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# Macroeconomic Announcements and Asymmetric Volatility in Bond Returns*

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**Abstract**

This study analyses the impact of macroeconomic news announcements on the conditional volatility of bond returns. Using daily returns on the 1, 3, 5 and 10 year U.S. Treasury bonds, we find that announcement shocks have a strong impact on the dynamics of bond market volatility. Our results provide empirical evidence that the bond market incorporates the implications of macroeconomic announcement news faster than other information. Moreover, after distinguishing between types of macroeconomic announcements, releases of the employment situation and producer price index are especially influential at the intermediate and long end of the yield curve, while monetary policy seem to affect short-term bond volatility.

Keywords: Bond Market, Asymmetric Volatility, Macroeconomic Announcements.

JEL classification codes: G12, C22.

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# 1 Introduction

The efficient market hypothesis implies that price changes in bonds reflect the arrival and processing of relevant new information. While news itself is unpredictable, in turn making changes in bond returns prices unpredictable, the release dates of many macroeconomic announcements are known. On these pre-scheduled dates, information about macroeconomic fundamentals is released. Thus two types of news exist: scheduled and non-scheduled news. In this paper we focus on the scheduled news.

While firm-specific news is the main source of information in stock markets, in Treasury bond markets macroeconomic news is most important. Consequently, the effects of announcements are typically more pronounced on government backed securities than on equity (see, e.g., McQueen and Roley, 1993). Some recent studies examine the effects of macroeconomic news on Treasury bond volatility. Jones, Lamont and Lumsdaine (1998) and Christiansen (2000), for example, examine the response of Producers Price Index (PPI) and Employment (EMP) releases on Treasury bond market volatility. Their results indicate significant increases in bond market volatility on announcement days. This increase does not persist, as news is immediately incorporated in the prices.[1] Li and Engle (1998) study the effects of announcements of the producer price index, PPI, and employment situation on the volatility of the U.S. Treasury bond futures. They find that announcement shocks are not persistent, but bond futures volatility responds asymmetrically to announcement shocks. Piazzesi (2005) shows that the announcements of the Fed-

[1] Ederington and Lee (1993) and Fleming and Remelona (1999), for example, find that most bond prices response within one or two minutes to major macroeconomic announcements.

eral Open Market Committee (FOMC) are important for bond market volatility. In the Federal Reserve's FOMC, which is the main policymaking body in the United States[2], policy decisions are made involving the target level of the federal funds rate.

The asymmetric volatility effect, first noted by Black (1976), refers to the tendency that good and bad news in returns have a different impact on conditional volatility in stock markets. Several explanations for this phenomenon, which is especially apparent during volatile periods, are put forward. For example, Black (1976) and Christie (1982) argue that a drop in the value of the stock increases financial leverage, which makes the stock more risky and increases its volatility: the so-called leverage effect hypothesis. Alternatively, the asymmetric response to return shocks could simply reflect the presence of time-varying risk premia (see Pindyck, 1984). If volatility is priced, an anticipated increase in volatility would result in a higher required return, which would lead to stock price decline: the "volatility feedback" effect. Recently, Cappiello, Engle and Sheppard (2003) and De Goeij and Marquering (2004) report asymmetries in bond return volatility. As financial leverage is not applicable to government bonds, the leverage argument cannot explain the asymmetry in Treasury bond volatility.

Unfortunately, most empirical work has studied each of the above phenomena −announcement effects and asymmetric volatility− in isolation. This is ultimately not satisfactory. First, as scheduled news differs from non-scheduled news, it is an interesting question to what extent investors anticipate to announced news. Moreover, it is interesting to compare how volatility responds towards scheduled

[2]The policy of the FOMC is to promote economic growth, full employment, stable prices, and a sustainable pattern of international trade and payments.

and non-scheduled news. Second, it might be possible that (a large part of) the asymmetric volatility can be explained by announcement news, because investors can already anticipate before the news is released and over- or underreactions might be at stake. Third, as the model is considerably improved, it is likely that portfolio selection based on volatility forecast models with announcements effects outperform the traditional models. Additionally, risk management and derivative pricing can be ameliorated.

In this paper, we investigate the interaction between announcements and volatility, whether scheduled news differs from non-scheduled news, and to what extent asymmetric volatility is explained by macroeconomic announcements. As asymmetry is usually associated with large shocks, which are in turn associated with macroeconomic announcements, it is natural to examine the relation between announcements and asymmetries. If asymmetries are caused by announcements shocks, asymmetric volatility becomes predictable, and investors could potentially profit from it. More specifically, we investigate the response of government bond prices to regularly scheduled announcements including the aforementioned PPI, EMP and FOMC releases. We generalize the GJR specification of Glosten, Jagannathan and Runkle (1993) in such a way that macroeconomic announcements are accounted for. We use daily data from January 1982 to September 2004 on 1, 3, 5 and 10 year U.S. Treasury bonds and two corporate bond indices. We find empirical evidence that macroeconomic pre-announcements raise the level of conditional bond market volatility to a great extent. Announcement shocks are less persistent than regular shocks, which suggests that the bond market incorporates the implications of macroeconomic announcement news faster than other information. We also obtain some compelling results after discriminating between different kinds of announcements. Macroeconomic announcements seem to be especially influential at the intermediate and long end of the yield curve, while monetary policy seem to affect especially short-term bonds.

This paper differs from previous empirical studies in the following ways. First, while many studies examine the effects of announcements on volatility and the asymmetric volatility phenomenon, this paper interrelates these phenomena.[3] Second, whereas all studies, as far as we know, examining announcement effects on bond volatility use few types of announcements (usually one or two), we employ a very extensive announcement dataset of sixteen types of announcements. This way, the effects of announcements are potentially measured in a better way. Flannery and Protopapadakis (2002), use seventeen announcements to examine announcements effects in the stock market volatility, and show that announcements other than the most used ones (PPI and EMP), are important factors in the stock market volatility. While Balduzzi, Elton and Green (1996) and Beber and Brandt (2005) consider many announcements in the bond market, they do not examine their effect on bond market volatility. Third, while the articles most similar in spirit to ours, Christiansen (2000) and Li and Engle (1998), measure the effect of news by introducing a dummy variable for announcements, we also consider the surprise element in the macroeconomic news by using survey forecasts. This might measure news better, as some announcements are simply expected and will not in-

[3]In her paper, Christiansen (2000) allows for asymmetric reactions to announcement news, but not to any other news. Li and Engle (1998) also allow for the situation in which positive and negative announcement shocks differ significantly. Their setting is a univariate GARCH model for Treasury futures. These studies do not consider asymmetries in volatility for non-announcement days, such that the question whether (the reaction of) announcements causes asymmetries can not be answered using their models.

fluence returns and volatility. Fourth, this paper is the first that considers FOMC together with PPI and EMP announcements.[4] Looking at them separately, we are able in this paper to distinguish FOMC (interest rate) announcements effects and PPI and EMP from other announcements effects. This is interesting as financial press often suggest that the short term bond volatility is more affected by Fed rate changes than long term bonds, while labor market announcements especially affects long term bonds. Fifth, whereas most studies only consider one announcement effect, we consider a pre-announcement and a news effect.[5] Initially, there is a pre-announcement effect: investors know beforehand that there will be news, so a higher level of volatility on the day the news is released is anticipated. Next, there is a news (reaction) effect: once the news is released, investors process the newly received information (not previously incorporated into asset prices) which might raise the market volatility next day, as investors might disagree on the news consequences of the new information on asset prices (see, e.g., Varian, 1989 and Harris and Raviv, 1993). Separating these two effects, which to our knowledge has not been done before, might result in interesting new findings.

The remainder of this paper is organized as follows. Section 2 provides a brief description of the relation between news arrival and market volatility, and presents the empirical framework. We also discuss the way the model deals with pre-announcements effects and feedback effects after the announcement is made. Section 3 describes the data used in the analysis. In Section 4, we discuss the

[4] Jones, Lamont and Lumsdaine (1998) and Christiansen (2000), e.g., only consider the PPI and EMP announcements, whereas Piazzesi (2005) only includes the FOMC announcements in their models.

[5] Li and Engle (1998) and Christiansen (2000), for example, do not include a pre-announcement effect in their asymmetric volatility equations.

empirical results. Finally, Section 5 concludes.

## 2 A Volatility Model with Announcements Effects

In a recent study, Bekaert and Wu (2000) examine asymmetric volatility in the Japanese equity market. Using a multivariate GARCH model, they conclude that volatility feedback is the dominant cause of the asymmetry for the Japanese stock market. In addition, Wu (2001) develops a model that separates the leverage from the volatility feedback effect. Using monthly and weekly S&P 500 returns, he concludes that the leverage effect is an important source of asymmetric volatility, but that volatility feedback is stronger than previously documented (see Campbell and Hentschel, 1992). The models constructed by Campbell and Hentschel (1992) and Wu (2001) provide a good understanding of the volatility feedback hypothesis. However, these models are based on the dividend process of equity returns. Campbell and Hentschel (1992) use “news about dividends” and “news about volatility”, as factors in their model. Wu (2001) improves the model of Campbell and Hentschel by defining dividend volatility as a separate factor.

Treasury bonds have coupon payments and although these coupon payments can be considered as some kind of dividends, they are fixed in size. Therefore they do not provide any news to investors, as stipulated in Campbell and Hentschel (1992) and Wu (2001). It is interesting to investigate to what extent macroeconomic announcements can explain asymmetric volatility, as these are reported to be the most important source of information in Treasury bond markets.

We use an AR(1) process to model excess returns. To prevent that we find asymmetric effects in variances due to misspecification in the mean, we follow

Christiansen (2000) and include a dummy variable which captures the effects of announcements on bond returns. The resulting mean equation can be written as:

$$r_t^e = \mu + \gamma I_t^a + \alpha r_{t-1}^e + \varepsilon_t, \tag{1}$$

where

$r_t^e$ denotes the excess return on a Treasury bond in period $t$,

$I_t^a = 1$, if there is scheduled macroeconomic news at time $t$ and 0 otherwise, and

$\varepsilon_t$ denotes the unexpected excess return.

We assume that $\varepsilon_t|\mathcal{I}_{t-1} \sim N(0, h_t^2)$, where $\mathcal{I}_{t-1}$ denotes the information set at time $t-1$, and $h_t^2$ is the conditional variance of the unexpected excess returns. The timing of macroeconomic news releases is known by the economic agents. We use a dummy variable equal to one for the day that the news is announced. The coefficient $\gamma$ is typically larger than zero, as news arrivals are associated with higher risk. Thus, $\gamma$ could be interpreted as a premium for bearing the news arrival risk. To model the conditional variance, we extend the GJR specification of Glosten, Jagannathan and Runkle (1993). This specification has two appealing features. First, it allows us to examine the influence of macroeconomic announcements on bond market volatility. Second, it permits a certain level of asymmetry in the conditional variance. We know that volatility mainly responses asymmetrically after big shocks, i.e. very good or very bad news. These big shocks in the bond market are usually related to macroeconomic news, as macroeconomic news is the most important source of news. Thus, big shifts in bond prices are typically related to macroeconomic news. Our specification for the conditional volatility is:

$$h_{t+1}^2 = \omega + \omega^a I_{t+1}^a + b h_t^2 + (a + a^a I_t^a)\varepsilon_t^2 + (g + g^a I_t^a)(\varepsilon_t^-)^2 \ , \tag{2}$$

where $\varepsilon_t^-$ is an $N \times 1$ vector with elements $\varepsilon_t^- = \min[0, \varepsilon_t]$. The standard GJR model is obtained by imposing the restrictions $\omega^a = 0$, $a^a = 0$ and $g^a = 0$. Model (2) is very similar to the ones in Christiansen (2002) and Li and Engle (1998), but differs from the fact that we include a pre-announcement effect $\omega^a I_{t+1}^a$. Whereas the timing of macroeconomic news is exogenous to financial markets (as it is scheduled), the content of the news is not.

Equation (2) incorporates a pre-announcement and a news effect. The model predicts that on announcement days, the level of conditional volatility differs from non-announcement days, which is measured by $\omega^a$. Because important news might be released on these days, we expect that conditional volatility will be higher on announcement days. Next, once the news is released, investors start processing this news. The parameter vectors $a^a$ and $g^a$ predict the impact of news on the conditional volatility of the day after an announcement day. Varian (1989) and Harris and Raviv (1993) show that because of differences in opinions in the market, it might take some time before the calm returns. Alternatively, one might argue that news that is anticipated is followed more closely, such that the impact of news is processed faster than other kind of news. The parameter $a^a$ represents the persistency of announcement news. Finally, we allow for the possibility that negative announcement news is more persistent than negative news (reflected in $g^a$).

Ederington and Lee (1996) argue that the announcement of anticipated news resolves uncertainty, whereas unanticipated new increases uncertainty. Thus bond prices are expected to respond to new information in each announcement, and not to anticipated news. Consequently, we examine the unexpected component of each announcement as well. Following Balduzzi, Elton and Green (2001), the unexpected components of the announcements are calculated as the standardized difference between the actual announcement values and the median expected value on the macroeconomic announcements. Since units of measurement differ across economic variables, we divide the surprises by their standard deviation across all observations. The surprise dummy, denoted by $I_t^s$, is equal to one for big shocks, i.e. unanticipated announcements in absolute value larger than one standard deviation. The resulting volatility equation becomes:

$$h_{t+1}^2 = \omega + \omega^a I_{t+1}^a + b h_t^2 + (a + a^s I_t^s)\varepsilon_t^2 + (g + g^s I_t^s)(\varepsilon_t^-)^2 \ . \tag{3}$$

Note that the pre-announcement effect in (3), $\omega^a I_{t+1}^a$, is not changed because contemporaneously, the realized value of the news is not known.

The univariate models can be easily generalized to a multivariate setting. The news announcements may yield insights about the covariance of bond returns with different maturities. Following Christiansen (2000), the mean equation is assumed to follow the multivariate counterpart of (1): a VAR(1) with a level effect for announcement days. Now, the vector $\varepsilon_t|\mathcal{I}_{t-1} \sim N(0, H_t)$, with $H_t = \{h_{ij,t}\}$ containing the conditional covariances. The multivariate version of (3) becomes[6]:

$$h_{ij,t+1} = \omega_{ij} + \omega_{ij}^a I_{t+1}^a + b_{ij} h_{ij,t} + (a_{ij} + a_{ij}^s I_t^s)\varepsilon_{i,t}\varepsilon_{j,t} + (g_{ij} + g_{ij}^s I_t^s)\varepsilon_{i,t}^-\varepsilon_{j,t}^-, \tag{4}$$

$i, j = 1, ..., N$. In (4), $\varepsilon_{i,t}^-\varepsilon_{j,t}^-$ is nonzero for negative values of $\varepsilon_{i,t}$ and $\varepsilon_{j,t}$. This term assigns an asymmetric covariance effect on shocks in the same direction. Our model provides a generalization of the asymmetric univariate GJR model by allowing explicitly for asymmetric conditional covariance terms. The mean equations are

[6]Note that the univariate GJR model with announcements effects in (2) is obtained when $i = j$.

estimated using OLS. We estimate the parameters of the conditional volatility models using the quasi maximum likelihood (QML) method (see Bollerslev and Wooldridge, 1992), treating the residuals $e_t$ as observable data. The loglikelihood function (for the sample $1, ..., T$) is given by

$$\mathcal{L}(\tilde{\theta}) = -\frac{1}{2}TN\log 2\pi - \frac{1}{2}\sum_{t=1}^{T}\log(\det H_t(\tilde{\theta})) - \frac{1}{2}\sum_{t=1}^{T}e_t^{\prime}H_t^{-1}(\tilde{\theta})e_t,$$

where $\tilde{\theta}$ denotes the vector of unknown parameters. For inference, we use robust Bollerslev and Wooldridge (1992) standard errors. The Newton-Raphson gradient search algorithm is used to obtain the estimates. To guarantee that the conditional covariance matrix is positive definite we estimate the model using constrained maximum likelihood.[7] Note that the constraints are not binding in all estimation results. A range of starting values was used to ensure that the estimation procedure converged to a global maximum. We repeated the estimations with random restarts of the starting value, conditioned to the range of two times the standard error of the univariate estimates. None of the estimation results indicated any local maximum.

# 3 Data

This section describes the data used in the analysis; Treasury bonds and MMS survey data. To examine the effects of macroeconomic announcements in the bond market, we use daily excess returns on the 1, 3, 5 and 10 year U.S. Treasury bond. The data were obtained from the federal reserve bank in Chicago. We follow the same approach as in Jones, Lamont and Lumsdaine (1998) and Christiansen

[7]Following, e.g., De Goeij and Marquering (2004) we impose that the smallest eigenvalue of each covariance matrix has to be positive during estimation.

(2000) to calculate returns. The excess returns were calculated as the return of holding the bond in excess of the risk-free spot rate, approximated by the 3-month Treasury bill rate. We adjust for weekends and holidays in the daily returns calculations (Appendix A provides details on the calculations). Our data cover the period January 4, 1982 through September 30, 2004, providing a total of 5682 observations. For illustrative purposes, the evaluation of the daily excess returns on the 1, 3, 5 and 10 year bonds over time is presented in Figure 1. The graphs suggest that a model including heteroskedasticity is required to describe the evolution of the excess returns as there are signs of volatility clustering. The magnitude of daily excess returns is sometimes quite large, with returns for the 10 year bond as high as 4.8% (on October 20, 1987, one day after the crash) and as low as -2.7% (on April 4, 1994). Neither of these two dates is an announcement date.

*[Figure 1 about here]*

As surprises in announcements are arguably most relevant, we are interested in testing whether big unexpected shocks cause different volatility persistence following major announcements. The data on economic news announcements and median survey expectations are from Money Market Services (MMS) International. The MMS surveys are conducted once a week since 1977, usually on the Friday of the week before the release of each variable under consideration. The MMS data are the most commonly used data in studies of economic announcements, see, e.g., Ederington and Lee (1993), McQueen and Roley (1993), Li and Engle (1998), Balduzzi, Elton and Green (2001), Flannery and Protopapadakis (2002) and Beber and Brandt (2005). The median survey estimates are calculated from the MMS surveys of market participants and observers, and they serve as a measure of the market's expected value of the particular announcement. Balduzzi, Elton and Green (2001) show that the MMS forecasts are unbiased and efficient. Moreover, the MMS survey is an accurate representation of the consensus expectation in the market. We calculated announcement surprises by the difference between the median survey and the actual data.

Whereas most related studies consider maximum two or three announcements, we consider sixteen different macroeconomic announcements, providing a fairly complete characterization of the macro economy: the conditions of the money market by the Federal Open Market Committee federal funds target rate (FOMC), the perceived state of the economy by consumer confidence (CC) and by consumer credit (CRED), the inflationary process by the consumer price index (CPI) and producer price index (PPI), the conditions in the ordered goods market by the durable goods orders (DGO) and factory orders (FO), the condition of the financial balance by the trade balance (TB) and treasury budget (TRB), the state of the economy by the national association of purchasing managers index (NAPM) and index of leading indicators (LI), the situation in the labor market by the initial jobless claims (IJC), non-farm payrolls (EMP) and civilian unemployment rate (CU), the dynamic of consumption by the retail sales (RS), and the situation in the real estate market by housing starts (HS).

*[Table 1 about here]*

Table 1 describes the announcements variables in more detail. Balduzzi, Elton and Green (2001) show that these announcements are among the most important types of macroeconomic announcements for bond returns. Moreover, some unreported analyses on the effects of announcements on the mean, showed that the aforementioned announcements are the most influential ones. For some announcements the timing coincide with another announcement. For example, nonfarm payrolls and unemployment rates are always announced at the same time. Summary statistics on the Treasury bonds around announcement days are presented in Appendix B. In the next section we will consider the persistency of announcement shocks in more detail.

# 4 Empirical Results

We study the impact of macroeconomic news announcements on the conditional volatility of bond returns. In Section 4.1 we apply a univariate analysis using daily returns on the 1, 3, 5 and 10 year U.S. Treasury bonds. We expect that especially unanticipated news matters. Therefore we repeat the analysis separating anticipated and unanticipated news. In Section 4.2 we examine whether we find similar patterns in high- and medium grade corporate bonds. Section 4.3 proceeds with the multivariate analyses. We examine the dynamic covariances between bond returns. Section 4.4 addresses the question whether it is important to distinguish between FOMC, PPI/EMP and other announcements. Finally, we proceed to test whether the effects of FOMC announcements have a different impact on volatility after February 1994. From that time on, the Fed began the practice of announcing changes in its target for the federal funds rate immediately after FOMC meetings.

## 4.1 Announcements and Asymmetries in the Treasury Bond Market

In this section we examine in which way macroeconomic announcement shocks affect conditional bond market variance. Moreover, we study the interrelation between these announcement shocks with asymmetric volatility. Table 2 presents the estimation results for three specifications. The specification is without announcement effects, i.e. the standard GJR model. The other two specifications are with announcements effects. To see wether it is especially unanticipated news affecting volatility, we have one specification in which we consider announcements days (Ann days), and one specification in which we only consider big shocks in unanticipated announcements (Ann surpr). These correspond to model (2) and (3), respectively. We allow for asymmetries in all specifications.

The results in Table 2 show that the estimated constant in the GJR specification ($w$) increases with the maturity, which is expected as volatility increases with maturity. For the specifications with announcement effects we see that the estimated coefficients for the dummies on announcement days ($w^a$) are very high and significantly different from zero. Thus, most of the contemporaneous volatility is associated with announcement days (as $w^a$ is in all cases much greater than zero). Consequently, announcement days are associated with much higher contemporaneous bond market volatility. This reflects the increased risks in bond markets on days with announcements. Note that Li and Engle (1998) and Christiansen (2000) do not include the pre-announcement variable, $\omega^a I^a_{t+1}$, in their asymmetric volatility equations.

Next, we consider the effects of announcements when the magnitude of the announcement is known: the so-called news effect. It is of interest whether the persistency of announcement shocks differs from regular shocks. Our results show that announcement shocks do not persist. All the individual estimates considering the announcement shocks ($a^a$ and $a^s$) are negative and significantly different from zero. Thus, announcement shocks are less persistent than regular shocks, which suggests that the bond market incorporate the implications of macroeconomic announcement news faster than other information. This confirms the findings of Li and Engle (1998) and Christiansen (2000). An explanation for the fact that volatility caused by macroeconomic news does not persist is that the announcement of anticipated news resolves uncertainty, whereas unanticipated news increases uncertainty. This explanation was put forward by Ederington and Lee (1996).

*[Table 2 about here]*

Table 2 further shows that the Treasury bond returns tend to have asymmetries when a model without announcement effects is used. This is in line with some other empirical studies that find that the conditional variance of bond returns are asymmetric in response to good and bad news (see, e.g., Cappiello, Engle and Sheppard, 2003 and De Goeij and Marquering, 2004). If news turns out to be worse than expected, the volatility becomes relatively high, while if news is better than expected the variance of the Treasury bonds remains relatively moderate. After allowing for asymmetries in announcements, the asymmetries for non-announcement shocks are not significantly different from zero anymore, which is a novel result. However, this result might be related to the power of the tests. The estimation results show that negative announcements do not affect bond market volatility more than positive announcements ($g^a$ and $g^s$). The estimates for $g^a$ and $g^s$ are always positive, and are statistically significant for the 1 and 5 year Treasury bond. Thus, we find modest support that negative announcement shocks have a greater impact on the subsequent volatility than positive announcement shocks. While Christiansen (2000) find no indications of differences in the persistency of positive and negative announcement shocks, Li and Engle (1998) report that in the bond futures market negative announcement shocks increase subsequent volatility. They explain the existence of the announcement leverage effect by the fact that investors take highly leveraged positions on the futures market, which is not the case on the cash bond market. Thus, it is more likely to observe differences between positive and negative announcement shocks on the futures market than on the bond market. Finally, note that both versions with announcement shocks yield very similar results. Because, the log likelihood values do not indicate which of the two specifications is preferred, we will only employ the version with surprises in announcements shocks from now on.

## 4.2 Announcements and Asymmetries in Corporate Bonds

To examine whether the results for corporate bonds differ, we examine the asymmetries and announcement effect in high and medium grade corporate bonds. To average out firm-specific risk as much as possible, we use broad bond indices containing many corporate bonds. More specifically, we use Moody's AAA (high grade) and BAA (medium grade) corporate bond indices. The data are available over the period January 4, 1982 - September 30, 2004. Overall, the results are very similar to the ones of Treasury bonds. From the results in Table 3, we see that the asymmetric volatility in the model without announcements (GJR) 'disappears' after the announcements effects are introduced. This confirms the findings in Section 4.1. However, the asymmetries are not as strong as for the Treasury bonds. Similar to Treasury bonds, we find that announcement shocks in corporate bonds do not persist. As most of the dynamics of high grade bonds are most likely generated by the Treasury term structure, we also perform some multivariate analyses using Moody's AAA bond returns and the 1 year Treasury bonds. These results are presented in the next section.

*[Table 3 about here]*

### 4.3 Announcement Effects in Covariances between Bond Returns

The results in the previous sections are limited in the sense that they only examine the univariate response of return to risk. The news announcements may yield insights about the covariance of bond returns with other assets. Like Christiansen (2000), we examine the effects of announcements on the covariance structure of Treasury bonds. We apply a direct and straightforward way to examine these effects. We consider the conditional covariances between the 1 and 5 year Treasury bond returns, and between the 1 year Treasury bond returns and high grade bond returns.[8] In order to examine the impact of announcements on the conditional bond market covariances, we estimate the multivariate GJR specification with and without announcement effects. The results are presented in Table 4.

*[Table 4 about here]*

Looking at the pre-announcements effects of macroeconomic announcements, we see that the level of conditional covariances is much higher on announcement days than on non-announcement days: the estimates for the $w^a$-parameters are positive, and statistically significant. Again, the estimates of the lagged volatility parameters $b_1$, $b_2$ and $b_{12}$ are around 0.93 and highly statistically significant. This implies a high volatility clustering in variances and covariance. The estimates

[8] All other combinations of bond with other maturities have also been examined. These results are qualitatively very similar.

for $a^s_{12}$, the parameter that measures whether the degree of covariance persistency of announcement shocks differs from non-announcement shocks, are negative and significantly different from zero at the 5 percent level. Our findings show that the covariance persistence of announcements shocks are negative, which is another indication that the bond market learns the implications of macroeconomic announcements quicker than other information.

Looking at the differences between positive and negative announcement shocks, we see that the estimate for the asymmetric announcement effects in the covariance is not significantly different from zero. After including announcement dummies, the estimated coefficients of the asymmetry parameters for the covariance $g_{12}$ and $g^s_{12}$ are not significant anymore. Overall, the results for the conditional covariances are similar to the results we have found for the conditional variances in the previous sections.

### 4.4 Discriminating Between Announcements

The results in the previous sections are based on the restriction that all announcements have identical impact on conditional volatility. One might argue that allowing explicitly for different sources of announcements would be more appropriate. For example, Federal Open Market Committee announcements have previously been examined in isolation of other types of announcements. It is often suggested in financial press that the short term bond volatility is more affected by Fed rate changes than long term bonds, while labor market announcements especially affects long term bonds. Therefore, we look at their separate effects. Because we use sixteen different announcements, including the ones used in the aforementioned studies, it is an interesting question to examine whether FOMC and EMP/PPI announcements differ from other types of announcements.[9] Appendix B presents some summary statistics for the excess returns on (and around) FOMC, EMP and PPI, and the other announcement days. We find that the average bond return is, for most maturities, considerably higher on FOMC announcement days than on other announcement days.

In order to examine the different announcements on the conditional volatility, we make two changes to the model. First, we include three dummy variables in the mean equation. One dummy that is equal to one on FOMC announcement days, a second dummy that is equal to one on EMP and PPI days, and a third dummy variable for the remaining macroeconomic announcement days. Second, we let parameter $w^f$, $a^f$ and $g^f$ measure the impact of FOMC announcements, $w^m$, $a^m$ and $g^m$ measure the impact of PPI and EMP announcements, and $w^r$, $a^r$ and $g^r$ measure the remaining announcements. The specification for the conditional volatility becomes:

$$\begin{aligned} h_{t+1}^2 &= \omega + \omega^f I_{t+1}^f + \omega^m I_{t+1}^m + \omega^r I_{t+1}^r + b h_t^2 + (a + a^f I_t^f + a^m I_t^m + a^r I_t^r)\varepsilon_t^2 + \\ &\quad + (g + g^f I_t^f + g^m I_t^m + g^r I_t^r)(\varepsilon_t^-)^2. \end{aligned} \quad (5)$$

*[Table 5 about here]*

The results of estimating the conditional volatility models, using three announcement types, are shown in Table 5. The estimated parameters that govern the dynamics in bond market volatility are quite similar to the estimations in

[9] Ideally, we would like to consider all the other announcement separately as well, but the number of parameters become too large to estimate the system. Some experiments separating between different announcements showed that FOMC, EMP and PPI announcements are the most influential ones.

the previous sections. Striking is the difference between the level of volatility on FOMC and EMP/PPI days and the remaining announcements days. This pre-announcement effect is highly significant for FOMC and EMP/PPI days, but not for the remaining announcements. Macroeconomic announcements (PPI and EMP) seem to be especially influential at the intermediate and long end of the yield curve, while monetary policy (FOMC changes) seem to affect especially short-term bonds.

Volatility on announcement days does not persist for the short bond, consistent with the immediate incorporation of information into prices. For the 1 year Treasury bond, FOMC and EMP/PPI announcement shocks are much less persistent than other shocks. For the other maturities, the remaining announcements persistencies are also significant. Thus, the market seems to learn the implications of the remaining announcements quicker for the 3, 5 and 10 year bonds. Obviously, it is important to allow that different types of announcements have a different impact on volatility. We further find that the response to good and bad market news in the bond market typically do not differ significantly from zero. Thus negative macroeconomic announcement shocks in bond markets do not results in a higher than usual subsequent volatility.

*[Table 6 about here]*

The FOMC news announcements need some more attention, as this is an influential variable, and contains an important structural break. Federal Reserve's FOMC meetings are scheduled eight times a year. FOMC announcements are made public after the meetings in the afternoon. Most changes in the target of the federal funds rate have been either 25 or 50 basis points (the 75 basis-point increase on November 15, 1994 is a notable exception). The Federal Reserve typically announces rate decisions at their regularly scheduled meetings. However, they may announce rate cuts between meetings if they believe they need to act quickly. This occurred for example in September 2001 after the terrorist attack on the Pentagon and the World Trade Center.

In February 1994, the Fed began the practice of announcing changes in its target for the federal funds rate immediately after FOMC meetings. Since then most changes in the Fed's target for the federal funds rate have been made at the FOMC meetings. Prior to this, changes in the target were often made between regularly scheduled meetings. This suggests that FOMC meeting days have become more important in the eyes of the market participants since February 1994. To allow for the possibility that the effects of FOMC announcements have a different impact on volatility after February 1994, we include the dummy $I_t^{94}$ in model (5) which takes the value 1 after February 1994. The new model becomes

$$\begin{aligned} h_{t+1}^2 &= \omega + \omega^f I_{t+1}^f + \omega_{94}^f I_{t+1}^f I_{t+1}^{94} + \omega^m I_{t+1}^m + \omega^r I_{t+1}^r + b h_t^2 + (a + a^f I_t^f + \\ &\quad + a_{94}^f I_t^f I_t^{94} + a^m I_t^m + a^r I_t^r)\varepsilon_t^2 + (g + g^f I_t^f + g_{94}^f I_t^f I_t^{94} + g^m I_t^m + g^r I_t^r)(\varepsilon_t^-)^2 \ . \end{aligned} \tag{6}$$

The results in Table 6 show that this extension has virtually no effect for the intermediate and long run bonds. For the 1 year Treasury bond, however, the two regimes differ significantly. First, the level effect of the 1 year bond decreases after 1994. This is probably because from 1994 onwards, the target level was announced, such that the uncertainty around FOMC announcement days decreased. Moreover, the magnitude of the news effects decreased, possibly because the market learns the implications of FOMC announcements quicker after 1994. An explanation of the fact that volatility caused by FOMC changes persist less from 1994 on, is that the announcement of anticipated news resolves uncertainty, whereas unanticipated news increases uncertainty (see Ederington and Lee, 1996). Only from 1994 on, the changes of target levels were announced, leading to less uncertainty. Overall, our results show that it is mainly important for short term Treasury bonds to allow for the structural break of 1994 in FOMC announcements.[10]

# 5 Concluding Remarks

This paper investigates the interaction between announcements and volatility in bond markets, whether announcement news differ from non-announcement news, and to what extent asymmetric volatility is explained by macroeconomic announcements. To this end, we accommodate the model of Glosten, Jagannathan and Runkle (1993) in such a way that macroeconomic announcements and their surprises in Treasury bond markets are accounted for. We use daily returns on the 1, 3, 5 and 10 year Treasury bond, for the period January 1982 - September 2004.

The most important reason that macroeconomic announcement shocks have a different impact on volatility is because they are regularly scheduled, such that the timing of these announcements is known in advance. While Li and Engle (1998) and Christiansen (2000) do not include pre-announcement effect in their models, we find that it is important. The anticipated conditional variances and covariances are much higher on macroeconomic announcement days. FOMC announcements are especially important for short term bonds, while for long term bonds PPI and EMP are the most important announcements. The impact of the remaining announcements are of a lesser order. The results show that volatility on announcement days does not persist for the Treasury and corporate bonds, consistent with the imme-

[10]Unreported tests show that for high- and medium grade corporate bonds, this structural break does not matter.

diate incorporation of information into prices. This confirms the findings of Li and Engle (1998) and Christiansen (2000). Negative announcement shocks typically have a greater impact on the subsequent volatility than positive announcement shocks. After introducing macroeconomic announcements into the model, none of the asymmetric volatility parameter estimates is individually significant anymore. We find similar results for high grade and medium grade corporate bonds, and for the covariances between bond returns. While the asymmetric volatility may disappear because of the introduction of announcements effects, this result might be related to the power of the tests.

The results of this study give raise to interesting future research topics. The use of options data to study the volatility impact of macroeconomic news could increase the power of the tests. Beber and Brandt (2005) for instance show that the cross-section of option prices embed the dynamics of volatility. As some industries depend more on macroeconomic factors than others, it is interesting to investigate industry stock portfolios. Moreover, as suggested by McQueen and Roley (1993) and Veronesi (1999) it is likely that the impact of macroeconomic news releases on bond returns depends on the state of the economy, i.e. whether we are in a recession or an expansion. Further research may elaborate on these issues in more detail.

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# Appendix A: Calculation of the Returns

In this appendix the calculations of the bond returns are given. We obtained the "daily constant maturity interest rate series" from the Federal Reserve Bank in Chicago. To calculate the bond returns, we follow the method in Jones, Lamont and Lumsdaine (1998).[11] The U.S. Treasury bonds have semi-annual coupon payments, and the coupon on the hypothetical bonds is half the stated coupon yield. Hence, the price of the bond at the beginning of the holding period is equal to its face value. We have calculated an end-of-period price on this bond using the next day's yield augmented with the accrued interest rate:

$$P_{n-\#hd,t+1} = \sum_{i=1}^{2n-1} \frac{\frac{1}{2}y_{nt}}{(1+\frac{1}{2}y_{n,t+1})^i} + \frac{1+\frac{1}{2}y_{nt}}{(1+\frac{1}{2}y_{n,t+1})^{2n}} + \frac{\#\text{ holding days}}{365} y_{nt}, \tag{7}$$

where $P_{n-\#hd,t+1}$ is the end-of-period price of the bond, $n$ is the number of years the bond is referring to, $t$ is the time and $y_{nt}$ is the yield of an $n$-period bond at time $t$. The $\#hd-$return, is calculated as

$$r_{t+1} = P_{n-\#hd,t+1} - 1. \tag{8}$$

Finally, the excess returns are calculated using the three-month interest rate as the risk-free rate that accrues over the holding period, which varies from one to five days due to weekends and holidays:

$$r^e_{t+1} = r_{t+1} - \frac{\#\text{ holding days}}{365} y_{3mo,t}.$$

[11] We thank Charles Jones, Owen Lamont and Charlotte Christiansen for their help with the program to construct the data.

## Appendix B: Summary Statistics

This appendix presents some preliminary analyses. Table 7 presents summary statistics for daily excess returns.

*[Table 7 about here]*

Panel A through C provide statistics for the full sample as well as only on announcement and non-announcement days. Panel D and E present the summary statistics one day before and one day after announcement days. From Panel A and B it is evident that the average excess returns on all assets are greater on announcement days. The differences in the mean on announcement (Panel B) and non-announcement days (Panel C) is substantial. For example, the mean return on 1 year Treasury bonds is 0.0053 on announcement days, while on non-announcement days it is only 0.0024. However, attributing this positive effect on the mean returns to a compensation for risk would be too premature, since economic news was generally positive for bonds over our sample period, which would automatically lead to a positive correlation between announcements and bond returns. Like Christiansen (2000) we find that unconditional correlations on announcement days are higher than on non-announcement days. This indicates that the advantage of diversification is less pronounced when the investor needs it most: at times when risk is high. As the variances and covariances on announcement days are typically greater than those on non-announcement days, we conduct a joint test for the null hypotheses that the covariance matrixes are identical in the two subsamples, cf. Basilevsky (1994, pp. 194-198). The resulting test statistics (see Table 8) show that covariances differ significantly on announcement and non-announcement days. Thus, we conclude that the covariance matrix for announcement days differs from the one for non-announcement days. This motivates to look at the conditional covariances as well.

*[Table 8 about here]*

Finally, as reports that financial markets are particularly quiet on the days prior to macroeconomic announcements are commonplace in the financial press, we consider the standard deviations on the day before an announcement. Several studies (e.g. Jones, Lamont and Lumsdaine, 1998) find support of this "calm before the storm" effect for bond returns. To obtain some indication of possible persistence in the announcement shocks, we also consider the returns on the day after an announcement (see Panel D and E ). The standard deviation is lower on days preceding macroeconomic announcements. Thus we find support for the "calm before the storm" effect. If the shocks to volatility on announcement days generate persistent volatility, we would expect that the day after an announcement day would have higher than average volatility. The literature shows (see, e.g., Jones, Lamont and Lumsdaine, 1998) that announcement shocks in the bond markets do typically not persist. We confirm this; the results in Panel E indicate that the shocks on announcement days do not generate persistent volatility. The standard deviation of bonds one day after the announcement is typically lower than on other non-announcement days. Overall, the summary statistics are in line with the findings of Jones, Lamont and Lumsdaine (1998) and Christiansen (2000).

*[Table 9 about here]*

Table 9 presents some summary statistics for the excess returns on (and around) FOMC, EMP and PPI, and the other announcement days. The table shows that the mean on the bond return is for most maturities considerably higher on FOMC announcement days than on other announcement days. For example, the mean return on the 5 year bonds is 0.1916% on FOMC announcement days (Panel A), 0.0341% on PPI/EMP announcements days (Panel D), and 0.0134% on the remaining announcement days (Panel G), whereas the mean on non-announcement days is only 0.0106% (see Table 7). Note that the standard deviations for FOMC and PPI/EMP announcement days tend to be higher than for other announcement days. Finally, note that for both types of announcements the correlation coefficients are similar, but remain larger than on non-announcement days. Looking at the summary statistics one day before the announcement, we find again some indication for a "calm before the storm" effect. The corresponding standard deviations are typically lower than for non-announcements days.

Table 1: **Announcement Releases**

| Variable | Abbrev. | Units | Available from |
|---|---|---|---|
| Federal Open Market Committee | FOMC | % level | January 1982 |
| Consumer Confidence | CC | % level | January 1991 |
| Consumer Credit | CRED | $ bln | January 1982 |
| Consumer Price Index | CPI | % change | January 1982 |
| Durable Goods Orders | DGO | % change | January 1982 |
| Factory Orders | FO | % change | January 1988 |
| Trade Balance | TB | $ bln | January 1982 |
| NAPM Index | NAPM | % level | January 1982 |
| Index of Leading Indicators | LI | % change | January 1982 |
| Initial Jobless Claims | IJC | thousands | January 1991 |
| Nonfarm Payrolls | EMP | thousands | January 1985 |
| Producer Price Index | PPI | % change | January 1982 |
| Housing Starts | HS | millions | January 1982 |
| Retail Sales | RS | % change | January 1982 |
| Treasury Budget | TRB | $ bln | January 1988 |
| Civilian Unemployment | CU | % level | January 1982 |

*Notes:* This table shows the announcements, their abbreviation, the reported units of the variables, and the date from which on the data on expectations and realizations is available.

Table 2: **Estimation Results: Macroeconomic Announcements and Asymmeric Volatility in 1, 3, 5 and 10 Year Treasury Bonds**

| | GJR | | Ann surpr | | Ann days | |
|---|---|---|---|---|---|---|
| | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. |
| | | | Panel A: 1 year Treasury bond | | | |
| $w$ | 0.0392** | 0.0039 | 0.0117 | 0.0099 | -0.0379** | 0.0117 |
| $w^a$ | | | 0.0712** | 0.0156 | 0.2285** | 0.0212 |
| $b$ | 0.9282** | 0.0028 | 0.9206** | 0.0038 | 0.8958** | 0.0050 |
| $a$ | 0.0603** | 0.0029 | 0.0911** | 0.0052 | 0.1561** | 0.0104 |
| $a^a$ | | | | | -0.1249** | 0.0122 |
| $a^s$ | | | -0.0675** | 0.0071 | | |
| $g$ | 0.0094* | 0.0049 | -0.0027 | 0.0069 | -0.0027 | 0.0135 |
| $g^a$ | | | | | 0.0161 | 0.0158 |
| $g^s$ | | | 0.0288** | 0.0098 | | |
| $\mathcal{L}(\hat{\theta})$ | 8,077.62 | | 8,098.34 | | 8,122.92 | |
| | | | Panel B: 3 year Treasury bond | | | |
| $w$ | 0.5880** | 0.0731 | 0.2915** | 0.1329 | -0.2138 | 0.1549 |
| $w^a$ | | | 1.0612** | 0.2032 | 3.0136** | 0.3044 |
| $b$ | 0.9347** | 0.0038 | 0.9206** | 0.0050 | 0.8981** | 0.0062 |
| $a$ | 0.0489** | 0.0036 | 0.0823** | 0.0065 | 0.1353** | 0.0106 |
| $a^a$ | | | | | -0.1139** | 0.0115 |
| $a^s$ | | | -0.0668** | 0.0084 | | |
| $g$ | 0.0046 | 0.0044 | -0.0009 | 0.0077 | -0.0086 | 0.0142 |
| $g^a$ | | | | | 0.0193 | 0.0159 |
| $g^s$ | | | 0.0136 | 0.0112 | | |
| $\mathcal{L}(\hat{\theta})$ | 1,419.18 | | 1,444.85 | | 1,458.21 | |
| | | | Panel C: 5 year Treasury bond | | | |
| $w$ | 1.6583** | 0.2204 | 1.1241** | 0.3539 | 0.1207 | 0.3990 |
| $w^a$ | | | 2.4722** | 0.5030 | 7.5507** | 0.8085 |
| $b$ | 0.9352** | 0.0047 | 0.9201** | 0.0060 | 0.8921** | 0.0072 |
| $a$ | 0.0427** | 0.0042 | 0.0726** | 0.0072 | 0.1365** | 0.0122 |
| $a^a$ | | | | | -0.1265** | 0.0134 |
| $a^s$ | | | -0.0610** | 0.0092 | | |
| $g$ | 0.0094** | 0.0041 | 0.0026 | 0.0074 | -0.0188 | 0.0149 |
| $g^a$ | | | | | 0.0476** | 0.0173 |
| $g^s$ | | | 0.0198* | 0.0118 | | |
| $\mathcal{L}(\hat{\theta})$ | -1,082.70 | | -1,064.16 | | -1,048.71 | |
| | | | Panel D: 10 year Treasury bond | | | |
| $w$ | 4.4728** | 0.6484 | 3.5640** | 0.9166 | 2.3602** | 0.9810 |
| $w^a$ | | | 3.6484** | 1.2749 | 8.0013** | 1.7655 |
| $b$ | 0.9349** | 0.0056 | 0.9283** | 0.0064 | 0.9218** | 0.0071 |
| $a$ | 0.0414** | 0.0045 | 0.0574** | 0.0069 | 0.0771** | 0.0100 |
| $a^a$ | | | | | -0.0566** | 0.0113 |
| $a^s$ | | | -0.0409** | 0.0092 | | |
| $g$ | 0.0091** | 0.0040 | 0.0081 | 0.0062 | -0.0018 | 0.0105 |
| $g^a$ | | | | | 0.0235 | 0.0145 |
| $g^s$ | | | 0.0078 | 0.0105 | | |
| $\mathcal{L}(\hat{\theta})$ | -3,705.68 | | -3,694.35 | | -3,693.86 | |

*Notes:* There are 5,682 observations used in the estimation. Standard errors are robust Bollerslev-Wooldridge (1992) standard errors. $\mathcal{L}(\hat{\theta})$ denotes the loglikelihood for the corresponding parameter estimates, and "*" and "**" indicate that the corresponding coefficient is statistically significant at the 10% and 5% level, respectively.

Table 3: **Estimation Results: Macroeconomic Announcements and Asymmeric Volatility in Corporate Bonds**

| | GJR | | Ann surpr | | GJR | | Ann surpr | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. |
| | Panel A: AAA Corporate Bond | | | | Panel B: BAA Corporate Bond | | | |
| $w$ | 0.4276** | 0.0800 | 0.2737* | 0.1647 | 0.7070** | 0.1115 | -0.1100 | 0.1665 |
| $w^a$ | | | 0.3732 | 0.3237 | | | 3.3730** | 0.4900 |
| $b$ | 0.9437** | 0.0032 | 0.9416** | 0.0034 | 0.9374** | 0.0040 | 0.9233** | 0.0053 |
| $a$ | 0.0505** | 0.0037 | 0.0582** | 0.0045 | 0.0551** | 0.0040 | 0.0760** | 0.0058 |
| $a^s$ | | | -0.0180** | 0.0076 | | | -0.0513** | 0.0096 |
| $g$ | 0.0074** | 0.0034 | 0.0063 | 0.0053 | 0.0008 | 0.0046 | -0.0060 | 0.0067 |
| $g^s$ | | | 0.0038 | 0.0107 | | | 0.0242* | 0.0129 |
| $\mathcal{L}(\hat{\theta})$ | -928.01 | | -925.84 | | -440.71 | | -422.75 | |

*Notes:* There are 5,692 observations used in the estimation. Standard errors are robust Bollerslev-Wooldridge (1992) standard errors. $\mathcal{L}(\hat{\theta})$ denotes the loglikelihood for the corresponding parameter estimates, and "*" and "**" indicate that the corresponding coefficient is statistically significant at the 10% and 5% level, respectively.

Table 4: **Estimation Results: Conditional Covariance Between 1 and 5 Year Treasury Bonds and between 1 year Treasury Bond and AAA Corporate Bond**

| | GJR | | Ann. surpr | | GJR | | Ann. surpr | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. |
| | Panel A: 1 and 5 year bond | | | | Panel B: 1 year and AAA bond | | | |
| $\omega_1$ | 0.0373** | 0.0029 | 0.0352** | 0.0085 | 0.0207** | 0.0021 | 0.0180** | 0.0071 |
| $\omega_{12}$ | 0.1797** | 0.0158 | 0.1015** | 0.0388 | 0.0386** | 0.0084 | -0.0473** | 0.0209 |
| $\omega_2$ | 1.3277** | 0.1282 | 0.5954** | 0.2218 | 0.6820** | 0.0819 | 0.4095** | 0.1382 |
| $\omega_1^a$ | | | 0.0262* | 0.0137 | | | 0.0181 | 0.0123 |
| $\omega_{12}^a$ | | | 0.2473** | 0.0655 | | | 0.1551** | 0.0388 |
| $\omega_2^a$ | | | 2.0884** | 0.3955 | | | 0.1972 | 0.2691 |
| $b_1$ | 0.9314** | 0.0021 | 0.9257** | 0.0026 | 0.9312** | 0.0020 | 0.9301** | 0.0022 |
| $b_{12}$ | 0.9388** | 0.0024 | 0.9341** | 0.0028 | 0.9544** | 0.0021 | 0.9581** | 0.0020 |
| $b_2$ | 0.9355** | 0.0031 | 0.9297** | 0.0035 | 0.9369** | 0.0031 | 0.9440** | 0.0029 |
| $a_1$ | 0.0574** | 0.0025 | 0.0726** | 0.0036 | 0.0615** | 0.0026 | 0.0726** | 0.0037 |
| $a_{12}$ | 0.0473** | 0.0025 | 0.0596** | 0.0036 | 0.0315** | 0.0027 | 0.0300** | 0.0031 |
| $a_2$ | 0.0487** | 0.0032 | 0.0625** | 0.0047 | 0.0520** | 0.0038 | 0.0458** | 0.0041 |
| $a_1^s$ | | | -0.0353** | 0.0053 | | | -0.0376** | 0.0054 |
| $a_{12}^s$ | | | -0.0302** | 0.0048 | | | -0.0159** | 0.0044 |
| $a_2^s$ | | | -0.0346** | 0.0060 | | | -0.0018 | 0.0069 |
| $g_1$ | 0.0072** | 0.0035 | 0.0009 | 0.0048 | 0.0138** | 0.0042 | 0.0031 | 0.0053 |
| $g_{12}$ | 0.0060** | 0.0030 | 0.0030 | 0.0043 | 0.0187** | 0.0031 | 0.0063 | 0.0037 |
| $g_2$ | 0.0046 | 0.0035 | 0.0047 | 0.0052 | 0.0133** | 0.0045 | 0.0192** | 0.0053 |
| $g_1^s$ | | | 0.0126* | 0.0073 | | | 0.0347** | 0.0080 |
| $g_{12}^s$ | | | 0.0078 | 0.0070 | | | 0.0035 | 0.0063 |
| $g_2^s$ | | | 0.0052 | 0.0083 | | | -0.0115 | 0.0092 |
| $\mathcal{L}(\hat{\theta})$ | 10,621.67 | | 10,645.81 | | 8,419.88 | | 8,449.60 | |

*Notes:* There are 5,682 observations used in the estimation. Standard errors are robust Bollerslev-Wooldridge (1992) standard errors. $\mathcal{L}(\hat{\theta})$ denotes the loglikelihood for the corresponding parameter estimates, and "*" and "**" indicate that the corresponding coefficient is statistically significant at the 10% and 5% level, respectively.

Table 5: **Estimation Results: Discriminating Between Macroeconomic Announcements**

| | Ann surpr | | FOMC/EMP/rest | | Ann surpr | | FOMC/EMP/rest | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. |
| | Panel A: 1 year Treasury bond | | | | Panel B: 3 year Treasury bond | | | |
| $w$ | 0.0117 | 0.0099 | 0.0085 | 0.0151 | 0.2915** | 0.1329 | 0.1294 | 0.1756 |
| $w^a$ | 0.0712** | 0.0156 | | | 1.0612** | 0.2032 | | |
| $w^f$ | | | 1.5390** | 0.1722 | | | 6.5735** | 2.0574 |
| $w^m$ | | | 0.7682** | 0.0755 | | | 7.7205** | 0.2361 |
| $w^r$ | | | -0.0223 | 0.0213 | | | 0.1636 | 0.9535 |
| $b$ | 0.9206** | 0.0038 | 0.8972** | 0.0045 | 0.9206** | 0.0050 | 0.9110** | 0.0061 |
| $a$ | 0.0911** | 0.0052 | 0.0917** | 0.0056 | 0.0823** | 0.0065 | 0.0781** | 0.0066 |
| $a^s$ | -0.0675** | 0.0071 | | | -0.0668** | 0.0084 | | |
| $a^f$ | | | -0.0522** | 0.0137 | | | -0.0449** | 0.0160 |
| $a^m$ | | | -0.0710** | 0.0134 | | | -0.0629** | 0.0122 |
| $a^r$ | | | -0.0035 | 0.0084 | | | -0.0214** | 0.0101 |
| $g$ | -0.0027 | 0.0069 | 0.0181** | 0.0083 | -0.0009 | 0.0077 | 0.0069 | 0.0082 |
| $g^s$ | 0.0288 | 0.0098 | | | 0.0136 | 0.0112 | | |
| $g^f$ | | | 0.0053 | 0.0671 | | | 0.0156 | 0.0573 |
| $g^m$ | | | -0.0002 | 0.0188 | | | 0.0146 | 0.0171 |
| $g^r$ | | | -0.0354** | 0.0143 | | | -0.0152 | 0.0141 |
| $\mathcal{L}(\hat{\theta})$ | 8,098.34 | | 8,165.82 | | 1,444.85 | | 1,469.22 | |
| | Panel C: 5 year Treasury bond | | | | Panel D: 10 year Treasury bond | | | |
| $w$ | 1.1241** | 0.3539 | 0.9785** | 0.4836 | 3.5640** | 0.9166 | 2.4858** | 1.1345 |
| $w^a$ | 2.4722** | 0.5030 | | | 3.6484** | 1.2749 | | |
| $w^f$ | | | 11.5767** | 5.6660 | | | 35.4117** | 14.4798 |
| $w^m$ | | | 19.2106** | 2.4065 | | | 41.6667** | 6.1275 |
| $w^r$ | | | 0.6745 | 0.6007 | | | -0.1321 | 1.3634 |
| $b$ | 0.9201** | 0.0060 | 0.9012** | 0.0078 | 0.9283** | 0.0064 | 0.9194** | 0.0074 |
| $a$ | 0.0726** | 0.0072 | 0.0772** | 0.0078 | 0.0574** | 0.0069 | 0.0614** | 0.0070 |
| $a^s$ | -0.0610** | 0.0092 | | | -0.0409** | 0.0092 | | |
| $a^f$ | | | -0.0339** | 0.0167 | | | -0.0670** | 0.0223 |
| $a^m$ | | | -0.0786** | 0.0139 | | | -0.0603** | 0.0124 |
| $a^r$ | | | -0.0190* | 0.0111 | | | -0.0215** | 0.0100 |
| $g$ | 0.0026 | 0.0074 | 0.0077 | 0.0083 | 0.0081 | 0.0062 | 0.0070 | 0.0066 |
| $g^s$ | 0.0198* | 0.0118 | | | 0.0078 | 0.0105 | | |
| $g^f$ | | | 0.0049 | 0.0652 | | | 0.0374 | 0.0628 |
| $g^m$ | | | 0.0243 | 0.0183 | | | 0.0231 | 0.0163 |
| $g^r$ | | | -0.0100 | 0.0152 | | | -0.0021 | 0.0129 |
| $\mathcal{L}(\hat{\theta})$ | -1,064.16 | | -1,036.75 | | -3,694.35 | | -3,671.87 | |

*Notes:* There are 5,682 observations used in the estimation. Standard errors are robust Bollerslev-Wooldridge (1992) standard errors. $\mathcal{L}(\hat{\theta})$ denotes the loglikelihood for the corresponding parameter estimates, and "*" and "**" indicate that the corresponding coefficient is statistically significant at the 10% and 5% level, respectively.

Table 6: **Estimation Results: Change in Policy from 1994 on**

| | 1 yr bond | | 3 yr bond | | 5 yr bond | | 10 yr bond | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. | Estimate | Std. Err. |
| $w$ | 0.0084 | 0.0167 | 0.0862 | 0.1949 | 0.9062* | 0.5306 | 2.7722** | 1.2684 |
| $w^f$ | 1.6640** | 0.1960 | 6.6896** | 2.1714 | 11.7707** | 5.8264 | 37.7648** | 14.8802 |
| $w^f_{94}$ | -0.0385** | 0.0132 | -0.2463 | 0.1647 | -0.3661 | 0.4858 | 1.8288 | 1.1678 |
| $w^m$ | 0.6393** | 0.0822 | 7.4035** | 0.9750 | 18.7610** | 2.4401 | 43.6258** | 6.1508 |
| $w^r$ | 0.0885** | 0.0258 | 0.6931** | 0.3318 | 1.4227 | 0.8519 | -2.2025 | 1.8915 |
| $b$ | 0.8870** | 0.0051 | 0.9071** | 0.0065 | 0.8992** | 0.0081 | 0.9185** | 0.0077 |
| $a$ | 0.1064** | 0.0079 | 0.0816** | 0.0080 | 0.0788** | 0.0088 | 0.0624** | 0.0078 |
| $a^f$ | -0.0771** | 0.0160 | -0.0529** | 0.0173 | -0.0379** | 0.0181 | -0.0615** | 0.0235 |
| $a^f_{94}$ | -0.0229** | 0.0092 | 0.0005 | 0.0090 | 0.0002 | 0.0104 | -0.0086 | 0.0099 |
| $a^m$ | -0.0821** | 0.0143 | -0.0667** | 0.0130 | -0.0798** | 0.0143 | -0.0609** | 0.0128 |
| $a^r$ | 0.0121 | 0.0097 | -0.0198* | 0.0111 | -0.0182 | 0.0121 | -0.0182 | 0.0109 |
| $g$ | 0.0082 | 0.0123 | 0.0068 | 0.0101 | 0.0082 | 0.0097 | 0.0058 | 0.0074 |
| $g^f$ | 0.1003 | 0.0816 | 0.0323 | 0.0608 | 0.0121 | 0.0674 | 0.0331 | 0.0634 |
| $g^f_{94}$ | -0.0014 | 0.0165 | -0.0037 | 0.0150 | -0.0020 | 0.0155 | 0.0072 | 0.0139 |
| $g^m$ | 0.0100 | 0.0202 | 0.0179 | 0.0178 | 0.0253 | 0.0188 | 0.0227 | 0.0165 |
| $g^r$ | -0.0334** | 0.0168 | -0.0156 | 0.0160 | -0.0103 | 0.0164 | -0.0043 | 0.0145 |
| $\mathcal{L}(\hat{\theta})$ | 8,181.03 | | 1,471.02 | | -1,036.19 | | -3,670.67 | |

*Notes:* There are 5,682 observations used in the estimation. Standard errors are robust Bollerslev-Wooldridge (1992) standard errors. $\mathcal{L}(\hat{\theta})$ denotes the loglikelihood for the corresponding parameter estimates, and "*" and "**" indicate that the corresponding coefficient is statistically significant at the 10% and 5% level, respectively.

Table 7: **Summary Statistics for 1, 3, 5 and 10 year Treasury Bond Excess Returns**

| | 1 yr bond | 3 yr bond | 5 yr bond | 10 yr bond |
|---|---|---|---|---|
| Panel A: Full sample | | | | |
| Mean | 0.0037 | 0.0098 | 0.0138 | 0.0197 |
| Std. Dev. | 0.0720 | 0.2019 | 0.3080 | 0.4854 |
| Covariances and **Correlations** | | | | |
| 1 yr bond | 0.0052 | 0.0124 | 0.0179 | 0.0257 |
| 3 yr bond | **0.8527** | 0.0408 | 0.0591 | 0.0877 |
| 5 yr bond | **0.8082** | **0.9509** | 0.0948 | 0.1415 |
| 10 yr bond | **0.7346** | **0.8955** | **0.9466** | 0.2356 |
| Panel B: Macroeconomic announcement days | | | | |
| Mean | 0.0053 | 0.0122 | 0.0175 | 0.0217 |
| Std. Dev. | 0.0679 | 0.2132 | 0.3287 | 0.5123 |
| Covariances and **Correlations** | | | | |
| 1 yr bond | 0.0046 | 0.0127 | 0.0185 | 0.0264 |
| 3 yr bond | **0.8765** | 0.0455 | 0.0672 | 0.0989 |
| 5 yr bond | **0.8295** | **0.9588** | 0.1080 | 0.1606 |
| 10 yr bond | **0.7575** | **0.9055** | **0.9541** | 0.2624 |
| Panel C: Non-announcement days | | | | |
| Mean | 0.0024 | 0.0078 | 0.0106 | 0.0180 |
| Std. Dev. | 0.0753 | 0.1919 | 0.2895 | 0.4616 |
| Covariances and **Correlations** | | | | |
| 1 yr bond | 0.0057 | 0.0121 | 0.0174 | 0.0251 |
| 3 yr bond | **0.8412** | 0.0368 | 0.0524 | 0.0784 |
| 5 yr bond | **0.7998** | **0.9427** | 0.0838 | 0.1254 |
| 10 yr bond | **0.7226** | **0.8852** | **0.9388** | 0.2130 |
| Panel D: 1 day BEFORE announcement days | | | | |
| Mean | 0.0040 | 0.0134 | 0.0194 | 0.0329 |
| Std. Dev. | 0.0639 | 0.1747 | 0.2680 | 0.4280 |
| Covariances and **Correlations** | | | | |
| 1 yr bond | 0.0041 | 0.0092 | 0.0134 | 0.0192 |
| 3 yr bond | **0.8257** | 0.0305 | 0.0441 | 0.0658 |
| 5 yr bond | **0.7820** | **0.9417** | 0.0718 | 0.1064 |
| 10 yr bond | **0.7012** | **0.8805** | **0.9286** | 0.1830 |
| Panel E: 1 day AFTER announcement days | | | | |
| Mean | 0.0006 | 0.0011 | 0.0042 | 0.0075 |
| Std. Dev. | 0.0648 | 0.1776 | 0.2692 | 0.4342 |
| Covariances and **Correlations** | | | | |
| 1 yr bond | 0.0042 | 0.0096 | 0.0136 | 0.0195 |
| 3 yr bond | **0.8365** | 0.0315 | 0.0452 | 0.0679 |
| 5 yr bond | **0.7799** | **0.9455** | 0.0724 | 0.1104 |
| 10 yr bond | **0.6939** | **0.8805** | **0.9448** | 0.1884 |

*Notes:* Summary statistics for the excess return on the 1, 3, 5 and 10 year Treasury bond for the period January 4, 1982 - September 30, 2004. All returns are daily returns in percentages (see Appendix A). Bold numbers are correlation coefficients.

Table 8: **Covariance Matrix Test**

| | test-statistic | *df* | *p*-value |
|---|---|---|---|
| 1 yr, 3 yr bond | 113.29 | 3 | 0.000 |
| 1 yr, 5 yr bond | 96.16 | 3 | 0.000 |
| 1 yr, 10 year bond | 59.00 | 3 | 0.000 |
| 3 yr, 5 yr bond | 20.75 | 3 | 0.000 |
| 3 yr, 5 yr bond | 12.39 | 3 | 0.006 |
| 5 yr, 10 yr bond | 19.73 | 3 | 0.002 |
| 1, 3, 5, and 10 yr bond | 145.92 | 10 | 0.000 |

*Notes*: This table reports the results of tests on differences in the unconditional covariance matrices. The test statistic follows a $\chi^2_{df}$-distribution, where *df* denotes the degrees of freedom.

Table 9: **Summary Statistics for 1, 3, 5 and 10 year Treasury Bond Excess Returns Around FOMC, PPI/EMP and Other Announcements**

| | 1 yr | 3 yr | 5 yr | 10 yr | 1 yr | 3 yr | 5 yr | 10 yr |
|---|---|---|---|---|---|---|---|---|
| Panel A: FOMC announcement days | | | | | Panel B: 1 day BEFORE FOMC days | | | |
| Mean | 0.0593 | 0.1244 | 0.1916 | 0.2304 | 0.0321 | 0.1000 | 0.1366 | 0.2120 |
| Std. Dev. | 0.1143 | 0.2981 | 0.4341 | 0.6491 | 0.0819 | 0.1823 | 0.2657 | 0.4171 |
| Covariances and **Correlations** | | | | | Covariances and **Correlations** | | | |
| 1 yr bond | 0.0128 | 0.0305 | 0.0409 | 0.0546 | 0.0066 | 0.0129 | 0.0165 | 0.0225 |
| 3 yr bond | **0.9113** | 0.0874 | 0.1218 | 0.1708 | **0.8800** | 0.0327 | 0.0439 | 0.0628 |
| 5 yr bond | **0.8378** | **0.9567** | 0.1854 | 0.2623 | **0.7692** | **0.9207** | 0.0695 | 0.1037 |
| 10 yr bond | **0.7482** | **0.8970** | **0.9462** | 0.4146 | **0.6707** | **0.8389** | **0.9506** | 0.1712 |
| Panel C: 1 day AFTER FOMC days | | | | | Panel D: PPI/EMP announcement days | | | |
| Mean | 0.0181 | 0.0387 | 0.0862 | 0.1351 | 0.0107 | 0.0235 | 0.0341 | 0.0468 |
| Std. Dev. | 0.0697 | 0.1970 | 0.3194 | 0.6044 | 0.0958 | 0.2870 | 0.4380 | 0.6632 |
| Covariances and **Correlations** | | | | | Covariances and **Correlations** | | | |
| 1 yr bond | 0.0048 | 0.0107 | 0.0147 | 0.0221 | 0.0092 | 0.0249 | 0.0366 | 0.0515 |
| 3 yr bond | **0.7943** | 0.0382 | 0.0561 | 0.0965 | **0.9081** | 0.0822 | 0.1219 | 0.1766 |
| 5 yr bond | **0.6694** | **0.9054** | 0.1004 | 0.1748 | **0.8731** | **0.9715** | 0.1915 | 0.2815 |
| 10 yr bond | **0.5326** | **0.8241** | **0.9206** | 0.3594 | **0.8116** | **0.9301** | **0.9707** | 0.4390 |
| Panel E: 1 day BEFORE PPI/EMP days | | | | | Panel F: 1 day AFTER PPI/EMP days | | | |
| Mean | 0.0038 | 0.0150 | 0.0151 | 0.0224 | -0.0023 | -0.0015 | -0.0018 | 0.0066 |
| Std. Dev. | 0.0626 | 0.1930 | 0.2981 | 0.4623 | 0.0623 | 0.1830 | 0.2773 | 0.4493 |
| Covariances and **Correlations** | | | | | Covariances and **Correlations** | | | |
| 1 yr bond | 0.0039 | 0.0102 | 0.0151 | 0.0209 | 0.0039 | 0.0095 | 0.0136 | 0.0193 |
| 3 yr bond | **0.8466** | 0.0372 | 0.0546 | 0.0792 | **0.8395** | 0.0334 | 0.0480 | 0.0715 |
| 5 yr bond | **0.8082** | **0.9505** | 0.0887 | 0.1302 | **0.7893** | **0.9477** | 0.0768 | 0.1176 |
| 10 yr bond | **0.7225** | **0.8896** | **0.9463** | 0.2133 | **0.6925** | **0.8715** | **0.9460** | 0.2015 |
| Panel G: All other announcement days | | | | | Panel H: 1 day BEFORE other days | | | |
| Mean | 0.0040 | 0.0103 | 0.0134 | 0.0171 | 0.0042 | 0.0133 | 0.0213 | 0.0347 |
| Std. Dev. | 0.0639 | 0.2083 | 0.3212 | 0.5008 | 0.0611 | 0.1708 | 0.2620 | 0.4231 |
| Covariances and **Correlations** | | | | | Covariances and **Correlations** | | | |
| 1 yr bond | 0.0041 | 0.0117 | 0.0171 | 0.0242 | 0.0037 | 0.0086 | 0.0124 | 0.0178 |
| 3 yr bond | **0.8777** | 0.0434 | 0.0642 | 0.0943 | **0.8233** | 0.0291 | 0.0422 | 0.0635 |
| 5 yr bond | **0.8305** | **0.9599** | 0.1031 | 0.1532 | **0.7749** | **0.9430** | 0.0686 | 0.1026 |
| 10 yr bond | **0.7560** | **0.9048** | **0.9531** | 0.2507 | **0.6908** | **0.8795** | **0.9262** | 0.1788 |
| Panel I: 1 day AFTER other days | | | | | | | | |
| Mean | 0.0007 | 0.0002 | 0.0030 | 0.0029 | | | | |
| Std. Dev. | 0.0636 | 0.1776 | 0.2700 | 0.4383 | | | | |
| Covariances and **Correlations** | | | | | | | | |
| 1 yr bond | 0.0040 | 0.0094 | 0.0133 | 0.0194 | | | | |
| 3 yr bond | **0.8332** | 0.0315 | 0.0455 | 0.0692 | | | | |
| 5 yr bond | **0.7782** | **0.9496** | 0.0728 | 0.1121 | | | | |
| 10 yr bond | **0.6983** | **0.8896** | **0.9481** | 0.1920 | | | | |

*Notes:* Summary statistics for the excess return on the 1, 3, 5 and 10 year Treasury bond for the period January 4, 1982 - September 30, 2004. All returns are daily returns in percentages (see Appendix A). Bold numbers are correlation coefficients.

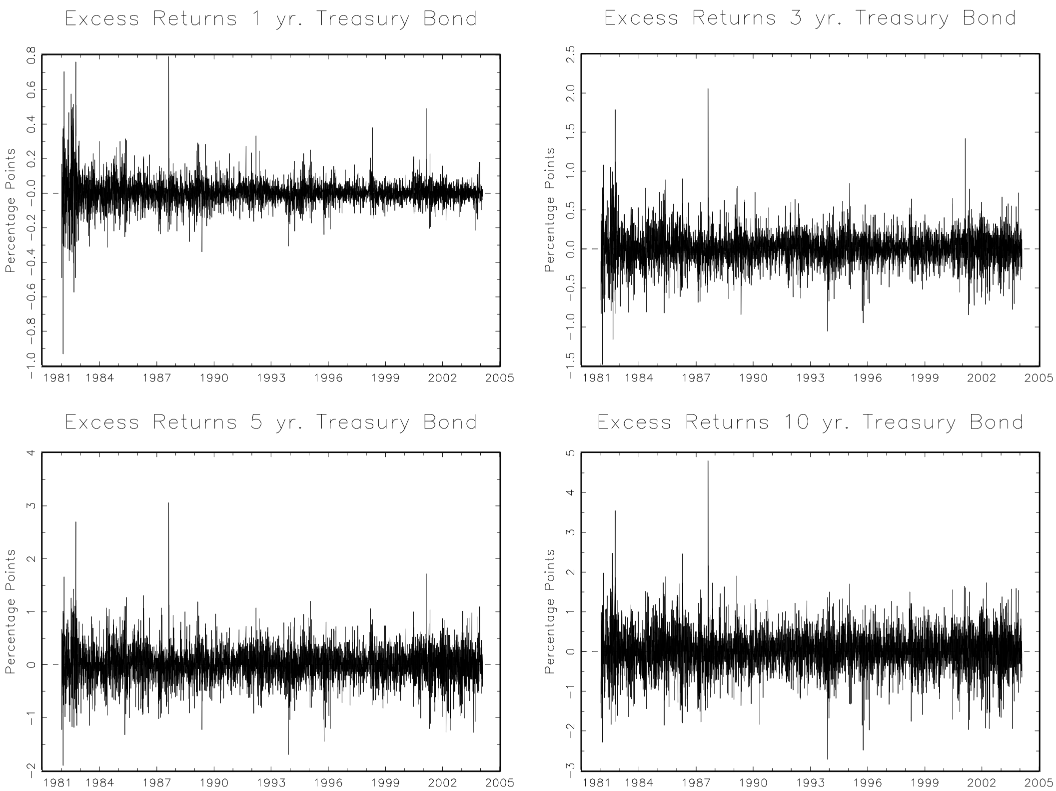


Figure 1: **Daily Excess Returns on 1, 3, 5 and 10 Year Treasury Bonds**