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Realized Bond-Stock Correlation: Macroeconomic Announcement Effects

Abstract: We investigate the effects of macroeconomic announcements on the realized correlation between bond and stock returns. Our results deliver insights into the dominating drivers of bond-stock comovements. We find that it is not so much the surprise component of the announcement, but the mere fact that an announcement occurs that influences the realized bond-stock correlation. The impact of macroeconomic announcements varies across the business cycle. Announcement effects are highly dependent on the sign of the realized bond-stock correlation which has recently gone from positive to negative. Macroeconomic announcement effects on realized bond and stock volatilities are also investigated.

Keywords: Bond-stock correlation; Macroeconomic announcements; Realized correlation; Realized volatility

JEL Classifications: G12; G13; G14

1 Introduction

How do markets adjust to important news arrivals? How and to what extent are bond and stock markets linked to fundamentals? Do macroeconomic announcement effects vary across assets? Do the price discovery processes in different markets proceed independently or in tandem? Does the current economic business cycle characterize the market's price reactions to macroeconomic news? In this paper, we attempt to shed new light on these important issues.

This paper studies the news impact of US macroeconomic announcements on realized variance and realized correlation of bond and stock returns. While the previous literature focuses on the price and volatility impact of scheduled macroeconomic news, we investigate the effect on the realized correlation between bond and stock returns. The study of comovement across asset classes is relevant for many reasons. First, asset correlation is a key issue in asset allocation decisions. Portfolio optimization hinges on the concept of correlation. Second, correlation is a central issue in risk management and hedging. Using trade-by-trade data, we analyze more than a decade of realized correlation between US government bonds and stocks. This long sample period allows us to address two essential features of bond-stock comovement: its time-varying nature and its state-dependence character. Furthermore, we investigate the macroeconomic news impact on realized correlation.

The analysis of market comovement of different assets surrounding the announcements illuminates the price discovery process. New information about fundamental asset values triggers the search for a new equilibrium value. This search process gets through the interactions of buyers and sellers as well as the operational characteristics of the marketplace. Market microstructure and trader behavior could determine the efficiency of the process in many aspects. Also, the arrival of important news items could cause a disruption in the price discovery process. Our study delivers insights into the synchronized process of price formation in different markets.

The intimate nature of the correlation between bond and stock returns is not well understood and is mainly confined to some stylized facts. First, bond-stock correlation may change sharply across time and economic conditions. For instance, after a long period of relatively high positive correlation, the US bond-stock correlation has witnessed a strong negative reversal. Second, in accordance with the "flight-to-quality" pattern, when risk aversion increases, investors adjust their portfolios to include more safe assets and fewer risky assets. As a consequence, government bond prices go up and stock prices fall. In this research, we attempt to extend the understanding of these stylized facts. We

provide further evidence on the time-varying comovement between bond and stock returns. By analyzing the state-dependence of the market reaction to macroeconomic news releases, we find that realized correlation strongly depends on general economic and market conditions and that different news items have different impacts. Our findings suggest that the dominating factors in the bond and stock pricing - and thereby in bond-stock comovements - vary across economic and market conditions.

Finally, this research adds to the literature on volatility and correlation measurement. First, we use the recent techniques based on the realized volatility and realized correlation. Second, we exploit the finest information contents provided by high-frequency data and real-time information releases. High-frequency data allow us to study price movements in nearly continuous time. Real-time macroeconomic information releases coupled with synchronized survey data on market participants' expectations enable us to infer the actual market impact of news surprises. Matching trade-by-trade data with real-time information, we can observe the cross-market movements and interactions.

The paper proceeds as follows: The related literature is surveyed in the following section. The data are introduced in Section 3. The empirical results are divided into two parts; in Section 4 we cover the macroeconomic announcement effects on bond realized variance and stock realized variance. The macroeconomic announcement effects on the realized bond-stock correlations are discussed in Section 5. Finally, Section 6 concludes.

2 Related Literature

In this section we describe the related literature. First we discuss the literature on macroeconomic announcement effects and then we briefly touch upon the realized variance literature. Finally, we survey the literature on the relation between bond and stock returns.

2.1 Macroeconomic Announcement Effects

The previous literature investigates the effect of macroeconomic announcements on the first and second moments of asset returns. Overall, the previous research shows that macroeconomic announcement effects are significant for asset returns. Some papers rely on dummy variables to distinguish between announcement days and non-announcement days, whereas other papers use the unexpected part (surprise) of a macroeconomic announcements as explanatory variables. In our empirical work (yet to be presented) we use both approaches;

we denote them "announcement effect" (announcement occurrence) and "news effect" (announcement surprise) analysis, respectively.

Some previous papers study the effect of macroeconomic announcements on the conditional volatility of asset returns, typically using the GARCH-volatility relying on daily data and indicator variables as explanatory variables. Jones, Lamont and Lumsdaine (1998) apply GARCH models to investigate government bond returns of varying maturity and find that the observed persistence in conditional volatility is not caused by macroeconomic releases. Christiansen (2000) uses a multivariate GARCH model to document that macroeconomic announcements induce common movement in the government bond market. Arshanapalli, Switzer and Vezina (2003) use a bivariate GARCH model to analyze bond and stock returns. The GARCH conditional covariance is regressed on various explanatory variables including announcement day indicators. The bond-stock GARCH conditional covariance is not significantly influenced by macroeconomic announcement effects. In contrast, we find that the realized bond-stock correlation is significantly influenced by macroeconomic announcements and surprises.

Other previous studies apply high frequency data which is the path that we follow here. Ederington and Lee (1993) use intradaily data for interest rates and exchange rates and find that volatility reacts very fast to new information. They measure volatility by absolute returns and use announcement dummies. Ederington and Lee (1995) corroborates these findings using tick-by-tick data. Fleming and Remolona (1997) show that the largest price changes (intradaily) in the 5-year Treasury note are due to macroeconomic announcements again relying on release times not announcement shocks. Balduzzi, Elton and Green (2001) find that announcement surprises affect government bond returns. Volatility effects (measured by the absolute price changes) persist longer than price effects.

Faust, Rogers, Wang and Wringht (2003) and Andersen, Bollerslev, Diebold and Vega (2004b) are closely related to our paper. Faust et al. (2003) show that announcement surprises affect the returns of several exchange rates and interest rates in a window around the announcements. Their data cover a fairly long period, from 1987 to 2002. Andersen et al. (2004b) conduct similar analyses using several futures contracts for a shorter period, from 1994 to 2002. They investigate the effects of business cycles, although their data include only one fairly short recession period. In this paper we conduct similar regressions, but we use realized variances and realized correlations for windows surrounding macroeconomic announcements.

2.2 Realized Variances and Realized Correlations

In recent years, the availability of high-frequency data has made the usage of realized variances popular. The realized variance for a given period is calculated as the sum of the squared returns for that period. The daily realized variance is used instead of other volatility measures such as GARCH-volatility. The realized variance is introduced by Andersen, Bollerslev, Diebold and Labys (2003) who find that the realized volatility performs well compared to other volatility measures.

The daily realized correlation is calculated as the correlation between (say) the 5-minute returns during the day. The realized correlation has not been applied widely in the empirical literature.

2.3 Bond-Stock Relations

To the authors' knowledge, macroeconomic announcement effects on bond-stock realized correlation have not been studied in the previous literature. Yet, Arshanapalli et al. (2003) find no effects on the bond-stock GARCH covariance, cf. discussion above.

In the literature, the present value model represents a straightforward framework for understanding how bond and stock prices are determined. Using annual data for the period 1948 to 1989, Shiller and Baltratti (1992) find that the present value model implies a small positive bond-stock return correlation. Campbell and Ammer (1993) use an econometric approach to recast the present value model and to break the excess returns of long-term bonds and stocks into unexpected components of future cash flows and future discount rates. They find that most of the stock variance is due to innovations in risk premia and dividends. For bonds, the relevance of inflation and risk premia varies across time. In the present value model, inflation (real interest rate) changes make bond and stock returns move in opposite (same) directions. Changes in risk premia and term premia typically affect bonds and stocks differently. Although the bond-stock return correlation is generally positive, the relation might be negative in periods of "flight to quality". Ilmanen (2003) shows that the bond-stock correlation has recently gone from positive to negative and that it is influenced by the inflation level and the state of the economy (the business cycle). Li (2002) shows that real interest rates drive the bond and stock comovements and that inflation shocks make bond and stock returns move in opposite directions. Other drivers that decrease the bond-stock correlation are dividends and risk premia. Moreover, he finds that the bond-stock correlation mainly depends on inflation

uncertainty.

Barberis, Schleifer and Wurgler (2002) provide evidence that comovements in stock markets are influenced by investors having fixed the proportions of investments in different asset classes. Another non-fundamental factor with some bearing on the correlation is the price discovery process, i.e. microstructure effects, cf. Andersen, Bollerslev, Diebold and Vega (2004a).

3 Data

3.1 High Frequency Bond and Stock Data

We analyze the futures contracts on the Standard & Poor's 500 Stock Price Index and 10 Year US Treasury Notes quoted on the Chicago Mercantile Exchange (CME) and Chicago Board of Trade (CBOT), respectively. The database has kindly been provided by the Swiss-Systematic Asset Management SA, Zurich. The data contain the time stamp to the nearest second and transaction price of all trades that occurred from November 11, 1988 to May 31, 2003. The trading hours are broken into 5-minute time intervals. In 1988, the trading day on the CBOT took place from 8.20 to 15.00 Eastern Time (all time indications are in ET). The trading hours at the CME were from 9.30 to 16.15.

We use the most actively traded nearest-to-maturity or cheapest-to-delivery futures contract, switching to the next-maturity contract five days before expiration, cf. Andersen et al. (2004b) for a similar approach. We then construct the exact matching between trading hours and official holidays between the CBOT and CME. If no trades occur in a given 5-minute interval, we copy down the last trading price in the previous time interval. After coupling the simultaneous price changes on the CBOT and CME, we are able to calculate realized volatilities and realized correlations of bond and stock returns.

Realized volatility is the sum of consecutive squared log price changes. Realized correlation is the correlation coefficient between synchronized 5-minute price returns. We calculate realized volatility and realized correlation from 10 minutes before the announcement to 90 minutes afterwards, i.e. the same window as in Andersen et al. (2004b). In particular, the window is from 9.50 to 11.30 as the announcements occur at 10.00. Considering the price movements prior to the news arrival, we account for any premature price adjustment or information leakage.

Table 1 shows various descriptive statistics for the realized variances and realized correlations. We show the summary statistics for the full sample and separately for announcement days and non-announcement days. Below we de-

scribe in more detail which announcements are included. The realized variances have been scaled by 100,000. As expected, the bond realized variances are much smaller than the stock realized variances; on average 0.31 compared to 2.67.[1]

Both the average bond and stock realized variances are larger on announcement days than on non-announcement days, and the same goes for their standard deviations. This is in line with the previous literature using returns or GARCH-variance, cf. e.g. Jones et al. (1998) and Faust et al. (2003). The realized variances show excess kurtosis and are strongly skewed. Thus, for all variables the null hypothesis of normal distribution is strongly rejected by the Jarque-Bera non-normality test (not tabulated). The Wilcoxon signed ranks test (not tabulated) strongly rejects the fact that the distributions of bond realized variance are identical on announcement days and non-announcement days. For the stock realized variance the Wilcoxon signed rank test cannot reject that the distributions are identical on announcement and non-announcement days (p-value equals 0.48).

In the regression analysis we apply the logarithm of the realized variances, because they are much closer to being Gaussian distributed. The skewness of the log bond realized variance equals 0.43 (compare to 6.45 for the realized variance itself) and the kurtosis equals 3.58 (compare to 79 for the realized variance itself). Equivalent for the stock realized variance, using logarithm the skewness reduces from 8.74 to 0.23 and the kurtosis from 134 to 3.17. The Jarque-Bera test statistics have been reduced vastly, but still we reject normality.

Figure 1 shows that the typical realized bond-stock correlation (9.50-11.30) changes between being positive and negative during the sample period. On average, the realized correlation is larger on announcement days than on non-announcement days, whereas its standard deviation is almost identical in the two sub periods. Again, we reject the hypothesis of a normal distribution. The Wilcoxon signed rank test rejects that the distributions are identical on announcement and non-announcement days.

Below, we make use of the Fisher transform of the realized correlation; $F(x) = \frac{1}{2}\log(\frac{1+x}{1-x})$. The Fisher transform has the advantage that it transforms the realized correlation to support the whole real line, whereas the realized correlation is restricted to the interval [-1;1]. The Fisher transform of the realized

[1]Since these assets are highly liquid, the realized variance and realized correlation are only marginally affected by microstructure issues such bid-ask bounces, difference of the bid-ask spread size between assets, and non-synchronized trading between assets. Moreover, the realized volatilities always concern the same time period of the day, so intraday patterns of bid-ask spreads are not important. Additional experiments to assess the possible biases due to bid-ask bounces on the realized volatility and realized correlation have been performed. Even after accounting for these microstructure biases the data remain qualitatively the same.

correlation has skewness of -0.51 (compare to -0.42 for the realized correlation itself) and skewness of 2.93 (compare to 2.23). The Jarque-Bera test statistic is smaller, indicating that the Fisher transform of the realized correlation is closer to being Gaussian than the realized correlation itself, although it is still significantly different from being normal.

We use 60-minute rolling windows to construct intraday patterns of the realized bond-stock correlation. For each trading day we obtain 56 hourly observations (ending from 10.25 to 15.00). Figure 2 shows the intraday pattern of the average 60-minute realized correlations for each year in the sample. Compared to how much the realized correlation changes across the period, there are no observable strong intradaily patterns.

3.1.1 GLOBEX Electronic Trading

The CME supplemented the floor session for the S&P futures contracts with the GLOBEX electronic trading platform in September 1993. From 1998, the CBOT also experimented with new afternoon and overnight trading sessions. We focus only on the price discovery process on the floor trading. Combining the electronic and the floor trading sessions would be inconsistent with at least two significant aspects. First, trading sessions outside the regular floor trading have been very illiquid. Only from 2003, trading intensity on the GLOBEX platform has reached a liquidity extent comparable to the floor session. Second, the market microstructure of the floor and the electronic trading differs in many important aspects. The GLOBEX is an electronic matching system strictly governed by the price-time priority rule. Its order book is highly transparent (e.g. information on the ten best bid and ask quotes are continuously available) and trading information is disseminated in real-time to a large trading community. On the other hand, the trading floor is based on an open-outcry auction system. Trading in the pits implies the traders' physical presence. Traders cannot trade anonymously with each other. The information formally available in the pit is much more limited (typically the best bid and ask) and heterogeneous (e.g. interpretation of incoming flow of orders). Domowitz (1993) shows the price discovery process in the open-outcry auction differs from the electronic systems in terms of market liquidity, transaction costs, price change volatility and speed. Hasbrouck (2003) and Ates and Wang (2005) provide empirical evidence on the differences in the intraday price discovery process between the open-outcry and the electronic trading systems.

For the above reasons we use only the floor data. This is in contrast to some previous studies, e.g. Andersen et al. (2004a) use the GLOBEX data to be able

to analyze 8.30 macroeconomic announcements.

3.2 Announcement Data

We obtain the announcement data from Informa Global Markets (Europe) Ltd.[2] For each different macroeconomic announcement we obtain a time series of the realized values as well as market forecasts based on survey expectations. With some exceptions the data are available during the sample period for which we have access to the high frequency data, namely from May 1988 to May 2003. Table 2 shows the eight different announcements for which we have data that occur at 10.00.

The announcement days are spread out almost evenly across the different days of the week, cf. Table 2.

In the empirical analysis we follow the previous literature, e.g. Balduzzi et al. (2001), and use the standardized news for announcement k:

$$S_{kt} = \frac{A_{kt} - E_{kt}}{\sigma_k} \tag{1}$$

where A_{kt} is the realized value for announcement k at time t, and E_{kt} is the corresponding expected value. σ_k is the standard deviation of the announcement surprise $(A_{kt} - E_{kt})$ across the entire sample. Hereby we are able to compare the size of various regression coefficients associated with different announcements.

3.3 Business Cycle Data

We construct a recession indicator variable which is equal to one when the economy is in recession as defined by the NBER business cycle data. The economy is in recession from July 1, 1990 to February 28, 1991 and again from March 1, 2001 to October 31, 2001. Thereby there are 334 recession days in the sample, which amounts to just above 9% of the sample. We denote the recession indicator for R_t.

4 Realized Variance

In this section we investigate how the realized variance of bonds and stocks react to macroeconomic announcements. Although the previous literature has investigated macroeconomic announcement effects upon volatility, the authors are not aware of any studies using realized volatility measured as the sum of

[2] In previous studies this data source is denoted the International Money Market Service (MMS).

squared returns. More importantly, the results for the realized volatility provide us with a convenient base of comparison for the subsequent analysis of the bond-stock realized correlation.

4.1 News Effects

In order to investigate the news impact of macroeconomic announcements, we regress the log realized variance ($\log(RV_t)$) (first for bonds then for stocks) on the absolute value of the standardized announcement shock, $|S_{kt}|$. The regression is repeated and is conducted separately for each announcement. The regression for announcement k is as follows

$$\log(RV_t) = \alpha_k + \beta_k |S_{kt}| + \varepsilon_t \tag{2}$$

where the realized variance applies in the window around the announcement on day t and ε_t is the NIID residual. The regression is similar to the regressions in Balduzzi et al. (2001), Andersen et al. (2004a), and Faust et al. (2003) who apply returns as dependent variable. In contrast to the previous studies, we use absolute announcement shocks (instead of raw announcement shocks) because we expect that large positive and negative surprises affect volatility identically.[3] The regression only includes observations from days with announcements, i.e. the regressions are based on between 62 and 172 observations. All models are estimated using the Ordinary Least Squares technique and we use Newey and West (1987) standard errors.

In Table 3 (column one) we show the estimated slope coefficients and the centered R^2s from the news regressions for bond realized volatility.[4] It is noticed that for the Consumer Confidence, Institute for Supply Management index and the New Home Sales there are significant news effects on the bond realized volatility.[5] The bond realized volatility is larger the greater the news contained in these reports. Moreover, the R^2s are all low. So it appears that surprises from macroeconomic releases have only limited bearing on the realized bond variance. This is in contrast to the findings for bond returns: Balduzzi et al. (2001) find that four (including Consumer Confidence, Institute of Supply Management index, and New Home Sales) out of the eight 10.00 announcements have significant news coefficients for the 10-year Treasury note. Balduzzi et al. (2001)

[3] In the news regression Balduzzi et al. (2001) correct for the fact that some announcements occur simultaneously. Here, this does not affect the results.

[4] We re-run the regression leaving out the 1% smallest and the 1% largest realized variances. This does not alter the conclusions. We confirm that all subsequent regression results are robust to outliers in a similar fashion.

[5] The Institute for Supply Management was denoted the National Association of Purchasing Managers (NAPM) until August 2002.

find that the news impact on bond returns are negative for these announcements and that the R^2s are much higher (average around 0.27). The results for the 30-year Treasury bond returns reported in Andersen et al. (2004b) also contain four (including Consumer Confidence, Institute for Supply Management index, and New Home Sales) out of eight significant slope coefficients for the 10.00 announcement surprises. Again the R^2s are much larger than here (average of around 0.26). Thus, the news impact from macroeconomic announcements is much more pronounced for bond returns than for bond realized volatilities in the window around announcements. This is not surprising since price and volatility reactions to news announcements have completely different patterns, especially in terms of magnitude and persistence.

For the stock realized volatility we find only weak evidence of news effects, cf. Table 3 (column three). Only for the Personal Consumption Expenditures is the news impact significant. Moreover, the R^2s are all small. Similarly, Andersen et al. (2004b) find that only one 10.00 announcement has significant news impact (namely the New Home Sales) upon the return of the S&P500 futures index. Their R^2 is slightly lower than what we find. So, it appears that the news impact on stock returns and realized volatility in the window around announcements are of about the same low level.

Confirming *a priori* expectations, the news impact is larger for bond realized volatility than for stock realized volatility. This expectation is based on the fact that stock markets have firm specific news items, whereas this is not the case for bond markets. Moreover, stronger bond reactions than stock reactions are consistent with the findings of Andersen et al. (2004b) regarding returns.

To investigate the impact of the state of the business cycle on news effects we include the recession dummy, R_t, in the intercept and the slope of the news regression:

$$\log(RV_t) = \alpha_k + \beta_k|S_{kt}| + \alpha_k^* R_t + \beta_k^* R_t|S_{kt}| + \varepsilon_t \tag{3}$$

Table 3 (column two) shows the estimates of β_k and β_k^* as well as the centered R^2s from the news regression for bond realized volatility including recession effects. Neither of the slope coefficients are significantly different during expansions than during expansions. This is in line with the bond return findings in Andersen et al. (2004b).[6]

Table 3 (column four) shows the results from conducting the business cycle

[6]Note that the recession periods in the sample only cover 334 days, so there are not that many announcements of each type during recession periods. This is, however, not unusual in these kinds of studies.

news regression for stock realized volatility. Only two news effects are significantly different during recessions, namely the Business Inventories and the Consumer Confidence. The news impacts are stronger during recessions than during expansions ($\beta_k^* > 0$). Boyd, Hu and Jagannathan (2005) and Andersen et al. (2004b) find that some macroeconomic news items cause a stronger price reaction in recessions. Our equity results go in the same direction; there is stronger market reaction in terms of realized variance during recessions.

To summarize, we learn that it is desirable to distinguish between the news impacts during recessions and expansion. Moreover, it appears the state of the business cycle is only important for stocks but not for bonds with respect to news effects upon realized volatilities. This is in line with the findings in Andersen et al. (2004b) where there are only business cycle effects at play for stock returns not for bond returns. Overall, there is only limited evidence of any news effects of macroeconomic announcements on the realized variances of bonds and stocks.

4.2 Announcement Effects

We also investigate whether the mere occurrence of an announcement has an effect on the realized variances of bonds and stocks. First for bonds then for stocks, we run a regression using all the days in the sample and regress the 9.50-11.30 realized variance on announcement dummy variables for all announcement types.

$$\log(RV_t) = a + \sum_{k=1}^{K} b_k D_{kt} + e_t \tag{4}$$

D_{kt} is an indicator function which equals one on days when announcement k is released and is zero otherwise and e_t is the NIID residual. There are $K = 7$ different announcements because the Personal Consumption Expenditures and the Personal Income are always released simultaneously. The regression is similar to the absolute return regression on equivalent dummy variables in Ederington and Lee (1993).

In Table 4 (column one) we show the slope coefficient estimates and the R^2 from the announcement regression for the bond realized volatility. There are significant announcement effects from almost all announcements to the bond realized volatility. The exceptions are Construction Spending and Personal Consumption Expenditures/Personal Income. The Institute for Supply Management index exerts most influence (it has the largest b_k-estimate). The bond realized volatility is larger on macroeconomic announcement days. The R^2 of the regression equals 0.06. Ederington and Lee (1993) conduct a similar

regression for the absolute returns as the dependent variable using long-term Treasury bonds futures. They find only one significant announcement effect, namely Construction Spending/Institute for Supply Management index (in the sample period (1988-1991) covered by Ederington and Lee (1993) the Construction Spending and Institute for Supply Management indexes are almost always released on the same day). Thus, the most influential announcement type in our study - the Institute for Supply Management index - is identical to that found in Ederington and Lee (1993). This implies that this finding is robust even when using a much longer sample period and a different volatility definition.

The results for the stock realized variance are shown in Table 4 (column three). On days of announcements from the Business Inventories, Institute for Supply Management index and the Personal Consumption Expenditures/Personal Income the stock realized volatility is significantly different from the volatility on non-announcement days. For the Institute for Supply Management announcements the realized variance is larger and for the Personal Expenditures/Personal Income announcements the realized variance is smaller. Fewer announcements provide significant impacts on stock realized volatility than on bond realized volatility. This is in line with the firm-specific news story that we confirm by the news regressions above. Moreover, the R^2 for the stock regression is much smaller than that for the bond regression.

Again, we investigate the effect of business cycles by including the recession dummy R_t both in the intercept and the slopes and run the following regression for the realized volatility of bonds and stocks:[7]

$$\log(RV_t) = a + \sum_{k=1}^{K} b_k D_{kt} + a^* R_t + \sum_{k=1}^{K} b_k^* R_t D_{kt} + e_t \tag{5}$$

Table 4 (column two) shows the results of conducting the business cycle announcement regression for the bond realized volatility. We test the null hypothesis that there are no recession announcement effects: $b_1^* = \cdots = b_K^* = 0$ and find strong evidence that the announcement effects are different during recessions. In particular, the announcement effects of the Business Inventories and the New Home Sales are significantly negative during recessions ($\widehat{b_k} + \widehat{b_k^*} < 0$), whereas they are significantly positive during expansions ($\widehat{b_k} > 0$). So, during recessions these announcements tend to reduce the bond realized volatility. We interpret this such that in recessions uncertainty is high and therefore any news item is welcomed in order to reduce uncertainty and thereby volatility.

[7] The Construction Spending and the Institute for Supply Management indexes are released simultaneous during recessions. Therefore, only the former is multiplied with the recession dummy and included in the regression.

For Consumer Confidence announcements the realized variance is significantly larger during recessions.

There are also business cycle announcement effects for stock realized volatility, cf. Table 4 (column four). The null hypothesis that $b_1^* = \cdots = b_K^* = 0$ is rejected. For the Consumer Confidence and the Personal Consumption Expenditures/Personal Income, the realized variance is larger on announcement days.

Overall, we find that it is not so much the surprise of macroeconomic announcements that matters. Rather, it is the mere fact that an announcement occurs that has implications for the realized volatilities of bond and stock returns. Our results appear to be more significant than those found in the previous literature, even for some new bulletins that have rarely been found to impact on return volatility (e.g. Business Inventories). There are at least two explanations. First, our dataset allows us to analyze a longer sample period. Therefore, we can investigate more precisely the news impact across recessions and expansions. Second, we use the realized volatility technique. Most of the previous literature gauges the news impact on the second moment by means of absolute price changes (e.g. Ederington and Lee (1993)) or the absolute value of the regression residual for the price change impact (e.g. Andersen et al. (2004b)). It is more than likely that realized measures of volatility enhance the measurement precision.

5 Bond-Stock Realized Correlation

5.1 News Effects

We investigate the news effects from the unexpected part of macroeconomic announcements onto the bond-stock realized correlation. Figure 3 provides a graphical indication of the news effect on realized correlation in the specific case of Factory Orders announcements. Using 30-minute time intervals, this picture shows the realized correlation reaction to large positive news surprises during the announcement days.[8] The intraday pattern suggests that realized correlation is normal before the news release and it increases significantly afterwards. After one hour of immediate impact, realized correlation tends to decreases in the middle of the trading session and then it rises again before the closing.

To conduct a more comprehensive analysis in line with the approach above, we run similar regressions as in equation (2). The only difference is that the

[8] We define large positive surprises to be the 20% largest observations of the surprises.

Fisher transform of the realized correlation is the dependent variable. The explanatory variable is still the absolute surprise effect of the macroeconomic announcement.

The results are shown in Table 5 (column one). As for both bond and stock realized variances, there are only weak indications of news effects from macroeconomic announcements into the bond-stock realized correlation. Only in two instances (Business Inventories and Factory Orders) are the news effects significant. When the surprise is larger (in absolute terms) than expected the realized correlation increases.

We also run a regression that includes recession dummies in the intercept and slope, similar to equation (3) above. Table 5 (column two) shows that there weak are indications that the news effects are different during recessions and expansions (one β_k^* is significant). In recessions the news impact from Business Inventories is negative whereas it is positive in expansions.

It has been discussed widely that the sign of the bond-stock correlation has changed from positive to negative during 1997, cf. Ilmanen (2003). He argues that the reason for the flip in sign is that the order of causality has changed from bonds influencing stocks to the opposite. Here we accommodate for the fact that the sign of the correlation might have some bearing on the macroeconomic announcement effects by running the following news regression:

$$F(RC_t) = \alpha_k + \beta_k|S_{kt}| + \alpha_k^{\#}[F(RC_{t-1}) < 0] + \beta_k^{\#}[F(RC_{t-1}) < 0]|S_{kt}| + \varepsilon_t \quad (6)$$

Here, both the intercept and the slope depend on the sign of the realized correlation yesterday, in that the indicator $[F(RC_{t-1}) < 0]$ equals 1 if the realized correlation yesterday is negative and 0 if it is positive.[9] We use the the lagged value of the realized correlation to determine the sign in order to keep the explanatory variables exogenous from the dependent variable.[10]

Table 5 (column three) shows the results. Only the news effect of the Factory Orders is significantly dependent of the sign of the lagged realized correlation. It is noticeable that the R^2s are much higher now; on average 0.27. So, accounting for the sign of the correlation is of immense importance although it has less bearing on the news reactions. We conjecture that this is caused by the

[9] The sign of the realized correlation is identical to the sign of the Fisher transform of the realized correlation.

[10] The obtained results are similar to the results obtained if we instead of the sign indicator use a sub-period indicator which divides the sample into the period up to the middle of 1997 and the following period. Using the sign indicator we do not have to explicitly date the change in the bond-stock correlation which has been gradual.

difference in causality between bond and stock markets when the correlation changes sign.

5.2 Announcement Effects

The announcement effects on bond-stock realized correlation are investigated by running regressions similar to equation (4) where the explained variable is Fisher transform of the realized correlation. The results are shown in Table 6 (column one). There are significant announcement effects on the realized bond-stock correlation. The most influential announcement is the Business Inventories. The bond-stock correlation tends to increase when macroeconomic announcements occur. This is in line with the findings in Christiansen (2000) who shows that the correlations between bonds of different maturities are strengthened on macroeconomic announcement days.

We also run a similar regression as in equation (5) where the intercept and the slopes are allowed to differ during recessions. Table 6 (column two) shows that the announcement effects are significantly different during recessions. The null hypothesis that all slope coefficients are insignificantly different during recessions is strongly rejected (p-value for the null that $b_1^* = ... = b_K^* = 0$ is below 1%). The announcement effects are stronger during recessions than during expansions, $|\widehat{b_k}| < |\widehat{b_k} + \widehat{b_k^*}|$.

A natural question is why bond-stock comovement reacts differently across announcement types and why there are reversal effects during recessions for some news items. As discussed above, the discount factors for bond and stock pricing have common factors (real interest rates and inflation) as well as stock-specific factors (equity risk premia and dividends). For news items that increase the realized correlation in both expansions and recessions (Business Inventory and Personal Consumption Expenditures/Personal Income), the real interest rate appears to dominate. One explanation for the stronger positive correlation in downturns is that the inflation concern is less relevant; especially during the last recession in 2001 with a low inflation rate. On the other hand, stock-specific factors seem to dominate the price revision process driven by those macroeconomic news items with a negative impact on realized correlation in recessions. This is the case for Consumer Confidence. This interpretation is supported by other findings in the recent literature: Boyd et al. (2005) find that bonds and stocks have different news reactions in expansions and recessions. Bond and stock prices rise as a reaction to bad labor market news during expansions but only stock prices fall during contractions. Boyd et al. (2005) argue that unemployment news must convey more information about the real interest rates (risk

premia and dividends) in expansions (recessions). In the same line of reasoning, Andersen et al. (2004b) interpret the opposite market reaction as a change in the dominating factors that determine asset values. More specifically, the discount rate tends to dominate the information content of some macroeconomic news items during expansions, whereas the cash flow effects stand out during contractions. Our results support this view and suggest that the interpretation of macroeconomic news items depend on the economic situation. The influence of these factors varies over economic conditions and so do bond-stock comovements.

As above, we control for the changing sign of the realized correlation by allowing the slope and the intercepts to be different when yesterday's realized correlation is negative. Table 6 (column three) show the results from the following regression:

$$F(RV_t) = a + \sum_{k=1}^{K} b_k D_{kt} + a^{\#}[F(RC_{t-1}) < 0] + \sum_{k=1}^{K} b_k^{\#}[F(RC_{t-1}) < 0]D_{kt} + e_t \tag{7}$$

The p-value for the null hypothesis that $b_1^{\#} = ... = b_K^{\#} = 0$ is below 1%. So the announcement effects are strongly dependent on the sign of the realized correlation. Also, almost all the $b_k^{\#}$ parameters are individually significant and the R^2 is now as high as 0.36, thus the regression has strong explanatory power. When the realized correlation is positive, the impacts from announcements are positive ($\widehat{b_k} > 0$). When the realized correlation is negative the impact from announcements is typically stronger, in some cases positive and in other cases negative, $(|b_k|) < |b_k + b_k^*|$).

Overall, we find strong evidence that the bond-stock realized correlation is significantly influenced by releases of macroeconomic announcements and that the sign of the bond-stock correlation plays a dominant role. The time-varying patterns of realized correlation can be explained by the dominating drivers of bond-stock comovements and how they vary across economic conditions.

6 Conclusion

By analyzing the synchronized market movements of US bond and stock futures, this study delivers some insights into the parallel price discovery processes of bonds and stocks resulting from US macroeconomic news releases. We investigate the highly informative contents of a long sample period of trade-by-trade data. We measure the separate market reactions by the realized variances and

the joint market responses by means of realized correlation between bond and stock returns. Both announcement effects and surprise effects are examined.

We find that the surprise component of macroeconomic news releases has a small impact on realized volatility. The mere releases of scheduled news items have a stronger impact. Also, the volatility reaction varies across assets and economic conditions. Bonds respond more than stocks to these information events. Importantly, the market reaction is stronger during recessions than expansions.

Overall, macroeconomic announcements have a significant impact on realized bond-stock return correlation. This evidence holds especially in terms of scheduled announcement times. It is worth emphasizing, however, that different news items have very different impacts and that the market response radically depends on the business cycle. In expansions, a macroeconomic news release typically strengthens bond-stock comovements. This finding suggests that the real interest rate is the dominating factor in expansions. Concerns of interest rate increases seem to affect the market participants. On the other hand, the market reaction in recessions significantly depends on which macroeconomic announcement is released. Releases on Business Inventory and Personal Consumption Expenditures/Personal Income typically strengthen bond-stock return correlation. Instead, Consumer Confidence is associated with a weakened correlation. For this news item, stock-specific factors seem to dominate the price revision process for stocks, but not for bonds.

Adding to the debate regarding the changing sign in the bond-stock correlation, we find that macroeconomic announcement effects of the bond-stock realized correlation are highly dependent on the sign of the bond-stock correlation. Once we account for these sign differences, we find very strong announcement effects.

Our study raises further questions to be answered by future research. The time-varying nature of realized correlation calls for a better understanding of at least two main issues: First, the way the market participants process the information content of news items into prices. Second, the implications for asset pricing models and, in particular, for realized betas.

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Table 1: Summary Statistics

	Mean	Std. Dev.	Skewness	Kurtosis	Obs.
Bond RV*100,000					
Full Sample	0.31	0.40	6.45	79	3633
Ann. Days	0.44	0.57	5.98	64	782
Non-Ann. Days	0.28	0.33	5.51	49	2851
Stock RV*100,000					
Full Sample	2.67	4.39	8.74	134	
Ann. Days	2.89	5.52	9.01	112	
Non-Ann. Days	2.61	4.02	8.05	133	
Realized Correlation					
Full Sample	0.06	0.42	-0.42	2	
Ann. Days	0.12	0.43	-0.06	2	
Non-Ann. Days	0.05	0.42	-0.40	2	

The table shows the mean, standard deviation, skewness, and kurtosis of the bond realized variance, stock realized variance and bond-stock realized correlation applying in the interval [9.50;11.30], respectively. The realized variances are multiplied by 100,000. The summary statistics are shown for the full sample, macroeconomic announcement days, and non-announcement days.

Table 2: Summary of Macroeconomic Announcements

				Day of the Week				
Announcement	**Source**	**Period**	**Obs.**	Mon	Tue	Wed	Thu	Fri
Business Inventories	BC	Nov. 1988 - Dec. 1996	98	21	5	28	14	30
Construction Spending	BC	Nov. 1988 - May 2003	172	66	29	30	23	24
Consumer Confidence	CB	Jul. 1991 - Jan. 2003	139	1	132	3	2	1
Factory Orders	BC	Nov. 1988 - Feb. 2003	170	2	24	46	57	41
Institute for Supply Management Index	ISM	Feb. 1990 - May 2003	160	62	30	21	26	21
New Home Sales	BC	Nov. 1988 - May 2003	172	23	49	40	32	28
Personal Consumption Expenditures	BEA	Nov. 1988 - Dec. 1993	62	13	1	12	17	19
Personal Income	BEA	Nov. 1988 - Dec. 1993	62	13	1	12	17	19

The table provides a summary of the macroeconomic announcements. BC: Bureau of the Census, BEA: Bureau of Economic Analysis, CB: Conference Board, ISM: Institute for Supply Management (ISM was denoted the National Association of Purchasing Managers until August 2002). In January 1997 Business Inventories announcements were moved from 10.00 to 8.30. In December 1993 Personal Consumption Expenditures and Personal Income announcements were moved from 10.00 to 08.30. Missing forecast data for New Home Sales on February 2, 1989.

Table 3: Variance News Regressions

	Bond RV		Bond RV - Recession			Stock RV		Stock RV - Recession		
Announcement	β_k	R^2	β_k	β_k^*	R^2	β_k	R^2	β_k	β_k^*	R^2
Business Inventories	0.070	0.004	0.066	-0.560	0.023	-0.002	0.000	-0.004	1.613**	0.085
Construction Spending	-0.160	0.012	-0.122	-0.332	0.019	0.050	0.001	0.075	-0.068	0.032
Consumer Confidence	0.558***	0.174	0.538***	-0.014	0.184	0.135	0.006	0.040	0.453**	0.060
Factory Orders	0.002	0.000	0.032	-0.124	0.004	0.061	0.002	0.059	-0.129	0.021
Institute for Supply Management Index	0.517***	0.132	0.512***	0.063	0.132	0.139	0.007	0.151	0.006	0.027
New Home Sales	0.214*	0.023	0.195	-0.052	0.038	-0.084	0.003	-0.063	0.218	0.036
Personal Consumption Expenditures	0.126	0.011	0.154	-0.088	0.015	0.310*	0.054	0.237	-0.335	0.234
Personal Income	-0.015	0.000	-0.015	-0.117	0.002	-0.068	0.004	0.018	-0.102	0.208

Columns one and three of the table show the estimated β_ks and the centered R^2s from the following regressions: $\log(RV_t) = \alpha_k + \beta_k|S_{kt}| + \varepsilon_t$. RV_t is the bond realized variance and stock realized variance, respectively, that applies in the time bracket from 10 minutes before the announcement to 90 minutes after. The RV_ts are multiplied with 100,000. S_{kt} is the standardized news for announcement k.
Columns two and four of the table show the estimated β_ks and β_k^*s and the centered R^2 from the following regressions: $\log(RV_t) = \alpha_k + \beta_k|S_{kt}| + a_k^* R_t + \beta_k^* R_t|S_{kt}| + \varepsilon_t$. R_t is a recession indicator.
*, **, *** indicates that the parameter is significant at a 10%, 5%, and 1% level of significance based on the Newey and West (1987) standard errors.

Table 4: Variance Announcement Regressions

	Bond RV	Bond RV - Recession		Stock RV	Stock RV	
Announcement	b_k	b_k	b_k^*	b_k	b_k	b_k^*
Constant	-1.619***	-1.617***	-0.017	0.428***	0.359***	0.742***
Business Inventories	0.204***	0.233***	-0.353**	-0.417***	-0.405***	-0.037
Construction Spending	-0.089	-0.089	-0.035	-0.102	-0.076	-0.276
Consumer Confidence	0.373***	0.331***	0.674**	0.043	0.047	0.345**
Factory Orders	0.230***	0.236***	-0.070	0.102	0.122	-0.236
Institute for Supply Management Index	0.910***	0.914***		0.422***	0.425***	
New Home Sales	0.293***	0.332***	-0.425***	0.077	0.098	-0.168
Personal Consumption Expenditures	-0.029	-0.044	0.076	-0.517***	-0.601***	0.419*
R^2	0.061	0.063		0.014	0.059	
Wald test for $b_1^*=...d_K^*=0$ (p-value)		0.003			0.045	

Columns one and three of the table show the estimated b_ks and the centered R^2 from the following regressions: $\log(RV_t) = a + \sum_{k=1}^{K} b_k D_{kt} + e_t$. RV_t is the bond realized variance and stock realized variance, respectively, that applies in the time bracket from 10 minutes before the announcement to 90 minutes after. The RV_ts are multiplied with 100,000. D_{kt} is the indicator function for announcement type k occurring at time t.

Columns two and four of the table show the estimated parameters and the centered R^2 from the following regressions: $\log(RV_t) = a + \sum_{k=1}^{K} b_k D_{kt} + a^* R_t + \sum_{k=1}^{K} b_k^* R_t D_{kt} + e_t$. R_t is a recession indicator.

*, **, *** indicates that the parameter is significant at a 10%, 5%, and 1% level of significance based on the Newey and West (1987) standard errors.

Table 5: Correlation News Regressions

	(i)		(ii)			(iii)		
Announcement	β_k	R^2	β_k	β_k^*	R^2	β_k	$\beta_k^\#$	R^2
Business Inventories	0.095*	0.034	0.107**	-0.275**	0.050	0.095*	-0.015	0.038
Construction Spending	0.097	0.011	0.088	0.048	0.017	0.116	-0.137	0.304
Consumer Confidence	0.017	0.000	0.048	0.051	0.064	0.071	-0.099	0.395
Factory Orders	0.070*	0.010	0.101**	-0.115	0.025	-0.030	0.280***	0.284
Institute for Supply Management Index	-0.024	0.001	-0.021	-0.082	0.009	-0.037	0.054	0.355
New Home Sales	0.073	0.006	0.088	-0.452	0.050	0.086	-0.097	0.454
Personal Consumption Expenditures	0.099	0.040	0.077	0.103	0.050	0.106	-0.084	0.188
Personal Income	0.008	0.000	0.004	0.229	0.028	-0.022	0.056	0.156

(i) shows the estimated β_ks and the centered R^2s from the following regressions: $F(RC_t) = \alpha_k + \beta_k|S_{kt}| + \varepsilon_t$. RC_t is the realized bond-stock correlation that applies in the time bracket from 10 minutes before the announcement to 90 minutes after. S_{kt} is the standardized news for announcement k. F is the Fisher transform: $F(x) = \frac{1}{2}\log(\frac{1+x}{1-x})$.

(ii) shows the estimated β_ks and β_k^*s and the centered R^2 from the following regressions: $F(RC_t) = \alpha_k + \beta_k|S_{kt}| + \alpha_k^* R_t + \beta_k^* R_t|S_{kt}| + \varepsilon_t$. R_t is a recession indicator.

(iii) shows the estimated β_ks and $\beta_k^\#$s from the following regressions $F(RC_t) = \alpha_k + \beta_k|S_{kt}| + \alpha_k^\#[F(RC_{t-1}) < 0] + \beta_k^\#[F(RC_{t-1}) < 0]|S_{kt}| + \varepsilon_t$

*, **, *** indicates that the parameter is significant at a 10%, 5%, and 1% level of significance based on the Newey and West (1987) standard errors.

Table 6: Correlation Announcement Regressions

	(i)	(ii)		(iii)	
Announcement	b_k	b_k	$b_k{}^*$	b_k	$b_k{}^\#$
Constant	0.039*	0.059***	-0.206***	0.285***	-0.608***
Business Inventories	0.301***	0.273***	0.316***	0.067*	0.533***
Construction Spending	0.015	0.011	0.045	-0.038	0.270*
Consumer Confidence	-0.027	-0.014	-0.364***	0.014	-0.069
Factory Orders	0.043	0.038	0.031	-0.008	0.121*
Institute for Supply Management Index	0.091	0.093		0.145**	-0.360**
New Home Sales	0.070*	0.080**	-0.092	0.127***	-0.144**
Personal Consumption Expenditures	0.243***	0.207***	0.323**	0.054	0.338***
R^2	0.016	0.031		0.356	

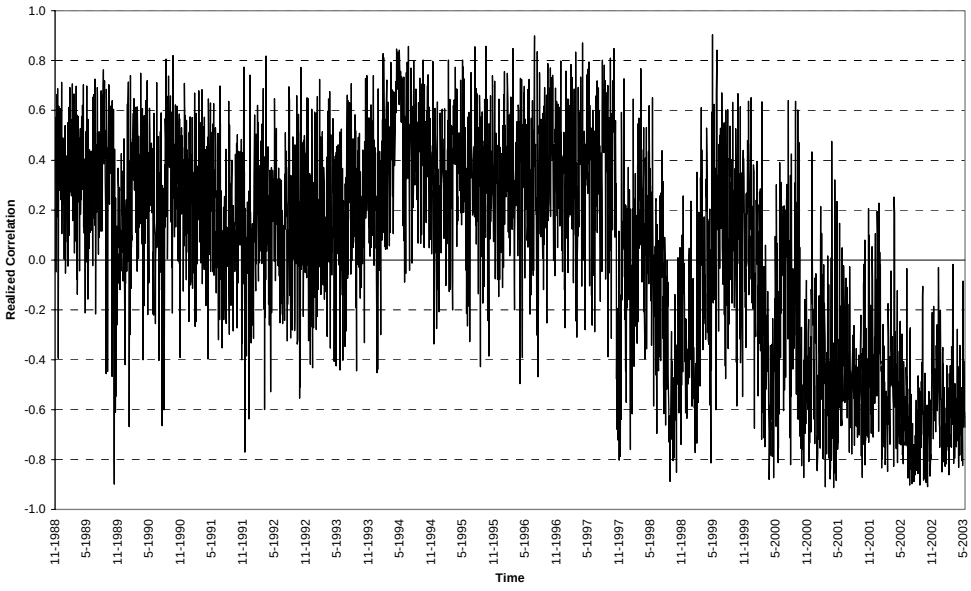
(i) shows the estimated b_ks and the centered R^2 from the following regression: $F(RC_t) = a + \sum_{k=1}^{K} b_k D_{kt} + e_t$. RC_t is the bond-stock realized correlation that applies in the time bracket from 10 minutes before the announcement to 90 minutes after. D_{kt} is the indicator function for announcement type k occurring at time t. F is the Fisher transform: $F(x) = \frac{1}{2}\log(\frac{1+x}{1-x})$.

(ii) shows the estimated parameters and the centered R^2 from the following regression: $F(RC_t) = a + \sum_{k=1}^{K} b_k D_{kt} + a^* R_t + \sum_{k=1}^{K} b_k^* R_t D_{kt} + e_t$. R_t is a recession indicator.

(iii) shows the estimated parameters and the centered R^2 from the following regression: $F(RC_t) = a + \sum_{k=1}^{K} b_k D_{kt} + a^\#[F(RC_{t-1}) < 0] + \sum_{k=1}^{K} b_k^\#[F(RC_{t-1}) < 0] D_{kt} + e_t$

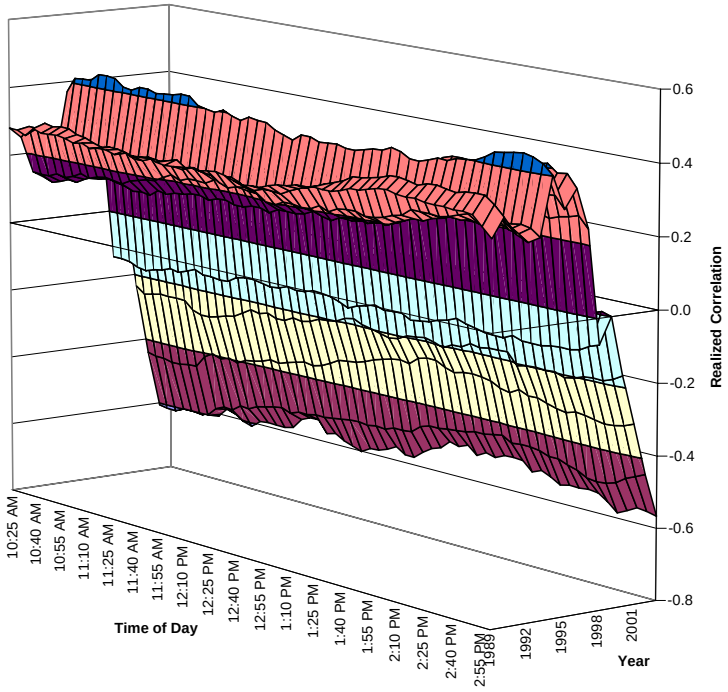
*, **, *** indicates that the parameter is significant at a 10%, 5%, and 1% level of significance based on the Newey and West (1987) standard errors.

Figure 1: Time Series of Realized Correlations



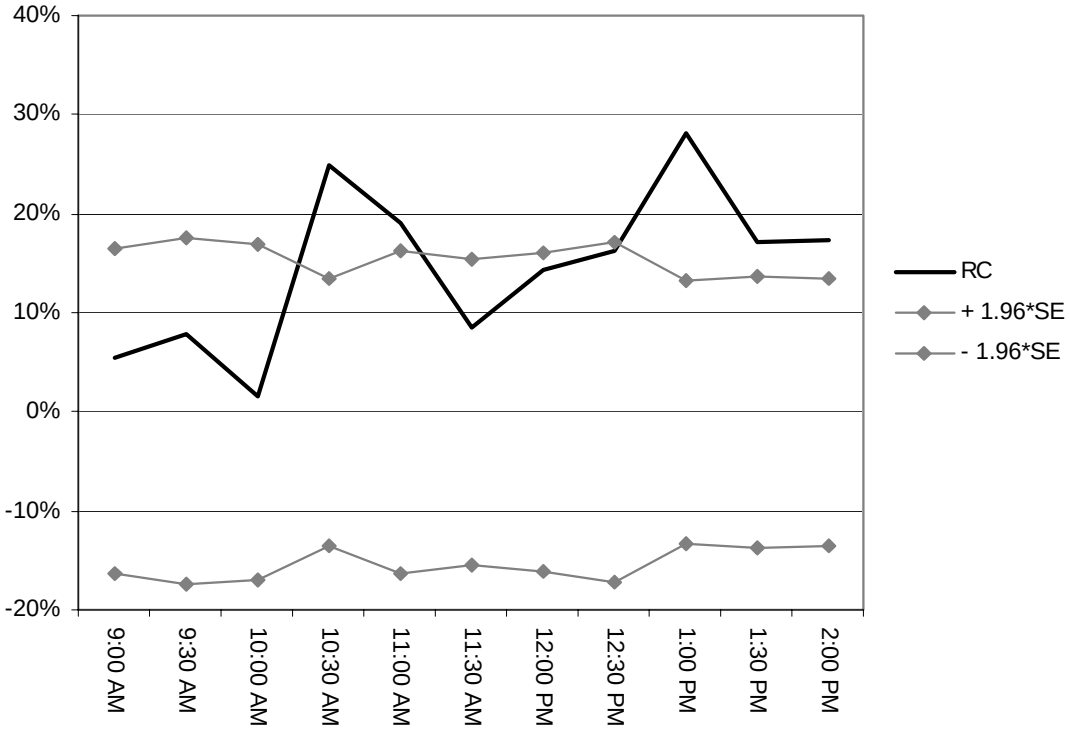
The figure shows the time series of the bond-stock realized correlation applying in the interval [9.50;11.30] each day.

Figure 2: Intraday Pattern of Average Bond-Stock Realized Correlation for Each Year



The figure shows the intraday pattern of the average hourly bond-stock realized correlation for each year.

Figure 3: Effects on Realized Correlation due to Large Positive Surprises from Factory Orders Announcements



The black line shows the average size of realized correlation during the day of factory orders announcements released at 10:00 a.m. The dotted grey lines show the standard errors times 1.96 defining the 95% confidence interval. We define large positive surprises by taking the fifth quintile of the standardized surprise component of the news (34 observations).

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