Macro Factors and Volatility of Treasury Bond Returns

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Abstract

This paper investigates the impact of macro variables on the volatility of Treasury-bond returns. By using principal components analysis, we extract the "real" and "money" factors from the real activities and monetary variables, respectively. We find that the macro factors have a significant effect on the volatility of bond returns. In particular, the real variables affect the volatility across all maturities, while the monetary variables are significantly related to the return volatility of short-term bonds but weakly related to the return volatility of medium-term bonds. The implications of these findings are as follows: the monetary authorities can employ macroeconomic policy to affect the volatility of Treasury-bond returns; meanwhile, investors can improve their portfolio management by analyzing the macroeconomic conditions.

JEL classification: E44; G12; G17

Keywords: Bond volatility; Real factor; Money factor; Volatility decomposition

1. Introduction

Recent empirical evidence has showed that the volatility of Treasury bond returns can be predictable. For instance, Jones et al. (1998), Christiansen (2000), and Goeij and Marquering (2006) find that the announcements of macroeconomic variables significantly affect the volatility of Treasury-bond returns. Viceira (2007) finds that the short-term nominal interest rates positively forecast bond volatility. Balduzzi et al. (2001) and Fleming and Remolona (1999) also study the impact of macro news on bond volatility. Using principal-components analysis with a large number of macroeconomic variables, Ludvigson and Ng (2007a, 2007b) find that the macro fundamentals greatly affect stock market volatility, the variation in excess bond returns, and bond risk premia. However, few studies have examined whether macroeconomic fundamentals themselves, rather than their announcements, predict bond-return volatility, which is the first question we will investigate in this paper.

Empirical evidence has also documented that monetary shock and macro news releases affect the shape of the term structure of interest rates. For example, Evans and Marshall (1998) find that a monetary shock has an impact on short-term interest rates, with a smaller effect on medium-term rates and almost no effect on long-term rates. Goeij and Marquering (2006) find that releases of employment data and producer price index affect the medium- and long-term bond volatility, while monetary policy only affects short-term bond volatility. As such, it is interesting to investigate whether the monetary variables have different effects on the volatilities of bond returns with different maturities, which is the second question we will study in this paper.

First, using principal-components analysis, we extract the “real” and “monetary” factors from the macroeconomic variables. We regress the volatilities of bond returns with maturities of 1, 5, 10, and 30 years on both the “real” and “monetary” factors, and we find that the “real” factor significantly affects the bond volatility of all maturities, while the “money” factor is only strongly related to 1- and 5-year bond volatility. Next, to untangle the impacts of maturity on the volatility of bond returns from that caused by market risk, following Campbell et al. (2001), we decompose the bond volatility into market-level-volatility and maturity-dependent volatility. We find that the macroeconomic variables significantly affect bond volatility. Specifically, the real activities affect the bond volatility of all maturities, while the monetary variables are significantly related to the volatility of short-term bonds and weakly related to the volatility of medium-term bonds.

This paper differs from previous papers in two ways. First, many studies (e.g., Jones et al., 1998; Christiansen, 2000; Goeij and Marquering, 2006) examine the effects of macroeconomic announcements on the volatility of bond return, but none of them investigates the relationship between the macroeconomic variables and bond volatility. In particular, we find that “real” and “monetary” factors have different impacts on the volatility of bond returns across various maturities. Second, this is the first paper to use the CAPM to decompose the volatility of Treasury-bonds into two components—market-level and maturity-dependent volatility—and that examines the relationship with macroeconomic variables.

The rest of the paper is organized as follows. Section 2 describes the data used in our empirical analysis, Section 3 examines the impact of macro variables on the volatility of bond returns, and Section 4 concludes.

2. Data

2.1 Bond and stock data

We use data on daily returns of constant-maturity bonds of 1, 5, 10, and 30 years for the period July 1961 through September 2007 from the CRSP Daily Treasury Fixed-term File. The excess returns are calculated using the bond returns in excess of the 3-month Treasury-bill rates, taken from the Federal Reserve Board of Governors.

Figure 1 plots the daily excess returns on the 1-, 5-, 10- and 30-year bonds. The graphs suggest that the daily excess bond returns are quite large for the period of September 1979 through August 1982. This is not surprising because the Federal Reserve's target of monetary policy switched from the funds rate to the nonborrowed depository institutional reserves for this period.

Table 1 illustrates the descriptive statistics of daily excess returns. It should be noticed that the average daily excess returns on all maturities in the sample period are quite close, while their standard deviations are strikingly different. For example, there is a volatility of 7.5% for 1-year Treasury bonds, and 30%, 45.7%, and 62.6% for the 5-, 10- and 30-year bonds, respectively. This leads us to investigate the economic source behind the obvious difference in bond volatilities.

Following French et al. (1987) and Schwert (1989), we use the daily bond returns to calculate the realized monthly volatility for each maturity, as follows:

$$\sigma_i^B(t) = \left[\sum_{d=1}^{D} \left(r_{i,d}^B(t) - \overline{\overline{r}}_i^B(t) \right)^2 \right]^{1/2} \quad i = 1,2,3,4, \qquad (1)$$

where $\sigma_i^B(t)$ is the *t*-th month volatility of the excess bond returns on 1-, 5-, 10-, and 30-year bonds; $r_{i,d}^B(t)$ is the excess daily return; and $\overline{\overline{r}}_i^B(t)$ is the mean of $r_{i,d}^B(t)$ in month *t*.

To calculate the bond-market capitalization, we obtain the face value of outstanding debt from the CRSP Daily Treasury Master File and the bid and ask bond prices from the CRSP Daily Treasury Fixed-term File. The capitalization of the bond market is calculated by multiplying the debt outstanding by the average price (of bid and ask), and then dividing by the face value of 100.

The stock returns are obtained from the CRSP Daily Stock Indices File, which includes the daily returns on the value-weighted portfolio of all stocks traded on the NYSE, the AMEX, and the NASDAQ of the same period.

2.2 Macroeconomic variables

The monthly macroeconomic variables are collected from the Global Insight Basic Economics (GIBE) database for the period May 1961 through September 2007, and they are classified into the two categories of real activities and monetary variables. The variables of real activities include the index of Help Wanted Advertising in Newspaper (LHEL), the unemployment rate (LHUR), the industrial production index (IPS10), and the National Association of Production Management (NAPM) production index (PMP). All of these variables except PMP are used by Ang and Piazzesi (2003) to reflect the real activities. The monetary variables consist of the Federal funds rates (FYFF), nonborrowed reserves (FMRNBA), and M2 (FM2). From October 1979 to August 1982, FMRNBA was chosen as the policy target, and for the rest of the sample period FYFF was chosen as the target by the Federal Reserve.

Following Stock and Watson (2002) and Ang and Piazzesi (2003), we use principle-component analysis to estimate the common factors for each group of variables, respectively. First, we transform the series of variables to be stationary, and a code summarizing these transformations is given in the Appendix. Second, we standardize each series separately to have a mean of zero and unit variance. Finally, we represent the real activities and money variables as $X^R = (LHEL,\ \ LUHR,\ \ IPS10,\ \ PMP)$ and $X^M = (FYFF\ \ \ FMENBA,\ \ FM2)$, which gives

$$X^i(t) = \beta^i f^i(t) + \varepsilon^i(t) \quad i = R, M. \qquad (2)$$

We denote f^R and f^M as the "real" and "money" factors, respectively. The first "real" factor accounts for 57% of the variance of real variables. That means that this factor loads much information about the real variables, so we use it to measure the real activities. Similarly, the first "money" factor accounts for 48.4% of the variance of monetary variables, so we use it as a proxy for the monetary variables. The correlations between the first "real" factor and the four real variables are -0.667, 0.725, -0.798, and -0.821, respectively. As we anticipated, the signs of the correlations indicate the state of the economy in such a way that when the LHEL, IPS10, and PMP increase and the LHUR decreases the economy tends to be healthy. The correlations between the first "money" factor with the three monetary variables are 0.822, 0.74, and -0.477. Again, the signs of these correlations are intuitive: to maintain a level of total reserves consistent with the FOMC's target federal funds rate, increases in borrowed reserves must generally be met by a decrease in nonborrowed reserves, and therefore the FMRNBA and the FYFF are negatively correlated.

Table 2 reports the correlations between the macro factors and the bond volatilities, from which we can gain the preliminary information about their relationship. We find that the "real" factor is highly correlated with the bond volatilities and that the correlations are almost the same for all maturities (around 0.25), while the "money" factor is weakly correlated with bond volatility. In particular, the correlation of the "money" factor with 1- and 5-year bond volatility is much higher than that with 10- and 30-year bond volatility—e.g., -0.071 and -0.062 vs. -0.025 and -0.031. This suggests that the "real" factor might be positively and significantly related to the bond volatility of all maturities, while the "money" factor weakly and negatively affects the bond volatility and its effect is not significant for the volatility of long-term Treasury bonds. These conjectures will be further examined and confirmed in the following section.

3. Empirical Analysis

This section examines whether the volatility of Treasury-bond returns is related to the macro factors. In particular, we are interested in whether the bond volatilities of different maturities are driven by different macro factors. We first regress the bond volatility on the macro factors to see their relationship. Then we decompose the bond volatility of each maturity into the bond-market-level (or stock-market-level) volatility and maturity-dependent volatility, and then we separately regress them on the macro factors.

3.1 Preliminary analysis

We use one-month-lagged "real" and "money" factors, lagged log nominal short rate proxied by the 3-month Treasury-bill rate, and lagged volatility value to forecast the bond volatility. Because Viceira (2007) finds that the nominal short-term interest rates positively forecast the bond volatility, we also include this variable in the regression models.

Table 3 presents the estimated results for the monthly volatility of 1-, 5-, 10-, and 30-year bonds on the lagged "real" and "money" factors, the lagged log short rate, and the lagged volatility value. We find that the "real" factor significantly affects the 1-, 5-, 10-, and 30-year bond volatility and that the "money" factor is strongly related to the 1- and 5-year bond volatility. The results confirm our preliminary information that the "real" factor significantly and positively affects the bond volatilities of all maturities, while the "money" factor is only related to the bond volatility of short- and medium-term bonds, which is consistent with Viceira (2007), who finds that the nominal short rate significantly affects the stock and bond volatility up to a 60-month horizon. In our paper, we analyze the 1-month excess bond returns and find that the nominal short rate has significant impact on the volatility of 1-, 5-, and 10-year bonds, while its influence on the volatility of 30-year bonds is relatively limited.

Our findings are also consistent with the findings of Evans and Marshall (1998) and Goeij and Marquering (2006). Evans and Marshall (1998) find that a contractionary monetary policy shock induces a pronounced positive but transitory response in short-term interest rates and has a smaller effect on medium-term rates and almost no effect on long-term rates. Goeij and Marquering (2006) find that the announcements of monetary policy only affect the volatility of short-term bonds. However, this paper focuses on the connection between bond volatility with monetary variables.

3.2 Volatility decomposition based on value-weighted bond-market index

Campbell et al. (2001) decompose the stock volatility into three components—market-level, industry-level and firm-specific volatilities, and they find that these three components have different patterns over time. Following their method, we decompose the volatility of government bonds into bond-market-level and maturity-dependent volatilities.

Maturity is denoted by subscript *i*, and the excess bond return with maturity *i* is denoted by r_i^B. For simplicity, we assume that the total bond-market capitalization is calculated on the basis of 1-, 5-, 10-, and 30-year bonds. The weight of maturity *i* in the total bond market is denoted by w_i, and the excess bond-market return is $r^B = \sum_{i=1}^{4} w_i r_i^B$. In the next step, we decompose the excess bond return on each maturity by using the CAPM given by

$$r_i^B(t) = \alpha^B + \beta_i^B(t) r^B(t) + v_i(t). \qquad (3)$$

Because $r^B(t)$ and $v_i(t)$ are orthogonal, the variance of bond returns is therefore

$$Var\left(r_i^B(t)\right) = Var\left(\beta_i^B(t) r^B(t)\right) + Var\left(v_i(t)\right), \qquad (4)$$

where $Var\left(r_i^B\right), Var\left(\beta_i^B r^B\right)$, and $Var\left(v_i\right)$ are called bond variance, risk-adjusted variance of the bond-market, and maturity-dependent bond variance, respectively. To differentiate from the risk-adjusted variance of the bond market, we call $Var\left(r^B\right)$ the variance of the bond market. Moreover, we denote the bond volatility of maturity *i*, the risk-adjusted volatility of the bond-market-level, the volatility of the bond-market-level, and the maturity-dependent volatility by $\sigma_i^B \equiv \sqrt{Var\left(r_i^B\right)}$, $\sigma_i^{\beta B} \equiv \sqrt{Var\left(\beta_i^B r^B\right)}$, $\sigma^B \equiv \sqrt{Var\left(r^B\right)}$, and $\sigma_i^v \equiv \sqrt{Var\left(v_i\right)}$, respectively.

In decomposing the stock volatility, Campbell et al. (2001) assume that the CAPM beta of industry *i* with respect to the stock market is constant over time. Following their methodology, we also assume that the beta in Eq. (3) is constant over the sample period.

Picture 2 shows plots of the bond volatility of each maturity, σ_i^B , and its two components: the bond-market-level volatility, $\sigma_i^{\beta B}$, and the maturity-dependent volatility, σ_i^v. We find that the bond volatilities of 5, 10 and 30 years are much higher than that of 1 year, while the maturity-dependent volatility is embodied by the bond volatility of 1 year more effectively than by 5, 10, and 30 years. This means that the maturity-dependent volatility is more important in explaining the volatility of short-term bonds than of medium- and long-term bonds.

In the previous section, we studied the impact of “real” and “money” factors on bond volatility of each maturity. The next step is to investigate the impacts of “real” and “money” factors on the two components of total volatility: the bond-market-level volatility, σ^B, and the maturity-dependent volatility, σ_i^v.

Table 4 presents the regression results of “real” and “money” factors on the bond-market-level volatility. For all combinations of explanatory variables, the coefficients of the “real” factor are positive, and the *t*-values demonstrate that the “real” factor significantly affects the bond-market-level volatility. It is not surprising to find that the “money” factor is not significant, although it is still negatively correlated with the bond-market-level volatility. The reason is that the effect of the “money” factor on the maturity-dependent volatility has been removed leaving the effect of the “real” factor on the volatility of bond-market-level. Moreover, when the “real” factor is excluded from the regressions, the nominal short rate is still significant in affecting the bond-market-level volatility.

Table 5 presents the estimates of “real” and “money” factors on the maturity-dependent volatility. Similar to the analysis of the bond volatility of each maturity and the bond-market-level volatility, the “real” factor significantly affects the maturity-dependent volatility of all maturities, while the “money” factor only affects the maturity-dependent volatility of 1-year bonds. This is different from the results in Table 3, in which the “money” factor significantly affects the bond volatility of 1- and 5-year bonds.

Fama and French (2005), Ang and Chen (2007), and other papers suggest that the CAPM betas vary over time. Next, we will take the time-varying CAPM betas into account and reproduce the regressions of maturity-dependent volatility on the “real” and “money” factors. To calculate the time-varying CAPM betas for each month of the sample period, we regress the daily excess bond returns of maturity *i* on the daily bond-market returns like Eq. (3) to gain the series of monthly betas. Picture 3 plots the bond volatility of each maturity and its two components for the case of time-varying betas. Similar to the case for constant betas, the bond volatilities of 5-, 10-, and 30-year maturities are much higher than that of 1-year bonds, while the maturity-dependent volatility explains the bond volatility of 1 year more effectively than those of 5, 10, and 30 years. Therefore, the maturity-dependent volatility is more significant for the short-term bonds than for the medium- and long-term bonds.

Table 6 presents the estimates of “real” and “money” factors on the maturity-dependent volatility for the case of time-varying betas. The results are interesting because they are more similar to those in Table 3 than to the ones in Table 5. The “real” factor significantly affects maturity-dependent volatility of all maturities, while the “money” factor only affects the 1- and 5-year maturity-dependent volatility.

In summary, when we decompose bond volatility into market-level volatility and maturity-dependent volatility, we find that the macro factors significantly affect the maturity-dependent bond volatility. In particular, the “real” factor affects the bond-return volatility across all maturities, while the “monetary” variables are significantly related to the return volatility of short-term bonds, weakly related to the return volatility of medium-term bonds, and have no influence on the volatility of the long- term bonds.

3.3 Volatility decomposition based on value-weighted stock-market index

In the previous section, we used the CAPM to decompose the bond return into bond-market return and maturity-dependent bond return. In this section, we will calculate the CAPM beta between the bond return of each maturity and the stock-market return by employing the value-weighted stock-market index, which has been used by Viceira (2007) to proxy for the bond risk. By using the same methodology as in the previous section, we can express the bond return on each maturity *i* as follows:

$$r_i^B(t) = \alpha^S + \beta_i^S(t) r^S(t) + u_i(t), \qquad (5)$$

where r^S is the stock return in excess of the 3-month Treasury-bill rates, and

$$Var\left(r_i^B(t)\right) = Var\left(\beta_i^S(t) r^S(t)\right) + Var\left(u_i(t)\right). \qquad (6)$$

Figures 4 and 5 plot the bond volatility of each maturity and its two components of market-level and maturity-dependent volatility of bond return. Much like in Figures 2 and 3, the maturity-dependent volatility is more important in explaining the volatility of short-term bonds than that of medium- and long-term bonds.

Tables 7 and 8 illustrate the estimates of maturity-dependent volatility for the cases of constant and time-varying betas when we use the daily stock returns on the value-weighted portfolio as the market portfolio. Consistent with the results in Tables 5 and 6, the regression results in Tables 7 and 8 show that the "real" factor significantly affects the volatilities of bond return of all maturities, while the "monetary" factor is only significantly related to the return volatilities of short-term bonds.

Therefore, the results from the analysis presented in this section provide further evidence that the macro factors significantly affect the bond volatility. In particular, the “real” factor affects the bond volatility of all maturities while the monetary variables are significantly related to the volatility of short-term bonds and weakly related to the volatility of medium-term bonds.

4. Conclusion

This paper investigates the impact of macro variables on the volatility of government bond returns. We extract the “real” and “money” factors from the real activities and monetary variables, respectively. Then we examine the two factors’ impact on the daily volatility of the 1-, 5-, 10- and 30-year U.S. Treasury bonds. We find that both “real” and “money” factors significantly affect the bond return volatility. In particular, the “real” factor affects the volatility across all maturities, while the monetary variables are significantly related to the volatility of short-term bonds and weakly related to the volatility of medium-term bonds.

Through all of the above discussions and findings, we can conclude that the monetary authorities can employ macroeconomic policy to affect the volatility of Treasury bonds. At the same time, investors can improve their portfolio management by analyzing macroeconomic conditions.

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Appendix

Description of Macroeconomic Variables

This table describes the real activities and monetary variables used in our analysis. In the transformation column, lv denotes the level of the series, Δlv denotes the difference of the level, Δln denotes the first difference of logarithm, and Δ^2ln denotes the second difference of logarithm. Data on all seven series are from the Global Insight Basic Economics database.

Series	Mnemonic	Description	Trans
Real activities			
1	**LHEL**	Index of Help-Wanted Advertising in Newspapers (1967=100; SA)	Δln
2	**LHUR**	Unemployment Rate: All Workers, 16 Years & Over (%, SA)	Δlv
3	**IPS10**	Industrial Production Index – Total index	Δln
4	**PMP**	NAPM Production Index (Percent)	lv
Monetary variables			
1	**FYFF**	Interest Rate: Federal Funds (Effective) (% Per Annum, NSA)	Δlv
2	**FMRNBA**	Depository Inst Reserves: Nonborrowed, Adjusted Reserve Requirement Changes (Mil$, SA)	Δ^2ln
3	**FM2**	Money Stock: M2 (M1+O'NITE RPS, EURO$, G/P&B/D MMMFS & Sav & SM Time Dep (Bil$, SA)	Δ^2ln

Table 1

Descriptive statistics of daily excess bond returns (1961.07~2007.09)

This table presents the sample statistics of daily returns on 1-, 5-, 10-, and 30- year Treasury bonds in excess of the 3-month Treasury-bill rates. The bond returns are obtained from the CRSP Daily Treasury Fixed-term File. The 3-month Treasure-bill rates are taken from the Federal Reserve Board of Governors.

	1-year	**5-year**	**10-year**	**30-year**
Mean	0.025	0.028	0.026	0.026
Median	0.02	0.02	0.017	0.013
Std dev	0.075	0.3	0.457	0.626

Table 2

Correlations among (real and money) factors and bond return volatility (1961.07~2007.09)

This table presents the correlations between the realized volatility of 1-, 5-, 10-, and 30-year bonds and the one-month-lagged "real" and "money" factors. The correlations among bond volatilities are also presented in the following table.

	1-year	**5-year**	**10-year**	**30-year**
Real$_{-1}$	0.287	0.25	0.247	0.256
Money$_{-1}$	-0.071	-0.062	-0.025	-0.031
5-year	0.591			
10-year	0.484	0.739		
30-year	0.471	0.624	0.655	

Table 3
Estimates of money and real Factors on *bond volatility* (1961.07~2007.09)

This table presents monthly regressions of realized volatility of 1-, 5-, 10-, and 30- year bonds on the lagged "real" factor Real $_{-1}$, the lagged "money" factor Money $_{-1}$, the lagged log short rate r_{-1}, and the lagged bond volatility. The t-values are reported in the brackets.

Real $_{-1}$	Money $_{-1}$	r_{-1}	Vol_{-1}	R^2
		1-year		
0.404 (3.71)			0.51 (13.947)	0.322
	-0.457 (-3.467)		0.561 (15.982)	0.318
		1.732 (5.536)	0.474 (12.787)	0.339
0.439 (4.068)	**-0.502 (-3.847)**		0.519 (14.328)	0.337
0.345 (3.225)		**1.626 (5.211)**	0.444 (11.723)	0.351
	-0.42 (-3.265)	**1.679 (5.404)**	0.487 (13.165)	0.352
0.38 (3.574)	**-0.462 (-3.61)**	**1.556 (5.032)**	0.455 (12.096)	0.366
		5-year		
1.716 (3.875)			0.436 (11.509)	0.243
	-1.078 (-1.966)		0.473 (12.708)	0.228
		4.692 (3.729)	0.438 (11.529)	0.241
1.829 (4.123	**-1.313 (-2.415)**		0.436 (11.555)	0.25
1.494 (3.359)		**4.028 (3.191)**	0.412 (10.739)	0.256
	-1.035 (-1.909)	**4.64 (3.696)**	0.44 (11.605)	0.246
1.607 (3.605)	**-1.248 (-2.312)**	**3.916 (3.112)**	0.413 (10.794)	0.263
		10-year		
2.434 (3.622)			0.439 (11.545)	0.242
	-0.899 (-1.082)		0.475 (12.734)	0.226
		4.902 (2.604)	0.458 (12.182)	0.233
2.536 (3.757)	-1.216 (-1.473)		0.44 (11.567)	0.245
2.197 (3.229)		**3.853 (2.033)**	0.43 (11.261)	0.248
	-0.854 (-1.033)	**4.862 (2.582)**	0.459 (12.212)	0.235
2.3 (3.364)	-1.152 (-1.398)	**3.749 (1.978)**	0.431 (11.286)	0.25
		30-year		
1.981 (2.732)			0.589 (17.064)	0.386
	-1.078 (-1.219)		0.615 (18.447)	0.38
		3.742 (1.868)	0.606 (18.043)	0.382
2.099 (2.883)	-1.35 (-1.528)		0.588 (17.061)	0.389
1.798 (2.444)		2.876 (1.42)	0.585 (16.901)	0.388
	-1.049 (-1.189)	3.701 (1.848)	0.607 (18.068)	0.383
1.92 (2.596)	-1.306 (-1.478)	2.765 (1.365)	0.584 (16.9)	0.391

Table 4
Estimate of money and real factors on *bond-market-level volatility*

This table presents monthly regressions of bond-market-level volatility on the lagged "real" factor Real $_{-1}$, the lagged "money" factor Money $_{-1}$, the lagged log short rate r_{-1}, and the lagged bond volatility. The t-values are reported in the brackets.

Real $_{-1}$	**Money $_{-1}$**	**r_{-1}**	**Vol_{-1}**	**R^2**
1.082 (2.946)			0.589 (17.21)	0.387
	-0.508 (-1.124)		0.615 (18.411)	0.379
		2.317 (2.258)	0.601 (17.834)	0.383
1.139 (3.088)	-0.656 (-1.455)		0.588 (17.21)	0.389
0.968 (2.603)		1.857 (1.792)	0.582 (16.902)	0.39
	-0.489 (-1.087)	**2.297 (2.238)**	0.602 (17.784)	0.384
1.026 (2.744)	-0.627 (-1.392)	1.804 (1.741)	0.581 (16.907)	0.392

Table 5
Estimates of money and real factors on *maturity-dependent volatility* with *value-weighted bond-market index* and *constant beta*

This table presents monthly regressions of maturity-dependent volatility (for the case of value-weighted bond-market index and constant CAPM betas) on the lagged "real" factor Real $_{-1}$, the lagged "money" factor Money $_{-1}$, the lagged log short rate r_{-1}, and the lagged bond volatility. The t-values are reported in the brackets.

Real $_{-1}$	Money $_{-1}$	r_{-1}	Vol$_{-1}$	R^2
		1-year		
0.379 (3.882)			0.413 (10.632)	0.23
	-0.27 (-2.28)		0.464 (12.338)	0.216
		1.711 (6.131)	0.369 (9.437)	0.259
0.401 (4.117)	**-0.314 (-2.658)**		0.419 (10.828)	0.239
0.318 (3.334)		**1.609 (5.783)**	0.338 (8.458)	0.273
	-0.237 (-2.043)	**1.682 (6.037)**	0.377 (9.621)	0.264
0.339 (3.553)	**-0.274 (-2.383)**	**1.569 (5.651)**	0.345 (8.65)	0.281
		5-year		
0.945 (4.103)			0.263 (6.439)	0.117
	-0.292 (-1.018)		0.302 (7.491)	0.092
		3.167 (4.851)	0.252 (6.184)	0.127
0.98 (4.234)	-0.416 (-1.463)		0.264 (6.458)	0.121
0.79 (3.441)		**2.814 (4.297)**	0.226 (5.494)	0.146
	-0.26 (-0.923)	**3.153 (4.827)**	0.254 (6.213)	0.129
0.823 (3.565)	-0.368 (-1.311)	**2.779 (4.243)**	0.227 (5.519)	0.148
		10-year		
1.474 (3.888)			0.226 (5.461)	0.092
	0.533 (1.125)		0.258 (6.32)	0.07
		4.54 (4.233)	0.223 (5.417)	0.097
1.445 (3.789)	0.349 (0.743)		0.225 (5.451)	0.093
1.242 (3.266)		**3.954 (3.667)**	0.199 (4.795)	0.114
	0.577 (1.238)	**4.57 (4.262)**	0.221 (5.371)	0.099
1.205 (3.149)	0.419 (0.9)	**3.993 (3.7)**	0.198 (4.779)	0.115
		30-year		
1.623 (3.003)			0.158 (3.773)	0.048
	-0.38 (-0.56)		0.181 (4.345)	0.033
		3.417 (2.244)	0.171 (4.099)	0.041
1.673 (3.079)	-0.597 (-0.884)		0.159 (3.776)	0.049
1.444 (2.628)		2.648 (1.716)	0.153 (3.651)	0.053
	-0.352 (-0.522)	**3.403 (2.233)**	0.171 (4.107)	0.042
1.494 (2.702)	-0.553 (-0.82)	2.599 (1.683)	0.154 (3.656)	0.054

Table 6
Estimates of money and real factors on *maturity-dependent volatility* with *value-weighted bond-market index* and *time-varying beta*

This table presents monthly regressions of maturity-dependent volatility (for the case of value-weighted bond-market index and time-varying CAPM betas) on the lagged "real" factor Real $_{-1}$, the lagged "money" factor Money $_{-1}$, the lagged bond volatility, and the lagged log short rate r_{-1}. The t-values are reported in the brackets.

Real $_{-1}$	Money $_{-1}$	r_{-1}	Vol_{-1}	R^2
		1-year		
0.307 (3.668)			0.457 (12.047)	0.266
	-0.273 (-2.678)		0.511 (13.898)	0.258
		1.446 (6.041)	0.412 (10.75)	0.295
0.325 (3.91)	**-0.303 (-3)**		0.468 (12.358)	0.278
0.257 (3.149)		**1.367 (5.725)**	0.382 (9.749)	0.307
	-0.235 (-2.368)	**1.41 (5.899)**	0.425 (11.015)	0.302
0.275 (3.376)	**-0.263 (-2.663)**	**1.321 (5.545)**	0.394 (10.038)	0.316
		5-year		
0.597 (4.732)			0.486 (13.193)	0.319
	-0.425 (-2.763)		0.55 (15.459)	0.301
		1.55 (4.367)	0.496 (13.594)	0.315
0.63 (5.018)	**-0.487 (-3.222)**		0.492 (13.488)	0.332
0.535 (4.259)		**1.358 (3.854)**	0.452 (12.109)	0.337
	-0.397 (-2.615)	**1.51 (4.271)**	0.506 (13.864)	0.324
0.569 (4.542)	**-0.456 (-3.05)**	**1.3 (3.709)**	0.461 (12.398)	0.348
		10-year		
0.67 (3.678)			0.62 (18.76)	0.442
	0.283 (1.27)		0.653 (20.417)	0.43
		2.716 (5.129)	0.589 (17.397)	0.454
0.653 (3.566)	0.203 (0.918)		0.62 (18.75)	0.443
0.579 (3.218)		**2.536 (4.8)**	0.563 (16.314)	0.464
	0.319 (1.464)	**2.741 (5.178)**	0.586 (17.326)	0.456
0.557 (3.082)	0.249 (1.144)	**2.562 (4.846)**	0.562 (16.29)	0.466
		30-year		
1.15 (4.007)			0.377 (9.557)	0.199
	-0.569 (-1.611)		0.426 (11.062)	0.181
		2.926 (3.648)	0.391 (10.065)	0.196
1.201 (4.18)	-0.7 (-2)		0.381 (9.672)	0.206
1.011 (3.508)		**2.488 (3.095)**	0.357 (8.999)	0.213
	-0.528 (-1.511)	**2.887 (3.601)**	0.396 (10.168)	0.199
1.063 (3.679)	-0.65 (-1.872)	**2.418 (3.011)**	0.361 (9.113)	0.218

Table 7
Estimates of money and real factors on *maturity-dependent volatility* with *value-weighted stock-market index* and *constant beta*

This table presents monthly regressions of maturity-dependent volatility (for the case of value-weighted stock-market index and constant CAPM betas) on the lagged "real" factor Real $_{-1}$, the lagged "money" factor Money $_{-1}$, the lagged log short rate r_{-1}, and the lagged bond volatility. The t-values are reported in the brackets.

Real $_{-1}$	**Money $_{-1}$**	**r_{-1}**	**Vol_{-1}**	**R^2**
		1-year		
0.405 (3.723)			0.507 (13.834)	0.317
	-0.453 (-3.436)		0.559 (15.88)	0.315
		1.68 (5.389)	0.476 (12.853)	0.335
0.44 (4.075)	**-0.497 (-3.814)**		0.516 (14.213)	0.335
0.347 (3.236)		**1.571 (5.053)**	0.446 (11.765)	0.347
	-0.418 (-3.239)	**1.628 (5.259)**	0.488 (13.229)	0.347
0.381 (3.58)	**-0.459 (-3.583)**	**1.503 (4.876)**	0.456 (12.136)	0.362
		5-year		
1.705 (3.846)			0.431 (11.306)	0.237
	-1.068 (-1.946)		0.468 (12.523)	0.222
		4.186 (3.341)	0.439 (11.58)	0.232
1.815 (4.088)	**-1.298 (-2.385)**		0.431 (11.361)	0.245
1.504 (3.367)		**3.499 (2.781)**	0.413 (10.744)	0.248
	-1.029 (-1.891)	**4.135 (3.207)**	0.442 (11.662)	0.237
1.615 (3.608)	**-1.241 (-2.291)**	**3.387 (2.7)**	0.413 (10.807)	0.255
		10-year		
2.423 (3.603)			0.432 (11.301)	0.236
	-0.85 (-1.023)		0.468 (12.512)	0.22
		4.056 (2.162)	0.457 (12.145)	0.225
2.519 (3.729)	-1.16 (-1.406)		0.433 (11328)	0.239
2.232 (3.27)		2.95 (1.561)	0.427 (11.154)	0.239
	-0.814 (-0.983)	**4.018 (2.142)**	0.458 (12.175)	0.226
2.33 (3.397)	-1.111 (-1.347)	2.85 (1.508)	0.428 (11.182)	0.242
		30-year		
1.932 (2.656)			0.58 (16.598)	0.374
	-0.974 (-1.1)		0.606 (17.992)	0.368
		2.692 (1.348)	0.602 (17.804)	0.368
2.04 (2.791)	-1.235 (-1.396)		0.579 (16.597)	0.376
1.81 (2.444)		1.76 (0.87)	0.579 (16.562)	0.375
	-0.954 (-1.078)	2.656 (1.33)	0.603 (17.826)	0.37
1.923 (2.582)	-1.208 (-1.363)	1.656 (0.818)	0.578 (16.562)	0.377

Table 8
Estimates of money and real factors on *maturity-dependent volatility* with *value-weighted stock-market index* and *time-varying beta*

This table presents monthly regressions of maturity-dependent volatility (for the case of value-weighted stock-market index and time-varying CAPM betas) on the lagged "real" factor Real $_{-1}$, the lagged "money" factor Money $_{-1}$, the lagged log short rate r_{-1}, and the lagged bond volatility. The t-values are reported in the brackets.

Real $_{-1}$	Money $_{-1}$	r_{-1}	Vol_{-1}	R^2
		1-year		
0.405 (3.867)			0.483 (12.971)	0.295
	-0.446 (-3.507)		0.537 (15.004)	0.291
		1.766 (5.862)	0.442 (11.695)	0.318
0.438 (4.224)	**-0.489 (-3.896)**		0.493 (13.375)	0.313
0.345 (3.367)		**1.66 (5.531)**	0.411 (10.648)	0.331
	-0.406 (-3.276)	**1.711 (5.718)**	0.456 (12.089)	0.331
0.378 (3.714)	**-0.446 (-3.631)**	**1.589 (5.34)**	0.423 (11.042)	0.347
		5-year		
1.674 (3.962)			0.406 (10.546)	0.217
	-1.115 (-2.128)		0.444 (11.724)	0.201
		4.926 (4.091)	0.402 (10.391)	0.218
1.787 (4.226)	**-1.341 (-2.582)**		0.407 (10.619)	0.226
1.441 (3.403)		**4.288 (3.551)**	0.377 (9.654)	0.234
	-1.065 (-2.059)	**4.867 (4.052)**	0.405 (10.49)	0.224
1.554 (3.664)	**-1.269 (-2.465)**	**4.168 (3.465)**	0.378 (9.736)	0.243
		10-year		
2.42 (3.916)			0.411 (10.665)	0.222
	-0.927 (-1.21)		0.45 (11.876)	0.202
		5.027 (2.893)	0.428 (11.227)	0.212
2.52 (4.064)	-1.234 (-1.625)		0.412 (10.711)	0.225
2.178 (3.487)		**3.997 (2.29)**	0.399 (10.318)	0.229
	-0.876 (-1.151)	**4.98 (2.867)**	0.431 (11.273)	0.214
2.279 (3.633)	-1.165 (-1.538)	**3.887 (2.228)**	0.401 (10.366)	0.232
		30-year		
2.254 (3.281)			0.53 (14.698)	0.33
	-1.091 (-1.299)		0.564 (16.128)	0.319
		3.884 (2.041)	0.553 (15.709)	0.322
2.372 (3.44)	-1.388 (-1.659)		0.53 (14.722)	0.333
2.071 (2.971)		2.886 (1.594)	0.526 (14.537)	0.332
	-1.059 (-1.263)	**3.837 (2.018)**	0.555 (15.75)	0.324
2.192 (3.131)	-1.342 (-1.604)	2.769 (1.444)	0.526 (14.563)	0.335

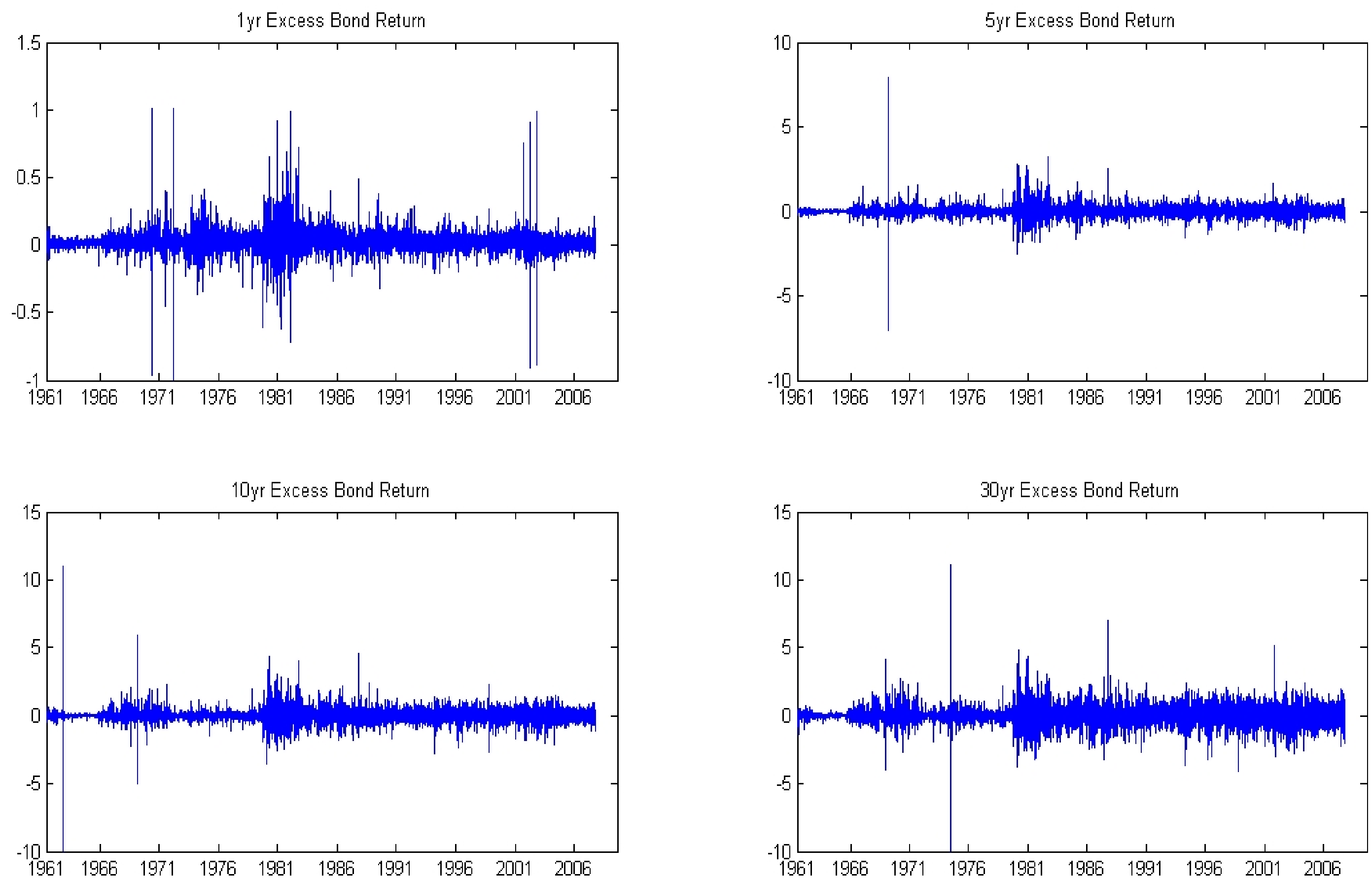

Figure 1: Daily excess returns on 1-, 5-, 10-, and 30-year Treasury bonds

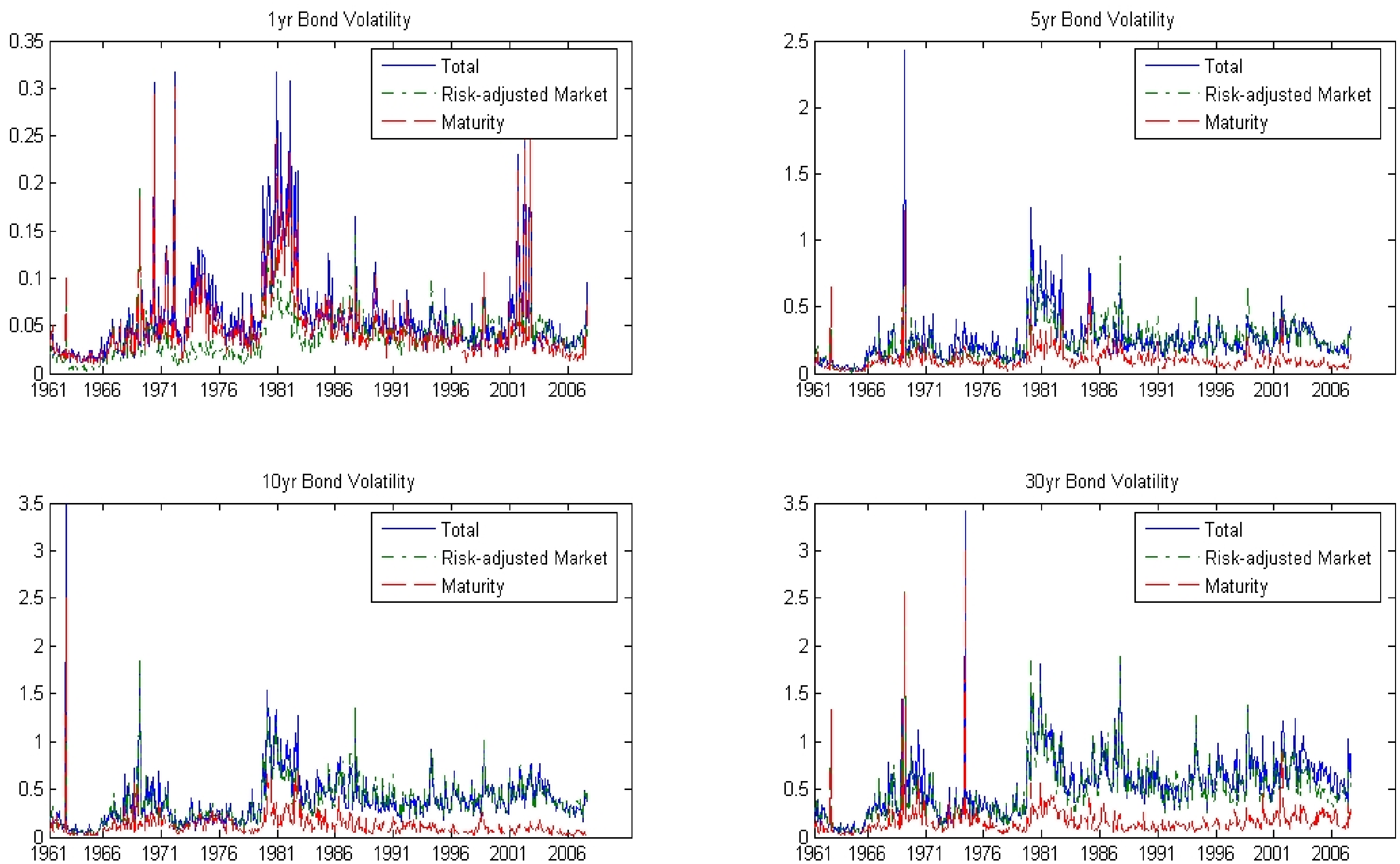

Figure 2: Volatility decomposition with value-weighted bond-market index and constant beta

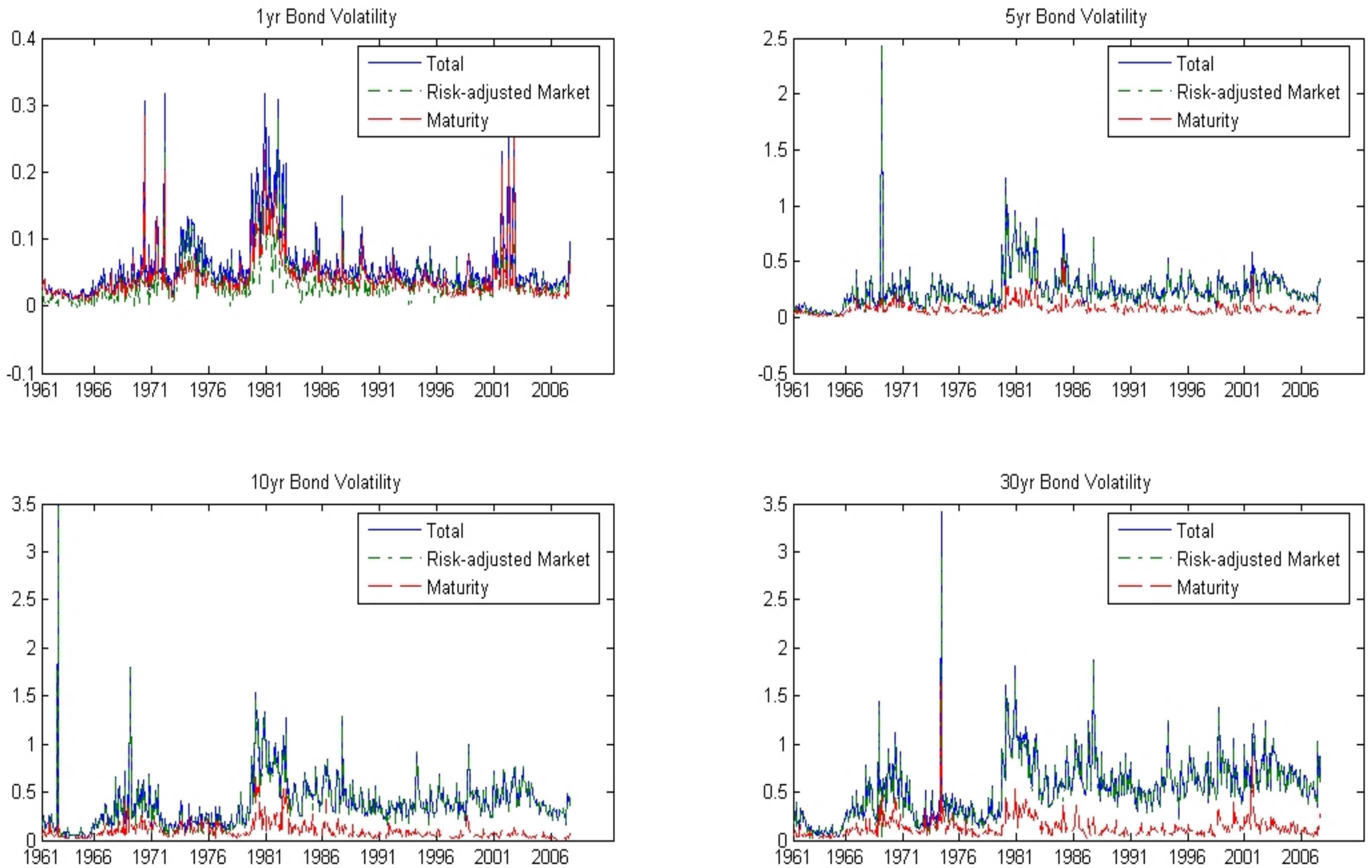

Figure 3: Volatility decomposition with value-weighted bond-market index and time-varying beta

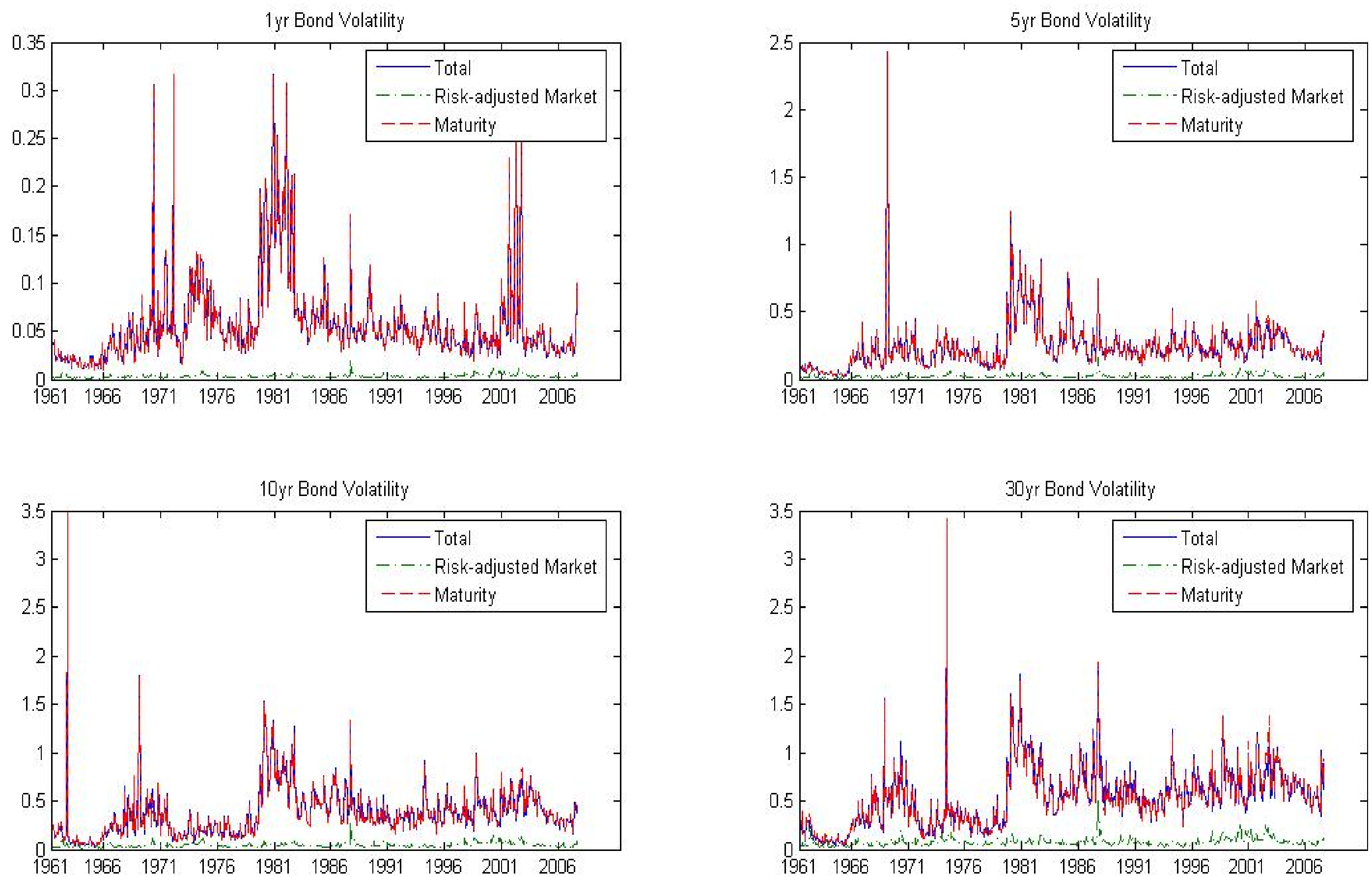

Figure 4: Volatility decomposition with value-weighted stock-market index and constant beta

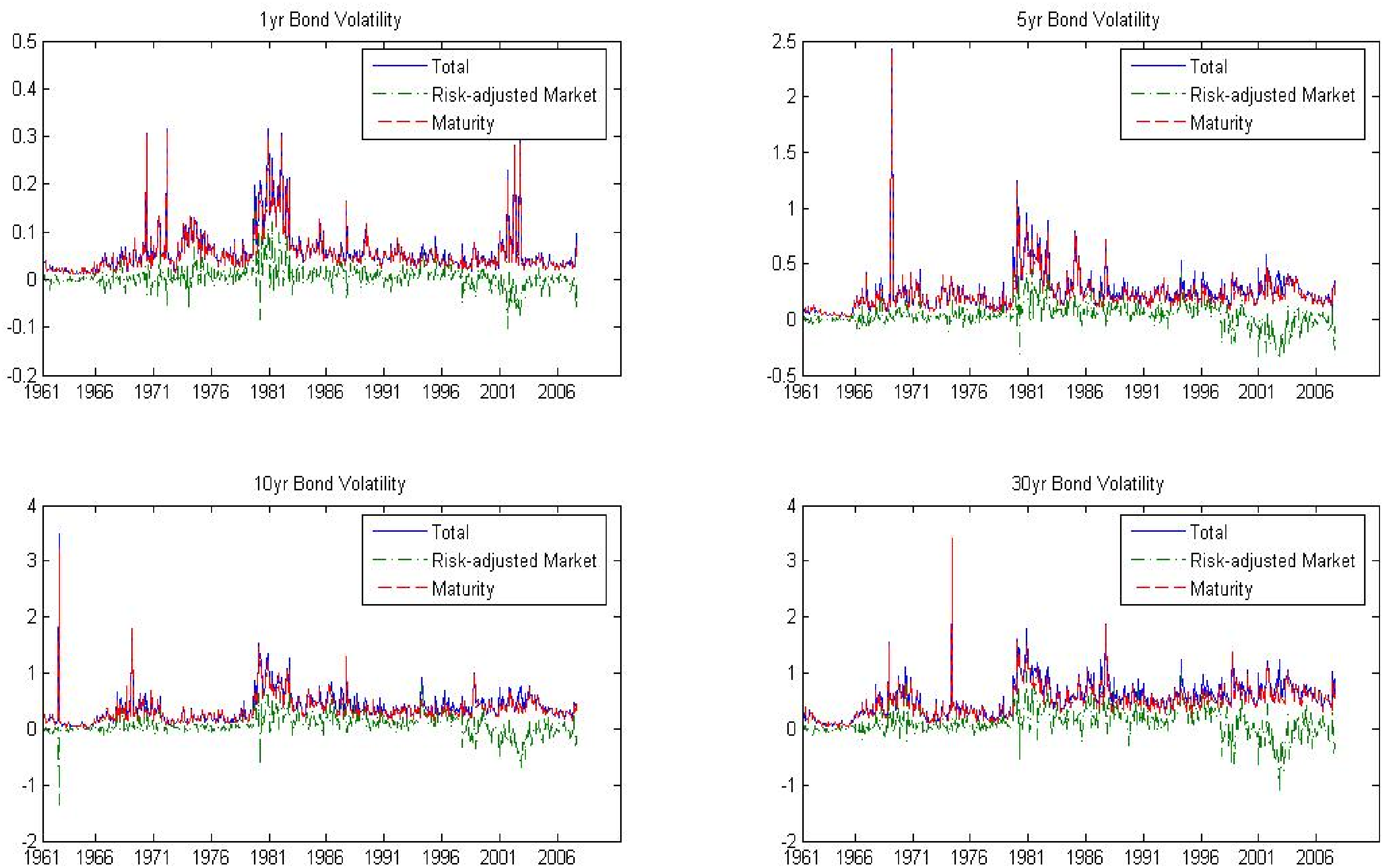

Figure 5: Volatility decomposition with value-weighted stock-market index and time-varying beta