect that the cumulative returns for holding cash are similar or may be even higher than holding a 10-year bond to maturity. According to Campbell et al. [2013b], in recent years, with BRP at such a depressed level, instead of an inflationary bet, investors regard the long-term bond as a deflationary (safe-haven) hedge. Hence we think that long-term bonds price is more sensitive to the change of $BRP(\text{safe haven})$ after 1997.

CONCLUSIONS

[4] Data available at: http://www.federalreserve.gov/pubs/feds/2005/200533/200533abs.html
Compared to the classic C-P BRP by Cochrane et al. [2005], a survey anchored BRP may be less prone to possible unrealistic BRP estimate.

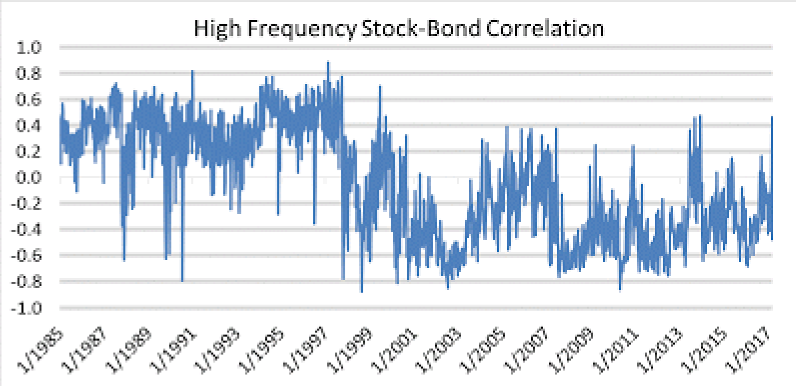
Asset correlations signal useful information of the macroeconomic conditions from an interesting perspective. The connection between the bond-stock correlation and the state of the macro-economy should be of special interest to both investors and policymakers.

Using high-frequency data, we have shown that a lower stock-bond correlation forecasts the best of both worlds of returns and risk for the 10-year bond. Not only does the 10-year bond have higher returns in the following weeks, but it is also less risky, if risk is measured by its equity market beta. Lower stock-bond correlation is thus beneficial to an asset only investor, especially if the investor has leveraged positions in bonds. But lower stock-bond correlation is detrimental to an investor with long-term bond-like liability, especially if the investor invests aggressively in equities and leverage is not allowed. The reverse is true when the stock-bond correlation is higher.

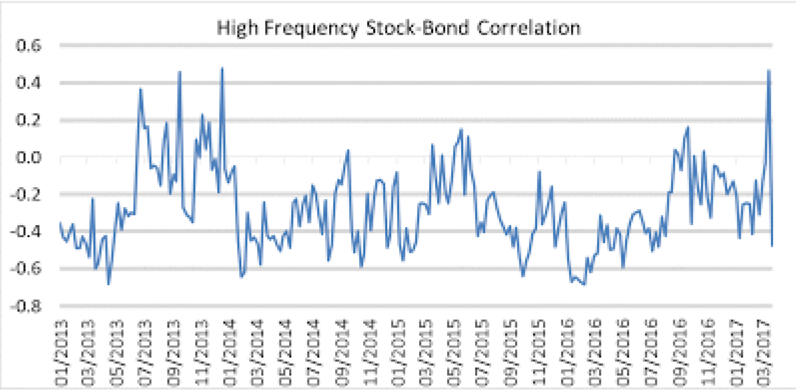
In accordance to the predictive power of high-frequency stock-bond correlation, we develop simple decile portfolios for the 10-year bond and 1-year bond respectively. For the 10-year bond, the decile portfolio is characterized with significant alpha, negative loading to the curve spread factor and also to the equity risk factor. It is thus a good overlay for a traditional stock and bond portfolio. For the 1-year bond, the decile portfolio has a high Sharpe ratio but the excess returns are primarily attributed to the yield momentum, curve spread and equity market uncertainties factors. For the 1-year bond, a possible explanation for the correlation effect is the markets or policy markers' under-reaction to the changing economic conditions implied by the stock-bond correlations. For the 10-year bond, a possible explanation of the correlation effect is the markets' initial under-reaction to the 10-year bond's safe-haven status implied by the stock-bond correlations.

Signals until end of March/2017

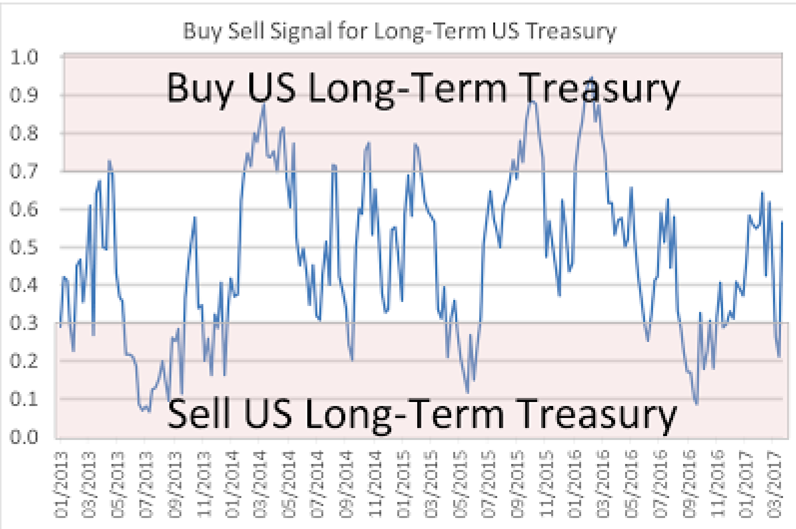
Historical data from 1985 to now



Historical data from 2013 to now



Buy/sell signals



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