Are the Mortgage and Capital Markets Fully Integrated?
An Fractional Heteroscedastic Cointegration Analysis

Keshab Shrestha, Howard E. Thompson and Wing-Keung Wong

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Abstract
In this article, monthly data on 30-year fixed-rate conventional mortgage rate and 10-year constant maturity Treasury yield for the period from April, 1971 to December, 2003 is used to test for the integration of the mortgage market with the broader capital markets. The article uses a more general concept of fractional heteroscedastic cointegration. Furthermore, an asymmetric error-correction model is used to model and test the possible non-linear relationship between the two series. The evidence indicates the presence of fractional heteroscedastic cointegration for the whole period as well as for both pre-deregulation (1971:04 – 1982:12) and post-deregulation (1983:01 – 2003:12) periods. The evidence from the asymmetric error-correction model indicates that the upward adjustment of the mortgage rate to disequilibrium is faster than its downward adjustment.

Keywords: Fractional Cointegration, GARCH, Asymmetric Error-Correction Model, Mortgage Market, Capital Market.

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1. Introduction

Efficiency of financial markets has been one of the important research areas in finance. In efficient financial markets, prices reflect all available information and any new information will be rapidly reflected in the prices. The efficiency of financial markets also implies that markets for different securities must be integrated so long as they are influenced by the same set of common factors. Therefore, the markets for mortgage and other debt securities are expected to be integrated under market efficiency. Specifically, the mortgage interest rate and yield on U.S. Treasuries are expected be closely related and are expected to move together (See Kau, Keenan, Muller, and Epperson (1987) and Titman and Torous (1989) for some theoretical justifications).

Therefore, it is not surprising that the relationship between mortgage rates and capital market rates has been the subject of several studies since the 1960s (see, for example, Klaman (1961), Guttentag and Beck (1970), Hillard and Haney (1982), Haney (1988), Roth (1988), Hendershott and Van Order (1989) Billinsley, Bonomo and Ferris (1992), Devaney, Pickerill and Krause (1992), Goebel and Ma (1993), Rudolph and Griffith (1997), Allen, Rutherford and Wiley (1999), and Sa-Aadu, Shilling and Wang (2000)). Even though, theoretically the mortgage market and the capital market is expected to be integrated under market efficiency, due to the presence of restrictive regulations and market imperfections like transaction costs and lack of trading volume, these two markets may be less than fully integrated. Therefore, many of the existing studies divide the sample period to pre-deregulation and post-deregulation with the cutoff year being, depending on the individual study, sometime in the 1980s. Then, separate analyses are performed to see if the markets were integrated in each sub-period as well as whole period. Examples of the deregulation include the Depository Deregulation and Monetary Control Act of 1980 as well as the Garn-St. Germain Act of 1982.

In terms of methodology, there are quite a few techniques being used to analyze the empirical relationship between the mortgage and capital market rates. For example,
Klaman (1961) uses cyclical peaks and troughs to identify the lead-lag relationship between the two rates and finds that the mortgage rates lagged the capital market rates by approximately four quarters during the 1947-1956 period. Guttentag and Beck (1970), using similar methods, find the lag length to vary from four to seven months during the 1954-1960 period.

Haney (1988), on the other hand, uses cross-spectral analysis to find the lead-lag relationship where the lead-lag relationship is given by the slope of the phase diagram. For the period from January 1973 to December 1981, Haney (1988) finds that the primary mortgage rate lagged the yield on U.S. Treasury by approximately three weeks. However, the secondary mortgage rate is found to lag the Treasury rate by only one day which he considers to be fully integrated. One attractive feature of cross-spectral analysis is that the method is model free and the method can be applied to situations where the series are weakly or wide-sense stationary.

However, the spectral analysis may not, in general, lead to as clear results as the ones provided by model based analysis. Furthermore, the spectral analysis will not be applicable when the series are non-stationary. Therefore, some of the studies use model based methods. Roth (1988), for example, uses linear model and finds the mortgage rates to be more responsive to capital market rate during post-1980 period compared to pre-1980 period. He attributes this phenomenon to the growth of the secondary mortgage market during 1980s. Roth (1988) also computes the correlation coefficient between the two rates for each year starting from 1970 to 1987 and finds the correlation coefficients for years 1981 and before to be insignificant whereas the correlation coefficients for years 1982 and later to be significant.

In recent years, some researchers have used the concept of cointegration to analyze the integration of mortgage market with capital market. This is the correct method to be used if the individual series are random walk series. For example, Devaney, Pickerill and Krause (1992) use Engle and Granger’s (1987) two-step method to test for the cointegration between the conventional mortgage rate and yield on the 10-year
Treasury note. They find that the two rates were not cointegrated during the pre-deregulation period (1970-1982). However, the evidence indicates that the two rates were cointegrated during the post-deregulation period (1983-1987). Similarly, Goebel and Ma (1993) use the multivariate cointegration method developed by Johansen (1988) as well as Engle and Yoo (1987) to test for the cointegration between the mortgage rate, 10-year Treasury yield and Level of Mortgage Credit measured by total mortgage loans for new or existing units originated by FHLBB or Office of Thrift Supervision member institutions. They use the monthly average of contract rate on new commitments to represent the mortgage rate and cover the period from January 1970 to October 1991. They also find the evidence of no cointegration for pre-1980 period, but cointegration for post-1980 period.

However, more recent studies have shown the existence of cointegration during pre-deregulation as well as post-deregulation period. For example, Rudolph and Griffith (1997) consider the period from April 1963 to December 1993 and find the mortgage rate to be cointegrated with the capital market rate for the sub-periods 1963:04 – 1968:12, 1969:01 – 1979:12 and 1980:01 – 1993:12. They also find cointegration for the whole period. Allen, Rutherford and Wiley (1999) and Sa-Aadu, Shilling and Wang (2000) also find cointegration during the pre-deregulation as well as post-deregulation periods. The difference in results for the pre-deregulation period can be explained by the difference in methodologies, yield series as well as time period used. Nothaft and Freud (2003) conclude that the integration of the multifamily mortgage into the broader capital markets helped to create new sources of credit as some traditional portfolio investors reduced their share of loan holdings and lead to a more stable spread relative to a benchmark security and a lower level of mortgage rates.

Based on the discussion of the existing literature presented above, it is clear that there exists strong evidence which shows that the mortgage market has been integrated with the capital market during the post-deregulation period. There also seems to be weaker evidence indicating that the mortgage market was integrated with the capital market even before the mortgage market was deregulated. Therefore, as implied by
market efficiency, the mortgage rate reacts to changes in yields in the broader capital markets.

Specifically, the evidence of cointegration of the mortgage rate with the Treasury rate implies that changes in the Treasury rate will be followed by the changes in the mortgage rate. Furthermore, the rate change in the current period should reflect the disequilibrium in the last period through an error-correction term. One key question in this regard is whether the response of the mortgage rate to the changes in Treasury rate is asymmetric, i.e., whether the mortgage rate follows the decrease in Treasury rate as fast as it follows the increase in Treasury rate. This issue is to some extent has been neglected.

The main purpose of this article is to analyze the possible asymmetric response of the mortgage rate to the disequilibrium in the long-run relationship. This analysis is done using an asymmetric version of error-correction model (ECM) which allows the computation of short-run pass-through, long-run pass-through as well as mean-lag effects. The article contributes to the existing literature in the following ways. Firstly, as mentioned, it uses the asymmetric version of the ECM model to analyze the relationship between the mortgage rate and Treasury rate. Secondly, in addition to the usual cointegration model, a more general heteroscedastic cointegration model is used. Thirdly, the concept of fractional integration and cointegration are used in the analysis in addition to the usual concept of integer integration and cointegration. Finally, the paper uses a more recent data up to December 2003. By doing so, it is hoped to capture the more recent phenomenon in the analysis.

2. Methodology

Granger (1981) first introduced the concept of cointegration that was later developed formally by Engle and Granger (1987).1 Even though there is an elaborate definition of

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1 See Hamilton (1994) for a detailed examination of the literature on cointegration.
cointegration, in most of the applied works it means a stationary linear relationship among non-stationary series. However, the conventional use of the cointegration analysis means integer cointegration instead of fractional cointegration. In the following subsection, we will briefly describe the concept of fractional cointegration. Additional information on this concept can be found in Cheung and Lai (1993), Baillie and Bollerslev (1994), Baillie (1996) and Shrestha (1999).

2.1 Fractional Integration and Cointegration

The fractionally integrated time series process was independently proposed by Granger and Joyeux (1980) and Hosking (1981). This process can be expressed by the following stochastic equation:

\[(1 - L)^d X_t = u_t\] (1)

where \(u_t\) is a stationary process, \(d\) is a real number and \(L\) is a lag operator, i.e., \(LX_t = X_{t-1}\). In general, the process \(X_t\) is called a \(I(d)\) (integrated of order \(d\)) process. When \(d = 1\), \(X_t\) is known as unit-root (\(I(1)\) or random walk) process. On the other hand, when \(d = 0\), the process \(X_t\) is said to be \(I(0)\) process which is also commonly known as stationary process. However, the condition that \(d = 0\) is only a sufficient condition for the process \(X_t\) to be stationary. In fact, the process is stationary if \(d < 0.5\). When \(d < 1\), the process \(X_t\) is said to be a mean-reverting process in the sense that its infinite cumulative impulse response is zero, implying no long-run impact of an innovation on \(X_t\) (see Cheung and Lai (1993)). An \(I(d)\) process, where \(d\) is allowed to be fraction, is known as fractionally integrated process.

Now, based on the condition for stationarity of a fractionally integrated process discussed above, fractional cointegration can be defined. For a set of non-stationary processes, if there exists a linear combination which is fractionally integrated \(I(d)\) with

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2 See Baillie (1996) for a comprehensive discussion on the long memory (fractional) process.
3 The conventional unit-root test or stationarity test tests for \(I(1)\) against \(I(0)\). It is important to note that stationarity does not require \(d\) to be zero.
$d < 1$, then the non-stationary processes are said to be fractionally cointegrated. For example, consider the following linear regression between two non-stationary processes $X_t$ and $Y_t$,

$$Y_t = \alpha_0 + \alpha_1 X_t + z_t. \quad (2)$$

If there exists two parameters $\alpha_0$ and $\alpha_1$ such that the residual process $z_t$ in equation (2) is fractionally integrated with fractional parameter $d$ less than 1 (i.e., $d < 1$ or mean-reverting), then the two processes $Y_t$ and $X_t$ are said to be fractionally cointegrated. Therefore, the test of fractional integration involves a two-step procedure. In the first step, the regression equation (2) is estimated. Then, in the second step, the fractional parameter of its residual process is estimated and tested for the condition that $d < 1$. This is the definition used by Cheung and Lai (1993), and Baillie and Bollerslev (1994). However, it is important to note that this definition includes a non-stationary relation in the definition of fractional cointegration so long as the relationship is mean-reverting. For example, let us suppose that $z_t$ in equation (2) is an $I(d)$ process, i.e., $I(d)$ with $d = 0.75$. Then, according to the above definition, $Y_t$ and $X_t$ are said to be fractionally cointegrated even though their linear relationship ($Y_t - \alpha_0 - \alpha_1 X_t$) is not stationary due to the fact that $d$ is greater than 0.5. Therefore, Shrestha (1999) considers the two processes to be fractionally cointegrated if $z_t$ is an $I(d)$ process with $d < 0.5$. In this article, both definitions are used.

The estimation of fractional parameter $d$ can be performed using the methodology suggested by Sowell (1992) and Beran (1995). In this article, the estimation is performed using FARIMA in S-Plus.

### 2.2 Heteroscedastic Fractional Cointegration

Since most of the financial series are found to have heteroscedastic, there is a possibility that the equilibrium relationship between the two series $X_t$ and $Y_t$ is a heteroscedastic
relationship, i.e., \( z_t \) in equation (2) is a heteroscedastic process instead of usual homoscedastic process. In other words, the equilibrium linear relationship between the two series is given by the following cointegrating regression, which is the usual GARCH\((p,q)\) model:

\[
y_t = \gamma_0 + \gamma_1 x_t + z_t, \quad z_t | \Omega_{t-1} \sim N(0, h_t) \quad (3)
\]

\[
h_t = \omega_0 + \sum_{i=1}^{p} \omega_i h_{t-i} + \sum_{i=1}^{q} \theta_i z_{t-i}^2. \quad (4)
\]

In the empirical analysis, the existence of heteroscedastic residual can be tested using the LM test suggested by Engle (1982). The LM test involves the estimation of the following autoregressive model in residual of the cointegrating equation (2),

\[
z_t^2 = a_0 + a_1 z_{t-1}^2 + \cdots + a_n z_{t-n}^2 + \nu_t. \quad (5)
\]

Under the null hypothesis that there is no ARCH effects, i.e., \( a_0 = a_1 = \ldots = a_n = 0 \), the LM test statistic is given by

\[
LM = T \cdot R^2
\]

where \( T \) is the sample size and \( R^2 \) is the coefficient of determination computed from regression equation (5). The LM statistic has asymptotic Chi-squared distribution with \( n \) degrees of freedom. Once the cointegrating relation is estimated using the GARCH model, the heteroscedastic fractional cointegration can be tested by estimating the fractional parameter of the standardized residual \( \hat{z}_t / \sqrt{\hat{h}_t} \). If the fractional parameter of the standardized residual is less than 1.0, then the two series are considered as fractionally cointegrated with heteroscedasticity.
2.3 Asymmetric Error-Correction Model

If the two series \(Y_t\) and \(X_t\) are fractionally cointegrated with the long-run cointegrating relationship given by in equation (3), the residual series \(z_t\) is considered as a disequilibrium series which represents the deviation from the long-run equilibrium. Therefore, the following asymmetric error-correction model can be used to estimate the response of \(Y_t\) to change in \(X_t\) (see Chong, Liu and Shrestha (2006)),

\[
\Delta Y_t = \delta_1 \Delta X_t + \delta_2 \lambda_{t-1} z_{t-1} + \delta_3 (1 - \lambda_{t-1}) z_{t-1} + \eta_t \tag{6}
\]

where the indicator series \(\lambda_t\) is defined as follows:

\[
\lambda_t = \begin{cases} 
1 & z_t > 0 \\
0 & z_t \leq 0
\end{cases} \tag{7}
\]

The parameter \(\delta_1\) is sometimes known as short-run pass-through which represents fraction of change in \(X_t\) that will be reflected in change in \(Y_t\) during the same period. The parameters \(\delta_2\) and \(\delta_3\) are speed of adjustments which represent how much of the disequilibrium in the last period gets corrected in the current period. The model allows different speeds of adjustments depending on whether \(Y_{t-1}\) was above long-run equilibrium (\(\delta_2\)) or below equilibrium (\(\delta_3\)) during the last period. Using the Wald test, the difference in speed of adjustment can easily be tested. The Wald statistic used to test the null hypothesis of \(\delta_2 = \delta_3\) has Chi-squared distribution with one degree of freedom.

For example, let \(Y_t\) denote the conventional mortgage rate and \(X_t\) denote the yield on Treasury. Then, if the mortgage rates are adjusted upward faster than downward, this implies that \(|\delta_3| > |\delta_2|\).\(^4\) Furthermore, the asymmetric error-correction model also allows the computation of mean adjustment lags (Hendry, 1995) for the case when the mortgage rate is above its equilibrium value (denoted by \(MAL^+\)) as well as the

\(^4\) Note that \(Y_{t-1}\) to be above its equilibrium value corresponds to \(z_{t-1}\) to be positive. Therefore, the correct adjustment requires \(\Delta Y_t\) to be negative. Thus, we expect the sign of both \(\delta_2\) and \(\delta_3\) to be negative.
case when it is below its equilibrium value (denoted by $MAL^-$) which are defined as follows:

$$MAL^- = (1 - \delta_1) \lvert \delta_2 \rvert$$  \hspace{1cm} (8)

$$MAL^- = (1 - \delta_1) \lvert \delta_3 \rvert.$$  \hspace{1cm} (9)

3. Empirical Results

In this paper, monthly data for the period from April 1971 to December 2003 is used. The 30-year fixed conventional mortgage rate from Federal Reserve (Release H.15) is used to represent the mortgage rate. The constant maturity 10-year Treasury yield also from Federal Reserve is used to represent the broader capital market rate. This is the same series used by many of the studies mentioned before. The use of the 10-year Treasury rate instead of 30-year Treasury rate has been justified due to the prepayment feature associated with mortgages. To see the effect of deregulation, the whole sample is divided into two sub-samples: 1971:04 – 1982:12 (pre-deregulation period) and 1983:01 – 2003:12 (post-deregulation period).

The summary statistics are presented in Table 1. The mortgage rate for the whole period is on the average about 9.57 percent whereas the Treasury yield is on the average 7.89 percent. The mortgage rate is seen to be a little more volatile compared to the Treasury rate. The unit-root test statistics as well as the estimates of the fractional parameters are summarized in Table 2. Both ADF and PP statistics as well as the estimate of fractional parameters indicate that both series are non-stationary for the whole sample period as well as for both sub-periods. The first differences of both series are found to be stationary.\(^5\)

\[\text{Please insert Table 1 and Table 2 here}\]

\(^5\) For simplicity, we skip reporting the results which are available on request.
Since both the series are found to be unit-root based on ADF and PP tests, the Johansen test is performed and the results are reported in Table 3. It is clear from Table 3 that both the Trace and Lambda Max statistics indicate the existence of one cointegrating vector. This is true for the whole period as well as for both sub-periods. However, the LM statistics reported in the last column of Table 4 are highly significant with their p-values (reported inside the parentheses) to be less than 1 percent. This clearly indicates possibility of heteroscedastic cointegrating relationship.6

Please insert Table 3 here

Thereafter, in order to accommodate the heteroscedasticity, a GARCH(1,1) model is estimated. The results of the two-step cointegration test on the standardized residuals are reported in Table 4. The estimates of the parameters of the mean and variance equations of the GARCH(1,1) model are presented in Table 5. It is interesting to note that the sum of the autoregressive and moving average parameters (ω_i + θ_i) in the variance equation is greater than 1, implying that the cointegrating relation follows a so-called integrated GARCH (IGARCH) process. However, as shown by Lumsdaine (1996), this does not cause any estimation difficulty and the estimators are still asymptotically consistent and normal.

Please insert Table 4 and Table 5 here

As pointed out earlier, for the existence of heteroscedastic cointegration, the standardized residual must be stationary or at least mean-reverting, i.e., the fractional parameter must be significantly less than 1. The results of the ADF and PP tests and the estimate of the fractional parameter are reported in Table 4. For the purpose of comparison, the ADF and PP tests as well as the fractional parameter of the homoscedastic residuals (residuals from equation (2)) are also reported in Table 4. As the estimates of the fractional parameter for the whole sample as well as for both sub-

6 Due to the presence of heteroscedasticity, both the Johansen method as well as the conventional Engle-Granger method will not be valid. Therefore, in this article, the stationarity test is performed on the standardized residual of the GARCH model.
samples are significantly less than 1, using the definition of Baillie and Bollerslev (1994), it can be said that the mortgage market and Treasury market were fractionally cointegrated during the post-deregulation as well as pre-deregulation periods. These results, which are obtained here using a more general model, are consistent with the ones obtained by Rudolph and Griffith (1997), Allen, Rutherford and Wiley (1999), and Saa-Aadu, Shilling and Wang (2000).

After having established a long-run cointegrating relationship between the mortgage market and the Treasury market, we come to the main focus of the article – the asymmetric relationship between the mortgage rate and Treasury rate as represented by the asymmetric error-correction model (equation (6)). The results of the estimation of equation (6) are presented in Table 6. The short-run pass-through as given by the estimates of $\delta_1$ is less than 1 for the whole period as well as for both sub-periods. Therefore, this implies that it takes more than one period for the mortgage rate to reflect the changes in the Treasury rate. The short-run pass-through for the pre-deregulation period is significantly less (31.96%) compared to the short-run pass-through (72.59%) for the post-deregulation period. The smaller value during the earlier period can be explained by the existence of more regulations during the pre-deregulation period.\footnote{It is important to note that this does not necessarily contradict the cointegrating relationship that has been found for the pre-deregulation period. This implies that even during the pre-deregulation period the mortgage rate moved with the Treasury rate even though the contemporaneous effect (short-run pass-through) was not as large as it was for the post-deregulation period.}

As expected, both the speed of adjustment parameters $\delta_2$ and $\delta_3$ are highly significant for the whole period as well as the two sub-periods. This implies that when the mortgage rate is above its equilibrium level period it decreases in the next period and when it is below its equilibrium level it increases in the next period. As to the asymmetric response to the disequilibrium, the results of the Wald test are all significant at either 1% or 5%, indicating that these two speeds of adjustment are significantly different from each other. This implies that when the mortgage rate is above its
equilibrium value, it goes down at a slower rate than it goes up which happens when it is below its long-run equilibrium level. In other words, the upward adjustment to disequilibrium takes place faster than the downward adjustment. This phenomenon holds for the whole period as well as for both sub-periods.

It is interesting to note that both the speeds of downward adjustment (represented by parameter $\delta_2$) and upward adjustment (represented by parameter $\delta_3$) are substantially lower for the post-deregulation period compared to the pre-deregulation period. On the contrary, as mentioned above, the short-run pass-through is found to be significantly higher for the post-deregulation period compared to the pre-deregulation period. Therefore, it would be interesting to see the effect of deregulation on the mean adjustment lag which reflects both the speed of adjustment as well as the short-run pass through. From Table 7, it is clear that the mean adjustment lag for the upward adjustment ($MAL^-$) has remained the same during the post and pre-deregulation periods. However, the mean adjustment lag for the downward adjustment ($MAL^+$) has substantially increased to about 3.19 months during the post-deregulation period from 2.02 months during the pre-deregulation period.

Finally it is interesting to note that the mean adjustment lag for the downward adjustment is higher than the mean adjustment lag for the upward adjustment. This is true for the whole period as well as for two sub-periods. The deregulations mentioned in the article have not been able to eliminate the apparent asymmetry in the mean adjustment lag as well as in the speed of adjustment.

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Please insert Table 7 here

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4. Conclusions
In this article, monthly data on 30-year fixed conventional mortgage rate and 10-year constant maturity Treasury yield for the period from April 1971 to December 2003 are used to test for the integration of the mortgage market with the broader capital market. In order to see the impact of deregulation during 1980s, the whole sample is divided into two sub-samples with 1971:04 – 1982:12 representing the pre-deregulation period and 1983:01 – 2003:12 representing the post-deregulation period.

In addition to using the conventional integer integration and cointegration analysis, the article use a more general concept of heteroscedastic fractional cointegration to perform the empirical test of the integration of the two markets. Furthermore, an asymmetric error-correction model is used to model and test the possible non-linear relationship between the two series. Based on both integer and fractional integration tests, both series are found to be non-stationary for the whole sample period as well as for both sub-periods. Even though the Johansen test suggests the presence of a single cointegrating vector, highly significant LM test statistics suggest the presence of heteroscedastic long-run relationship which makes the Johansen test invalid in the current situation. Therefore, the fractional cointegration test was performed on the standardized residual of the GARCH(1,1) model. The fractional cointegration test suggests the existence of fractional cointegrating relationship for the whole period as well as for both sub-periods. This indicates that even during the pre-deregulation period, these two rates were closely related. This result is consistent with the results obtained by Rudolph and Griffith (1997), Allen, Rutherford and Wiley (1999) and Sa-Aadu, Shilling and Wang (2000).

In terms of short-run pass-through, the pass-through is found to be around 31.96 percent during the pre-deregulation period whereas it is found to be about 72.59 percent during the post-deregulation period. The post-deregulation pass-through parameter that is nearly double the pre-deregulation period indicates a substantial impact of deregulation in the mortgage market in the latter period. The expected negative sign of the speed of adjustment indicates that the mortgage rate adjusts, in the next period, to any disequilibrium “left” after the pass-through in the current period. As to the nonlinear or
asymmetric relationship between the mortgage rate and Treasury rate, the Wald tests indicate that existence of an asymmetric relationship for the whole period as well as for both sub-periods. The results indicate that the upward adjustment to disequilibrium is faster than the downward adjustment. This is also reflected in the longer mean adjustment lag for the downward adjustment compared to upward adjustment. Further analysis is needed to identify the potential causes of this asymmetric relationship between the mortgage market and the broader capital market.
References


Likelihood Estimator in IGARCH(1,1) and Covariance Stationary GARCH(1,1) Models. Econometrica 64, 575-596.


Figure 1: Time Series Plot of 30-Year Conventional Mortgage Rate and 10-Year Treasury Rate.

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>Kurtosis</th>
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<tbody>
<tr>
<td>Mortgage</td>
<td>0.09572</td>
<td>0.02696</td>
<td>1.18257</td>
<td>3.93997</td>
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<tr>
<td>Treasury</td>
<td>0.07890</td>
<td>0.02450</td>
<td>0.89238</td>
<td>3.42347</td>
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Table 2: Conventional Unit-Root Tests and the Estimation of Fractional for the Original Series.

<table>
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<th>Conventional Unit-Root Tests</th>
<th>Fractional Root</th>
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<tr>
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<td>ADF PP</td>
<td>Critical Values</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5% 1%</td>
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<tr>
<td>1971:4-2003:12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortgage</td>
<td>-1.2091 -1.2519</td>
<td>-3.4469 -2.8688</td>
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<tr>
<td>Treasury</td>
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<tr>
<td>1971:4-1982:12</td>
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<td></td>
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<tr>
<td>Mortgage</td>
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<tr>
<td>Treasury</td>
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<td>Mortgage</td>
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<tr>
<td>Treasury</td>
<td>-1.2502 -1.2841</td>
<td>-3.4562 -2.8728</td>
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Table 3: Johansen’s Test of Number of Cointegrating Vectors

<table>
<thead>
<tr>
<th>No. of Cointegrating Vectors</th>
<th>Trace Statistics</th>
<th>Critical Values</th>
<th></th>
<th></th>
<th>Lambda Max</th>
<th>Critical Values</th>
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<tr>
<td>0</td>
<td>22.794**</td>
<td>17.85</td>
<td>19.96</td>
<td>24.6</td>
<td>21.470***</td>
<td>13.75</td>
</tr>
<tr>
<td>1</td>
<td>1.324</td>
<td>7.52</td>
<td>9.24</td>
<td>12.97</td>
<td>1.324</td>
<td>7.52</td>
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<td>1971:4-1982:12</td>
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<td>0</td>
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<td>17.85</td>
<td>19.96</td>
<td>24.6</td>
<td>16.571**</td>
<td>13.75</td>
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<td>1</td>
<td>1.923</td>
<td>7.52</td>
<td>9.24</td>
<td>12.97</td>
<td>1.923</td>
<td>7.52</td>
</tr>
<tr>
<td>0</td>
<td>27.178***</td>
<td>17.85</td>
<td>19.96</td>
<td>24.6</td>
<td>23.121***</td>
<td>13.75</td>
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</table>

Note: Critical values are from Osterwald-Lenum (1992)
Table 4: Unit-Root and Fractional Tests of Homoscedastic and GARCH(1,1) Residuals

<table>
<thead>
<tr>
<th></th>
<th>Fractional d</th>
<th>Std. Error. of d</th>
<th>ADF</th>
<th>PP</th>
<th>1%</th>
<th>5%</th>
<th>10%</th>
<th>LM Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971:4-2003:12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homoscedastic Residual</td>
<td>0.7878</td>
<td>0.0396</td>
<td>-3.3021</td>
<td>-5.7669</td>
<td>-3.4471</td>
<td>-2.8688</td>
<td>-2.5707</td>
<td>104.8685</td>
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<tr>
<td>GARCH(1,1) Residuals</td>
<td>0.4826</td>
<td>0.0396</td>
<td>-5.9425</td>
<td>-8.7284</td>
<td>-3.4469</td>
<td>-2.8687</td>
<td>-2.5707</td>
<td>(0.0000)</td>
</tr>
<tr>
<td>1971:4-1982:12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homoscedastic Residual</td>
<td>0.6434</td>
<td>0.0662</td>
<td>-4.2081</td>
<td>-5.1710</td>
<td>-3.4793</td>
<td>-2.8829</td>
<td>-2.5782</td>
<td>22.1439</td>
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<tr>
<td>GARCH(1,1) Residuals</td>
<td>0.3913</td>
<td>0.0662</td>
<td>-3.6603</td>
<td>-6.6830</td>
<td>-3.4793</td>
<td>-2.8829</td>
<td>-2.5782</td>
<td>(0.0011)</td>
</tr>
<tr>
<td>Homoscedastic Residual</td>
<td>1.0057</td>
<td>0.0495</td>
<td>-3.9430</td>
<td>-4.0480</td>
<td>-3.4564</td>
<td>-2.8729</td>
<td>-2.5729</td>
<td>167.5256</td>
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<tr>
<td>GARCH(1,1) Residuals</td>
<td>0.5533</td>
<td>0.0495</td>
<td>-2.8098</td>
<td>-6.1294</td>
<td>-3.4568</td>
<td>-2.8731</td>
<td>-2.5730</td>
<td>(0.0000)</td>
</tr>
</tbody>
</table>

* p-values are shown in parentheses.

Table 5: Estimation of GARCH(1,1) Parameters

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>T-value</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Mean Equation</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Constant ($\gamma_0$)</td>
<td>0.0122</td>
<td>23.443</td>
<td>0.0017</td>
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<td>Treasury ($\gamma_1$)</td>
<td>1.0311</td>
<td>164.253</td>
<td>1.1523</td>
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<tr>
<td>variance equation</td>
<td>$\omega_0$</td>
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<tr>
<td></td>
<td>$\omega_1$</td>
<td>0.8396</td>
<td>5.861</td>
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<tr>
<td></td>
<td>$\theta_1$</td>
<td>0.2741</td>
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</table>
### Table 6. Estimation of the Asymmetric Error-Correction Model

<table>
<thead>
<tr>
<th>Year</th>
<th>$\delta_1$</th>
<th>T-value</th>
<th>$\delta_2$</th>
<th>T-value</th>
<th>$\delta_3$</th>
<th>T-value</th>
<th>Statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971:4-2003:12</td>
<td>0.5221***</td>
<td>14.627</td>
<td>-0.1487***</td>
<td>-6.928</td>
<td>-0.3186***</td>
<td>-5.346</td>
<td>7.222***</td>
<td>0.0072</td>
</tr>
<tr>
<td>1971:4-1982:12</td>
<td>0.3196***</td>
<td>5.448</td>
<td>-0.3368***</td>
<td>-7.805</td>
<td>-0.6526***</td>
<td>-6.835</td>
<td>9.168***</td>
<td>0.0025</td>
</tr>
<tr>
<td>1983:1 - 2003:12</td>
<td>0.7259***</td>
<td>25.175</td>
<td>-0.0860***</td>
<td>-4.734</td>
<td>-0.2639***</td>
<td>-3.466</td>
<td>5.172***</td>
<td>0.0230</td>
</tr>
</tbody>
</table>

Note: *** implies significant at 1%, ** implies significant at 5%.

### Table 7. Estimation of the Mean Lag Effects

<table>
<thead>
<tr>
<th>Year</th>
<th>MAL+</th>
<th>MAL-</th>
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</thead>
<tbody>
<tr>
<td>1971:04-2003:12</td>
<td>3.2136</td>
<td>1.4998</td>
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<tr>
<td>1971:04-1982:12</td>
<td>2.0201</td>
<td>1.0426</td>
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<td>1983:01 - 2003:12</td>
<td>3.1877</td>
<td>1.0388</td>
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</tbody>
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