Why does the correlation between stock and bond returns vary over time?⋆

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Abstract

This paper examines the impact of inflation and economic growth expectations and perceived stock market uncertainty on the time-varying correlation between stock and bond returns. The results indicate that stock and bond prices move in the same direction during periods of high inflation expectations, while epochs of negative stock-bond return correlation seem to coincide with the lowest levels of inflation expectations. Furthermore, consistently with the "flight-to-quality" phenomenon, the results suggest that high stock market uncertainty leads to a decoupling between stock and bond prices. Finally, it is found that the stock-bond return correlation is virtually unaffected by economic growth expectations.

Keywords: stock-bond return correlation, dynamic conditional correlation, macroeconomic expectations, implied volatility

JEL classification: G10, E44

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1. Introduction

This paper examines the impact of macroeconomic expectations and perceived stock market uncertainty on the time-varying correlation between stock and bond returns. Understanding the dynamics of the time-varying relationship between stock and bond markets is important for several reasons. Asset allocation and risk management strategies that assume a constant relationship between stock and bond returns may be improved by properly taking into account the observed time-variation in the correlation between these two asset classes. A better understanding of the time-varying co-movements between stock and bond markets may also be useful for monetary policy purposes. Although central banks do not have specific price targets for financial assets such as bonds or stocks, monetary policy authorities are using the information contained in the prices of these assets to gauge, for instance, market participants' growth and inflation expectations. Hence, the stock-bond return correlation estimates may offer policymakers useful complementary information to determine whether markets are changing their views on inflation or economic activity prospects.

The relationship between stock and bond returns has received considerable attention in the literature. Shiller and Beltratti (1992) document a strong positive (negative) correlation between changes in stock prices and long-term bond prices (yields). They argue that this positive correlation is caused by the common discount rate effect. Also Campbell and Ammer (1993) find a positive, albeit low, correlation between stock and bond returns. However, both Shiller and Beltratti (1992) and Campbell and Ammer (1993) implicitly assume that the relationship between stock and bond prices remains constant over time. More recently, several studies have shown that the correlation between stock and bond returns exhibits considerable time-variation (see e.g., Gulko, 2002; Cappiello, Engle and Sheppard, 2003; Ilmanen, 2003; Connolly, Stivers and Sun, 2004; Jones and Wilson, 2004; Li, 2004). Although stock and bond prices, in general,

tend to move in the same direction, recent studies have also documented sustained periods of negative correlation.

Surprisingly little is known about the driving forces behind this time-varying correlation between stock and bond returns. One macroeconomic variable that, in theory, may affect the stock-bond return correlation is inflation. An increase in expected inflation tends to raise discount rates, and hence, is inevitably bad news for the bond markets. However, the impact of increasing inflation on stock prices is ambiguous, as both the expected future cash flows and the discount rates are likely to be affected. Ilmanen (2003) uses US data to examine the impact of inflation on the correlation between stock and bond returns, and finds that at high levels of inflation, changes in the discount rates dominate the changes in cash flow expectations, thereby inducing a positive stock-bond return correlation. Li (2004) examines the impact of uncertainty about expected long-term inflation on stock-bond return correlation, and shows that greater concerns about future inflation tend to result in stronger co-movements between stocks and bonds.

Apart from the fundamental changes in the macroeconomic environment, also financial market dynamics and changes in market participants' assessment about risk may have an important impact on the relationship between stock and bond returns. For instance, in periods of financial market turbulence, the equity risk premium demanded by the investors to hold stock may increase relative to the term premium for bonds. This may cause so-called "flight-to-quality" portfolio shifts from the stock markets to the bond markets, leading to some divergence in the returns between these two asset classes. Gulko (2002) focuses on the stock-bond correlations around stock market crashes, and shows that the periods of negative stock-bond correlation tend to coincide with stock market crashes. In a similar vein, Connolly et al. (2004) suggest that option-implied stock market volatility is a good indicator of financial market turmoil. They find that bond returns tend to be high (low) relative to stock returns during days when implied stock market volatility is high (low).

The purpose of this paper is to examine how inflation and economic growth expectations and perceived stock market uncertainty affect the correlation between stock and bond returns. The main contribution of this paper is the focus on the impact of expectations. The use of inflation and economic growth expectations, instead of the actual historical values, may be considered more appropriate, as the stock and bond prices should reflect market participants' expectations of future values of these fundamentals. In addition, this paper extends the literature by jointly examining the impacts of macroeconomic expectations and expected stock market uncertainty on the stock-bond return correlation. Following Connolly et al. (2004), volatility estimates extracted from option prices are used to assess stock market uncertainty. Finally, this paper contributes to the literature by applying recent techniques proposed by Engle (2002) to measure the time-varying correlation between stock and bond returns.

The empirical findings reported in this paper demonstrate that the correlation between stock and bond returns varies considerably over time. Using data from the United States and Germany, we show that the stock-bond correlations in both countries are positive most of the time, although sustained periods of negative correlation are also observed. Our findings also demonstrate that the stock-bond correlation may change substantially, and turn from positive to negative, in very short periods of time. Interestingly, the stock-bond correlations in the US and Germany exhibit rather similar patterns over time, as for instance the periods of negative correlation seem to coincide.

Furthermore, our empirical findings indicate that expected inflation is positively related to the time-varying correlation between stock and bond returns. Stock and bond prices tend to move in the same direction during periods of high inflation expectations, while epochs of negative stock-bond correlation seem to coincide with the lowest levels of inflation expectations. The empirical findings also demonstrate that expected stock market uncertainty, as measured by implied volatility, is negatively related to the stock-bond correlation. In particular, the results strongly indicate that high stock market uncertainty leads to a decoupling between

stock and bond prices. This finding is consistent with the "flight-to-quality" phenomenon. Finally, we are unable to find any systematic relationship between economic growth expectations and stock-bond return correlations.

The remainder of this paper is organised as follows. Section 2 describes the data used in the empirical analysis. The stock-bond return correlation measures used in this paper are presented in Section 3. Section 4 discusses the behaviour of the stock-bond return correlations over time. The empirical findings on the impact of inflation and growth expectations and expected stock market uncertainty on the stock-bond return correlations are reported in Section 5. Finally, Section 6 provides concluding remarks.

2. Data

The empirical analysis in this paper is performed using daily data on US and German stock and bond returns. The US stock returns are calculated from the S&P 100 index, while the DAX index is applied to calculate the German stock returns. The stock index data used in the analysis are obtained from Reuters. The bond returns for both the US and Germany are extracted from the benchmark 10-year government bond price indices.[1] The bond price indices are taken from Thomson Financial Datastream. The sample period used in the analysis spans from January 1991 to April 2004 for the United States and from January 1994 to April 2004 for Germany.

The impact of macroeconomic expectations on the stock-bond return correlation is examined using monthly data on inflation and growth expectations. We use expected growth rates of the US and German consumer price indices (CPI) and real gross domestic products (GDP) over the next 12 months. The data on these macroeconomic expectations are obtained from Consensus

[1] The analysis was also conducted using 2-year government bond price indices. However, since the stock-bond return correlations are virtually similar regardless of the maturity of the bonds, we only report results based on 10-year bonds.

Economics. Every month, Consensus Economics surveys about 600 economists for their forecasts regarding future macroeconomic developments. The average forecasts of this survey are used to measure inflation and economic growth expectations. The expectations data are published on the second Monday of each month and consist of year-on-year growth expectations for the current and the next year. In order to obtain a comparable and consistent time-series of inflation and real GDP growth expectations, the expectations for the current year and the next year are weighted together to measure 12-month ahead expectations

$$E_{12,t} = \frac{m}{12} E_{C,t} + \frac{12-m}{12} E_{N,t} \tag{1}$$

where $E_{12,t}$ denotes the 12-month ahead expectations of a certain macroeconomic variable at time t, $E_{C,t}$ and $E_{N,t}$ denote the time t expectations of the macroeconomic variable for the current and the next year, respectively, and m is the number of remaining months during the current year.

To examine the impact of expected stock market uncertainty on the stock-bond return correlation, we use implied volatilities extracted from the prices of stock index options. Option-implied volatility may be regarded as the market participants' forecast of the future volatility of the underlying asset over the remaining life of the option contract. Provided that market participants are rational, implied volatility should incorporate all the available information that is relevant for forming expectations about the future volatility. Therefore, implied volatility is widely regarded as the best available estimate of market uncertainty.

To capture stock market uncertainty, we use the VIX and VDAX implied volatility indices, constructed by the Chicago Board Options Exchange (CBOE) and the Deutsche Börse, respectively. These implied volatility indices are obtained from Reuters. VIX is calculated from the S&P 100 index options as the average eight near-term and close-to-money call and put options. The implied volatilities of these S&P 100 index options are weighted together to create a single implied volatility estimate, which represents the expected stock market volatility over

the next 30 days.[2] Correspondingly, the VDAX is calculated from DAX index options by weighting together implied volatilities of near-term and close-to-money call and put options. The VDAX has a constant maturity of 45 days, thereby representing the expected stock market uncertainty over the next 1½ months.

3. Measuring the correlation between stock and bond returns

We use two methods to measure the time-varying correlation between stock and bond returns: (i) a simple rolling window sample correlation, and (ii) the dynamic conditional correlation (DCC) model proposed by Engle (2002).

The simplest method to capture the time-variation of the stock-bond return correlation is to compute sample correlation coefficients based on a rolling window of stock and bond returns. In this paper, a monthly estimate of the correlation between stock and bond returns is computed for the 15th day of each month using the returns of the previous 22 trading days. More formally, the 22-day rolling window correlation is calculated by dividing the equally weighted covariance estimate over the last 22 trading days by the square root of the product of the two 22-day variance estimates

$$\hat{\rho}_t = \frac{\sum_{i=1}^{22} r_{S,t-i,} r_{B,t-i}}{\sqrt{\sum_{i=1}^{22} r_{S,t-i}^2 \sum_{i=1}^{22} r_{B,t-i}^2}} \tag{2}$$

where $r_{S,t}$ and $r_{B,t}$ denote the stock and bond returns on day t, respectively. Although the rolling window correlation estimate is utterly simple to estimate, it captures, at least to some extent, the time-variation and "clustering" of the stock-bond return correlation. However, this correlation

[2] For additional details on implied volatility indices, see e.g. Fleming et al. (1995), Blair et al. (2001), and Graham et al. (2003).

estimate also has some severe drawbacks, as the rolling estimates can not adequately measure the dynamics of cross-return linkages. In particular, due to the equal weighting of the return observations in Equation (2), the correlation estimates adjust rather slowly to new information. Additionally, unusually small or large return observations will not gradually diminish over time, but instead lead to jumps in the correlation estimates when these observations fall out of the window. Moreover, since correlation estimates depend on market volatility, they may contain an upward bias over periods of market stress (see e.g., Forbes and Rigobon, 2002).

An alternative method applied in this paper to model the time-varying co-movements between stock and bond returns in the dynamic conditional correlation (DCC) model proposed by Engle (2002). DCC is a simplified multivariate generalized autoregressive conditional heteroskedasticity (GARCH) model. DCC has the flexibility of univariate GARCH models, but it still provides parsimonious correlation specifications without the computational difficulties of multivariate GARCH models.

In this paper, the time-varying covariance between stock and bond returns is assumed to be given by the following DCC(1,1) model

$$
\begin{aligned}
r_{i,t} &= \gamma_i + \phi_i r_{i,t-1} + \varepsilon_{i,t} \\
\sigma^2_{i,t} &= \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta \sigma^2_{i,t-1} \\
\sigma_{ij,t} &= \overline{\sigma}_{ij} + \alpha\left(z_{i,t-1} z_{j,t-1} - \overline{\sigma}_{ij}\right) + \beta\left(\sigma_{ij,t-1} - \overline{\sigma}_{ij}\right)
\end{aligned}
\tag{3}
$$

where $r_{i,t}$ denotes the return on asset i at time t, $\sigma_{i,t}$ is the conditional volatility of asset i at time t, $\sigma_{ij,t}$ is the time t conditional covariance between assets i and j, $z_{i,t} = r_{i,t} / \sigma_{i,t}$, and $\overline{\sigma}_{ij}$ is the unconditional expectation of the cross product $z_{i,t}\, z_{j,t}$. A further description of the DCC model and the estimation procedure is provided in Appendix 1.

(insert Table 1 about here)

The maximum likelihood estimates of the DCC model given by Equation (3) are reported in Table 1. As can be seen from the table, the estimated DCC(1,1) models appear statistically highly significant for both the US and Germany. For both countries, the sum of the α and β estimates in the conditional covariance equation is less than unity, and consequently the estimated models preserve mean-reversion of stock-bond return correlation.

4. How does the correlation between stock and bond returns behave over time?

Descriptive statistics of the rolling window and conditional stock and bond return correlation estimates for the United States and Germany are reported in Table 2. On average, the stock-bond correlations in both countries are positive, with mean correlation estimates of about 0.14, regardless of the estimation method used. The correlations have ranged from –0.87 to 0.80 in the US and from –0.71 to 0.88 in Germany. Interestingly, the median correlation estimates are much higher for the US than for Germany. It can also be noted from Table 2 that in terms of means and medians, the rolling window and dynamic conditional correlation estimates seem rather similar to each other. Moreover, virtually similar correlation estimates for both economies were obtained when 2-year government bond indices were used instead of 10-year bonds. Therefore, these results are not reported in the paper.

(insert Table 2 about here)

Developments of the stock-bond return correlations in the US and Germany are plotted in Figures 1 and 2. Several interesting features emerge from these figures. Although the correlations in both countries are positive on average, it is apparent that the relation between stock and bond returns has been rather unstable over time, and also sustained periods of negative correlation can be observed. For both countries, the correlations have been constantly

positive until November 1997, whereas during 1998 and after autumn 2000 the correlations appear to be mostly negative. Moreover, Figures 1 and 2 indicate that the stock-bond correlation may change substantially in very short periods of time. For instance, in October 1997 the conditional stock-bond correlation in the US was about 0.52, but already one month later in November the correlation had dropped to –0.18. This may pose challenges for asset allocation and risk management procedures.

(insert Figures 1 and 2 about here)

It may also be noted from Figures 1 and 2 that the conditional and rolling window stock-bond return correlations exhibit a very similar pattern over time. However, as expected, the rolling window correlation estimates appear to be considerably more erratic than the conditional correlations produced by the DCC model. Also, DCC estimates should account for the changes in volatility, and thereby be free from the potential upward bias during periods of financial turmoil.

In order to facilitate comparison of the behaviour of stock-bond return correlations across countries, the conditional correlation estimates for the US and Germany are overlapped in Figure 3. Interestingly, the stock-bond return correlations in the US and Germany exhibit rather similar patterns, thereby suggesting that some common factors may determine the time-varying relation between the two main asset classes. For both countries, the stock-bond correlation was positive until November 1997, and then suddenly dropped to levels below zero for a short-period during the late 1997 and early 1998. The correlations in both countries again became positive in March 1998, but fell back to negative levels already in the summer of 1998. During the exceptionally optimistic growth period from spring 1999 until summer 2000, the stock-bond correlations were soundly positive. After the stock market correction started in March 2000, the correlations both in the United States and Germany became less positive and started to wander

at levels close to zero. The correlations for both economies then turned negative in early 2001 and stayed below zero levels throughout 2002 and early 2003. During the latter part of 2003 and early 2004 the correlations have become less negative, coinciding with the rebound in stock markets.

(insert Figure 3 about here)

5. Why does the stock-bond return correlation vary over time?

The preceding analysis evidently demonstrates that the relation between bond and stock returns varies considerably over time. Against this background, it is of interest to examine what factors may cause this time-variation in the correlation between stock and bond returns. A priori, the potential determinants of the time-varying stock and bond return correlation may be deduced from the asset pricing theory, which postulates that the price of an asset equals the present value of all future cash flows from the asset discounted at an appropriate discount rate. Hence, the price of a stock S at time t can be expressed as the discounted sum of all expected future dividends

$$S_t = E\left[\sum_{t=1}^{\infty}\left(\frac{1+G_t}{1+Y_t+ERP_t}\right)^t D\right] \tag{4}$$

where D denotes dividends, Y is the government bond yield, G is the expected growth rate of the dividends, and ERP is the equity risk premium demanded by investors. Correspondingly, the time t price of a government bond B can be written as the discounted sum of all future coupon payments and the face value of the bond

$$B_t = E\left[\sum_{t=1}^{T}\frac{C_t}{(1+Y_t)^t}+\frac{FC}{(1+Y_T)^T}\right] \tag{5}$$

where *C* denotes coupon payment and *FC* is the face value of the bond. The government bond yield *Y,* used as the discount rate, reflects expectations about future short-term rates and the required bond risk premium demanded by investors for holding longer-term bonds.

According to the Fisher decomposition, the nominal government bond yield *Y* may be decomposed into a real interest rate component and a compensation for the expected inflation over the remaining life of the bond. Moreover, *Y* may also include a term premium, which investors demand for holding longer (i.e. more risky) assets. Consequently, the nominal government bond Y yield can be expressed as

$$Y_n = Y_n^r + \pi_n^e + \theta \tag{6}$$

where Y_n denotes the *n* period nominal bond yield, Y_n^r is the *n* period real interest rate, π_n^e is the expected inflation rate over *n* periods, and θ denotes the term premium. Since long-term real interest rates should, in theory, be closely linked to long-term real growth expectations, Equation (6) suggests that nominal government bond yields are decisively determined by growth and inflation expectations.[3] In particular, higher (lower) growth and/or inflation expectations should lead to higher (lower) bond yields. Consequently, given Equation (5), it is apparent that bond prices should be negatively related to growth and inflation expectations.

The impact of growth and inflation expectations on stock prices is rather ambiguous. Rising inflation or growth expectations may have no impact on stock prices, if the discount rates and expected growth rate of the dividends are equally affected by rising inflation and growth expectations. Nevertheless, in case of elevated inflation expectations, the discount rate effect

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[3] The link between economic activity and the real interest rate dates back to Fisher (1907), who showed that the real interest rate is determined by a ratio of optimal future consumption to optimal current consumption. This ratio, including the discount factor adjustment, is the marginal rate of inter-temporal substitution reflecting agents' preferences, and the presence of the discount factor ensures that the real rate of interest exceeds real consumption growth in the long run.

may outweigh the changes in expected future dividends, and hence, high inflation expectations tend to have a negative impact on stock prices (see e.g., Ilmanen, 2003).

Also relative changes in the equity risk premium and the term premium of long-term bonds may significantly affect the time-varying relation between stocks and bond returns. The term and equity risk premiums ultimately depend on the asset's perceived risk characteristics and on investors' risk aversion. For instance, during periods of financial market turbulence investors tend to become more risk averse, thereby prompting shifts of funds out of the stock market into safer asset classes, such as long-term government bonds. These so-called "flight-to-quality" episodes may be interpreted as an increase in the equity risk premium and a decrease in the bond term premium. Consequently, it may be expected that stock and bond prices move in the opposite direction during periods of market turmoil.

To examine how inflation and growth expectations and perceived stock market uncertainty affect the relationship between stock and bond returns, we calculate the average stock-bond return correlations in 12 different subsamples, which are created based on the levels of CPI growth expectations, real GDP growth expectations, and stock market volatility expectations. The average stock-bond return correlations in the quantile subsamples are reported in Table 3. As can be seen from the table, expected inflation appears to be positively related to the correlation between stock and bond returns. Panel A of Table 3 shows that the average stock-bond return correlation in the United States is about 0.30 during periods in which the expected inflation is in the highest quartile. Similarly, Panel B shows that in Germany, the correlation has also been highly positive, about 0.39, during periods of high expected inflation. On the contrary, during periods in which the expected inflation is in the lowest quartile, the correlations between stock and bond returns in both countries are negative, being about -0.20 in the US and -0.09 in Germany. The bootstrapped 95 % confidence intervals for the mean correlation estimates (reported in parentheses) suggest that the observed differences in stock-bond return correlations between different quantile subsamples are statistically highly significant.

(insert Table 3 about here)

Turning the focus onto the impact of growth expectations on stock-bond correlations, Table 3 shows no clear patterns. Regardless of the level of growth expectations, stock-bond correlations in both countries are consistently positive, without any systematic differences between different subsamples. For instance, the correlation in the US is most positive during periods of lowest growth expectations, while in Germany stock-bond correlation appears to be highest on medium levels of growth expectations. Consequently, no inferences about the impact of growth expectations on the time-varying correlation between stock and bond returns can be drawn from Table 3.

Finally, Table 3 clearly demonstrates that expected stock market uncertainty, as measured by implied volatility, is negatively related to the correlation between stock and bond returns. Panel A shows that the average stock-bond return correlation in the US is about -0.21 during periods of high stock market uncertainty, and strictly positive, 0.38, during periods in which implied volatility is in the lowest quartile. Correspondingly, Panel B shows a similar pattern for the German stock-bond correlation. During periods of stock market stress, stock-bond correlation is negative, -0.15, while during periods of low market uncertainty the correlation is highly positive, 0.45. The bootstrapped 95 % confidence bounds suggest that these differences in stock-bond return correlations between different subsamples are statistically significant.

To further examine the impact of inflation and growth expectations and perceived stock market uncertainty on the correlation between stock and bond returns, we regress the stock-bond return correlation estimates on the expected growth rate of consumer prices, expected growth rate of real gross domestic product, and implied stock market volatility. A potential difficulty in regressing stock-bond return correlation estimates is that the correlation coefficient is, by definition, restricted to the range [-1, +1], whereas the right hand side of the regression is not restricted to produce values within this range. In order to make the dependent variable

unrestricted, a generalized logit transformation is applied to transform the range of correlation estimates to [-∞, +∞]. Consequently, the following regression model is estimated

$$\log\left(\frac{1+\rho_t}{1-\rho_t}\right) = \alpha + \beta_1 CPI_{t-i} + \beta_2 GDP_{t-i} + \beta_3 IV_{t-1} + \varepsilon_t \quad (7)$$

where ρ_t denotes the correlation between stock and bond returns at time *t*, *CPI* is the expected growth rate of consumer price index, *GDP* is the expected growth rate of real gross domestic product, *IV* is the implied stock market volatility, and *i* is either 0 or 1 depending on whether contemporaneous or lagged impacts of expected inflation and growth on stock-bond correlation are examined. The Ljung-Box statistic indicates significant serial correlation in the residuals of the regressions, and hence AR(*p*) terms are added to the regression specifications.

To ascertain whether the explanatory variables used in the regression are stationary, the augmented Dickey-Fuller and Phillips-Perron unit root tests are performed. The lag length used in the tests is decided based on the Schwartz information criterion. The results of the unit root tests are reported in Table 4. As can be seen from the table, the unit root tests indicate that all explanatory variables, except the expected growth rate of the German CPI, are stationary, as the null hypothesis of a unit root can be soundly rejected for these time-series. Given that the there is considerable evidence for stationarity of inflation rates (see e.g., Rose, 1988; Lai, 1997; Lee and Wu, 2001), it is assumed in the subsequent analysis that the expected growth rate of the German CPI is stationary.[4]

(insert Table 4 about here)

[4] Moreover, since the main objective of the Deutsche Bundesbank and the European Central Bank has been to deliver low and stable inflation, the inflation expectations may be expected to wander around the inflation target, if the policy objective is considered credible among the market participants.

The regression results for the United States are reported in Table 5. In Panel A, the rolling window stock-bond return correlation is used as the dependent variable, whereas in Panel B the dependent variable is the dynamic conditional correlation. The estimation results indicate that expected inflation is positively related to stock-bond return correlation. In all four regression specifications, the estimated coefficient for CPI is positive. However, the coefficients are significant only when the rolling window correlation is used as the dependent variable. The results in Table 5 also demonstrate that expected stock market uncertainty has a negative impact on the correlation between stock and bond returns, as the estimated coefficient for implied volatility is negative, and statistically significant at the one percent level in all four regression specifications. Finally, it can be noted from Table 5 that the estimated coefficients for expected growth are always negative, but none of the four coefficient estimates appears statistically significant.

(insert Table 5 about here)

Table 6 reports the regression result for the German stock-bond return correlations. Panel A indicates that all the explanatory variables have an impact on the stock-bond correlation. Consistently with the results reported in Table 5, the estimated coefficients for implied volatility are negative and statistically significant at the one percent level, thereby suggesting that high stock market uncertainty tends to move stock and bond prices into opposite directions. The results reported in Panel A also show that inflation expectations are positively related to stock-bond correlations, as the coefficient estimates are positive and statistically highly significant. Finally, the results demonstrate negative, albeit only weakly significant, relation between growth expectations and stock-bond correlations. In Panel B of Table 5, the dynamic conditional stock-bond return correlation is used as the dependent variable. The signs of all coefficient estimates are consistent with the estimates reported in Panel A, being negative for

implied volatility and growth expectations and positive for inflation expectations. However, only the coefficient of contemporaneous growth expectation appears statistically significant, and only at the ten percent level.

(insert Table 6 about here)

Overall, the regression results for the United States and Germany are very similar. These results strongly indicate that expected inflation is positively related to the correlation between stock and bond returns. The estimated coefficients for expected growth rate of the CPI are always positive, and appear statistically significant in four regressions specifications. Since bond prices should be negatively related to inflation expectations, our findings suggest that high inflation expectations have a larger impact on the discount rates than on the expected future dividends, thereby causing a negative relation between stock prices and inflation expectations, and consequently a positive relation between inflation expectations and stock-bond return correlation. Furthermore, the estimated coefficients for implied volatility are negative in all eight regression specifications, and in most cases the coefficients are statistically significant at the one percent level. Hence, the estimation results strongly indicate that high stock market uncertainty tends to lead to a decoupling between stock and bond prices. This finding is consistent with the "flight-to-quality" phenomenon. Finally, the estimated coefficients for expected growth are always negative. However, the coefficients are statistically significant only in two of the regressions, and only at the ten percent level.

6. Conclusions

This paper examines the impact of macroeconomic expectations and perceived stock market uncertainty on the correlation between stock and bond returns. Our empirical findings demonstrate that the correlation between stock and bond returns varies considerably over time.

Using data from the United States and Germany, we find that the stock-bond correlations in both countries are positive most of the time, although sustained periods of negative correlation are also observed. Interestingly, the stock-bond correlations in the US and Germany exhibit rather similar patterns over time, as for instance the periods of negative correlation seem to coincide. Furthermore, our findings demonstrate that the stock-bond correlation may change substantially, and turn from positive to negative, in very short periods of time. These rapid changes in the relationship between stock and bond markets may pose challenges for asset allocation and risk management procedures.

Our empirical findings indicate that expected inflation is positively related to the time-varying correlation between stock and bond returns. Stock and bond prices tend to move in the same direction during periods of high inflation expectations, while epochs of negative stock-bond return correlation seem to coincide with the lowest levels of inflation expectations. The empirical findings also demonstrate that expected stock market uncertainty, as measured by implied volatility, is negatively related to the correlation between stock and bond returns. In particular, our results strongly indicate that high stock market uncertainty leads to a decoupling between stock and bond prices. This finding is consistent with the so-called “flight-to-quality” phenomenon. Finally, we are unable to find any systematic relationship between economic growth expectations and stock-bond return correlations.

Appendix 1.

Let $r_t \left| F_{t-1} \propto N(0, H_t) \right.$ denote an *n*-dimensional conditional multivariate normal process with zero expectations and a conditional covariance matrix $H_t = E_{t-1}(r_t r_t')$. To avoid unnecessary expansion, we get rid of the equation for mean in a GARCH process and assume that r_t are already detrended and demeaned residuals. DCC model, being a generalisation of Bollerslev's (1990) constant conditional correlation model, shares the same conditional correlation estimator

$$H_t = D_t R_t D_t .$$

where $D_t = diag\{\sqrt{h_{i,t}}\}$ is a diagonal matrix of time-varying standard deviations of the residuals of the mean equation of univariate GARCH models

$$h_{i,t} = E_{t-1}(r_{i,t}^{\ 2}), r_{i,t}^2 = \sqrt{h_{i,t}}\varepsilon_{i,t}$$

where $\varepsilon_{i,t} \propto WN(0,1)$ are standardised disturbances. In contrast to the constant conditional correlation model, the correlation matrix $R_t = E_{t-1}(\varepsilon_t \varepsilon_t')$ is now allowed to be time-dependent. Engle (2002) proposed to find the elements of *D*-matrix from the univariate GARCH models and to formulate the dynamic covariance structure as a following GARCH process

$$q_{ij,t} = \overline{\rho}_{ij} + \alpha(\varepsilon_{i,t-1}\varepsilon_{j,t-1} - \overline{\rho}_{ij}) + \beta(q_{ij,t-1} - \overline{\rho}_{ij})$$

where $\overline{\rho}_{ij}$ is the unconditional correlation of $\varepsilon_{i,t}$ and $\varepsilon_{j,t}$ and $\rho_{ij,t} = q_{ij,t} / \sqrt{q_{ii,t} q_{jj,t}}$. Thus, the conditional correlations $\rho_{ij,t}$ depend on the common GARCH parameters, α and β, and on the unconditional correlations. Then, the time-varying correlation matrix is given by

$$R_t = \sqrt{diag(Q_t)} Q_t \sqrt{diag(Q_t)} .$$

If the sum of positive coefficients α and β is less than one, the estimated model will preserve to be mean-reverting. The covariance matrix $Q_t = (q_{ij,t})$ is a weighted average of a positive semi-definite and a positive-definite matrices, and thus it is positive-definite.

The log-likelihood estimator

$$L = -\frac{1}{2}\sum_{t=1}^{T}(n\log(2\pi) + \log|D_t R_t D_t| + r_t' D_t^{-1} R_t^{-1} D_t^{-1} r_r)$$

can be decomposed in two parts, which depend on volatility and on conditional correlation

$$L = L_{vol} + L_{cor},\ L_{vol} = -\frac{1}{2}\sum_{t=1}^{T}(n\log(2\pi) + \log|D_t|^2 + r_t' D_t^{-2} r_r) \text{ and}$$

$$L_{cor} = -\frac{1}{2}\sum_{t=1}^{T}(\log|R_t| + \varepsilon_t' R_t^{-1}\varepsilon_r - \varepsilon_t'\varepsilon_r).$$

As suggested by Engle (2002), it can be estimated in a two-step procedure. Taking into account that D_t has a diagonal form, the volatility-dependent part of the likelihood function L_{vol} is the sum of separately estimated *n* likelihood functions for individual GARCH models, which are estimated in the first step. Given the maximising values of variances obtained from the first step, the dynamic conditional correlations are estimated in the second step.

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Table 1. Maximum likelihood estimates of the DCC(1,1) model.

The table reports the maximum likelihood estimates of the following DCC(1,1) model:

$$r_{i,t} = \gamma_i + \phi_i r_{i,t-1} + \varepsilon_{i,t}$$
$$\sigma^2_{i,t} = \omega_i + \alpha_i \varepsilon^2_{i,t-1} + \beta \sigma^2_{i,t-1}$$
$$\sigma_{ij,t} = \overline{\sigma}_{ij} + \alpha\left(z_{i,t-1} z_{j,t-1} - \overline{\sigma}_{ij}\right) + \beta\left(\sigma_{ij,t-1} - \overline{\sigma}_{ij}\right)$$

where $r_{i,t}$ denotes the return on asset i at time t, $\sigma_{i,t}$ is the conditional volatility of asset i at time t, $\sigma_{ij,t}$ is the time t conditional covariance between assets i and j, $z_{i,t} = r_{i,t} / \sigma_{i,t}$, and $\overline{\sigma}_{ij}$ is the unconditional expectation of the cross product $z_{i,t}\, z_{j,t}$.

	United States		Germany	
	Estimate	*t*-stat.	Estimate	*t*-stat.
γ_{STOCK}	0.001***	3.178	0.001**	2.444
γ_{BOND}	0.000	1.569	0.000**	2.191
ϕ_{STOCK}	-0.010	-0.488	-0.008	-0.364
ϕ_{BOND}	0.080***	5.121	0.005	0.229
ω_{STOCK}	0.000**	2.312	0.000***	4.937
ω_{BOND}	0.000***	2.850	0.000***	3.845
α_{STOCK}	0.077***	4.831	0.084***	7.694
α_{BOND}	0.041***	4.641	0.049***	6.652
β_{STOCK}	0.916***	52.557	0.907***	83.749
β_{BOND}	0.942***	83.616	0.936***	101.603
α	0.037***	37.283	0.029***	6.238
β	0.959***	845.016	0.969***	180.620

***significant at the 0.01 level
**significant at the 0.05 level
*significant at the 0.10 level

Table 2. Descriptive statistics of stock-bond return correlations.

The table reports descriptive statistics of the monthly rolling window correlation (RWC) and dynamic conditional correlation (DCC) estimates between stock and bond returns.

	US RWC	US DCC	German RWC	German DCC
Mean	0.140	0.135	0.139	0.140
Median	0.207	0.219	0.119	0.120
Minimum	-0.886	-0.674	-0.708	-0.488
Maximum	0.803	0.697	0.875	0.711
Standard Deviation	0.430	0.353	0.412	0.323
Skewness	-0.474	-0.494	0.041	0.075
Kurtosis	-0.737	-0.783	-1.159	-1.102
No. of Observations	160	160	124	124

Table 3. Stock-Bond return correlations and economic expectations.

The table reports average correlations between stock and bond returns in month *t* for subsamples created by sorting inflation expectations (CPI), real GDP growth expectations, and stock market volatility expectations (IV) in month *t*-1. The bootstrapped 95 % confidence intervals for the correlation estimates are reported in parentheses.

Panel A: US stock-bond return correlation

Quantile	CPI	GDP	IV
75^{th}-100^{th}	0.298	0.092	-0.208
	(0.25 0.344)	(-0.008 0.186)	(-0.316 -0.108)
50^{th}-75^{th}	0.399	0.109	0.070
	(0.356 0.474)	(-0.03 0.238)	(-0.042 0.154)
25^{th}-50^{th}	-0.015	0.087	0.251
	(-0.12 0.105)	(-0.025 0.189)	(0.165 0.338)
0-25^{th}	-0.205	0.176	0.379
	(-0.115 -0.279)	(0.084 0.276)	(0.328 0.421)

Panel B: German stock-bond return correlation

Quantile	CPI	GDP	IV
75^{th}-100^{th}	0.388	0.051	-0.153
	(0.296 0.466)	(-0.018 0.118)	(-0.236 -0.066)
50^{th}-75^{th}	0.308	0.217	0.084
	(0.202 0.398)	(0.098 0.307)	(-0.005 0.179)
25^{th}-50^{th}	-0.065	0.215	0.181
	(-0.121 0.058)	(0.091 0.360)	(0.085 0.275)
0-25^{th}	-0.086	0.072	0.448
	(-0.153 -0.022)	(-0.046 0.208)	(0.38 0.516)

Table 4. Unit root tests.

The table reports Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests for the inflation expectations (CPI), real GDP growth expectations, and stock market volatility expectations (IV). The lag length for the unit root tests is decided based on the Schwarz information criterion.

	ADF	p-value	PP	p-value
US CPI	-3.526	0.009	-3.339	0.015
US GDP	-3.732	0.005	-3.421	0.012
US IV	-3.406	0.012	-3.678	0.005
German CPI	-1.778	0.390	-1.624	0.468
German GDP	-2.898	0.048	-2.641	0.087
German IV	-2.655	0.085	-2.678	0.081

Table 5. US stock-bond return correlations.

The reported results are based on the following regression specifications:

$$\log\left(\frac{1+\rho_t}{1-\rho_t}\right) = \alpha + \beta_1 CPI_{t-i} + \beta_2 GDP_{t-i} + \beta_3 IV_{t-1} + \varepsilon_t$$

where ρ_t denotes the correlation between stock and bond returns at time t, *CPI* is the expected growth rate of consumer price index, *GDP* is the expected growth rate of real gross domestic product, *IV* is the implied stock market volatility, and i is either 0 or 1.

Panel A: Rolling window correlation

	Estimate	*t*-stat.	Estimate	*t*-stat.
Constant	0.169	0.384	0.281	0.742
CPI_t	0.203**	2.118		
GDP_t	-0.076	-1.205		
CPI_{t-1}			0.164*	1.845
GDP_{t-1}			-0.083	-1.568
IV_{t-1}	-0.020***	-3.002	-0.019***	-3.179
AR(1)	0.379***	4.283	0.386***	4.437
AR(2)	0.237***	3.025	0.251***	3.1791
Adjusted R^2	0.556		0.554	
F-stat.	40.764***		40.449***	
No. of observations	160		160	

Panel B: Dynamic conditional correlation

	Estimate	*t*-stat.	Estimate	*t*-stat.
Constant	0.378	0.511	0.983	1.221
CPI_t	0.241	1.207		
GDP_t	-0.129	-1.212		
CPI_{t-1}			0.064	0.281
GDP_{t-1}			-0.188	-1.547
IV_{t-1}	-0.021***	-2.920	-0.020***	-3.146
AR(1)	0.8505***	17.957	0.873***	20.280
Adjusted R^2	0.811		0.812	
F-stat.	171.962***		173.196***	
No. of observations	160		160	160

***significant at the 0.01 level
**significant at the 0.05 level
*significant at the 0.10 level

Table 6. German stock-bond return correlations.

The reported results are based on the following regression specifications:

$$\log\left(\frac{1+\rho_t}{1-\rho_t}\right) = \alpha + \beta_1 CPI_{t-i} + \beta_2 GDP_{t-i} + \beta_3 IV_{t-1} + \varepsilon_t$$

where ρ_t denotes the correlation between stock and bond returns at time t, *CPI* is the expected growth rate of consumer price index, *GDP* is the expected growth rate of real gross domestic product, *IV* is the implied stock market volatility, and i is either 0 or 1.

Panel A: Rolling window correlation

	Estimate	*t*-stat.	Estimate	*t*-stat.
Constant	0.202	0.724	0.230	1.219
CPI_t	0.252**	2.290		
GDP_t	-0.085*	-1.798		
CPI_{t-1}			0.213***	2.873
GDP_{t-1}			-0.062	-1.461
IV_{t-1}	-0.014***	-3.632	-0.015***	-3.923
AR(1)	0.5651***	8.269	0.554	8.121
Adjusted R^2	0.583		0.575	
F-stat.	43.363***		41.976***	
No. of observations	124		124	

Panel B: Dynamic conditional correlation

	Estimate	*t*-stat.	Estimate	*t*-stat.
Constant	0.174	0.695	0.154	0.811
CPI_t	0.021	0.245		
GDP_t	-0.051*	-1.740		
CPI_{t-1}			0.006	0.133
GDP_{t-1}			-0.031	-0.912
IV_{t-1}	-0.002	-0.656	-0.002	-0.538
AR(1)	0.9313***	38.695	0.932***	35.138
Adjusted R^2	0.874		0.873	
F-stat.	211.423***		208.792***	
No. of observations	124		124	

***significant at the 0.01 level
**significant at the 0.05 level
*significant at the 0.10 level

Figure 1. US stock-bond return correlations.

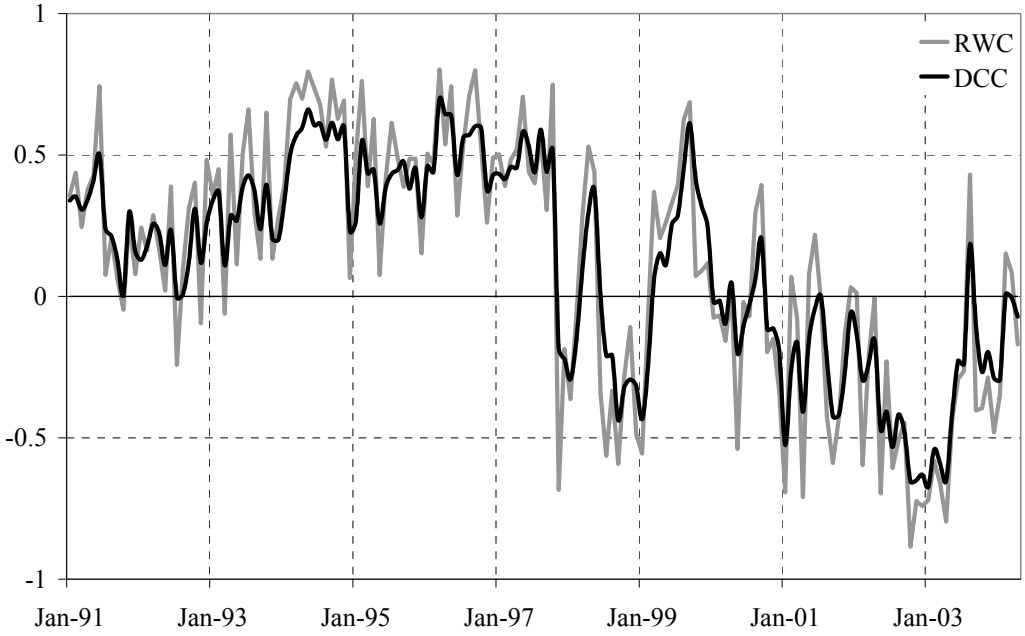

Figure 2. German stock-bond return correlations.

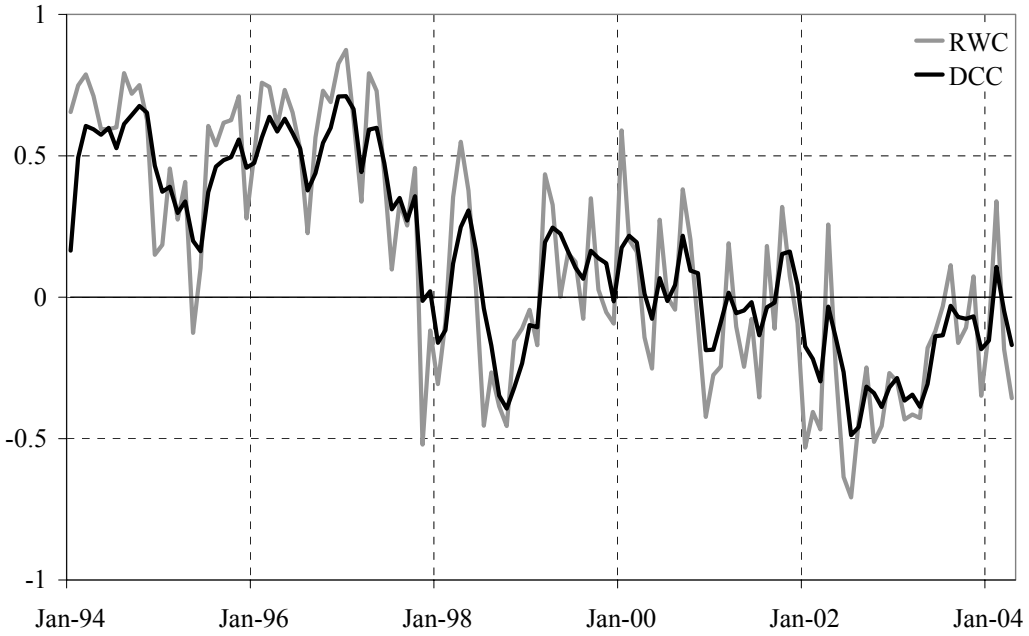

Figure 3. US and German stock-bond return correlations.