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# What's Unique About the Federal Funds Rate? Evidence from a Spectral Perspective*

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**Abstract**

A large empirical literature attempts to identify US monetary policy shocks using the effective federal funds rate. This paper compares the time series behavior of the effective federal funds rate to 10 US interest rates with maturities ranging from overnight to 10 years. Using a spectral estimation procedure that is particularly suitable and novel in this context, we identify idiosyncratic shocks to the federal funds rate and provide evidence on their impact on other US interest rates at various frequencies. Our results suggest that, while all of the interest rates examined have common shocks at low frequencies, the federal funds rate contains some unique information at high frequency, although this information appears to be relevant only at the short end of the term structure of interest rates. In turn, these results are open to various alternative interpretations.

JEL classification: E43.

Keywords: interest rates; federal funds rate; term structure.

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## 1. Introduction

A vast body of empirical literature has studied the response of economic variables to exogenous monetary policy shocks. A large proportion of this literature identifies monetary policy shocks using the effective federal funds rate (see, *inter alia*, Sims, 1982, 1986; Bernanke and Blinder, 1982; Rudebusch, 1995; Christiano, Eichenbaum and Evans, 1992, 1996a,b, 1999; Clarida, Gali and Gertler, 1998, 2000; Clarida, 2001; Thornton, 2001). The importance of the federal funds rate in the US money market and the US economy as a whole is unquestionable. Open market operations, which the Federal Reserve (Fed) regularly conducts to implement monetary policy, have a direct effect on reserves and, thereby, the federal funds rate. Moreover, the Fed has often relied explicitly on the overnight federal funds rate to implement policy. It did so from the mid-1970s until October 1979, and switched from a narrow money targeting procedure to an explicit federal funds rate operating procedure in the late 1980s.[1] Indeed, Goodfriend (1991) argues that the Fed has targeted the federal funds rate either implicitly or explicitly throughout its history.[2] Given the Fed's reliance on open market operations to implement policy and the role of the effective federal funds rate in the Fed's operating procedure, it is not surprising that the federal funds rate is routinely treated as the instrument of monetary policy in much research in empirical macroeconomics and monetary economics.

This paper contributes to this broad literature by explicitly attempting to identify more precisely information that is unique to the federal funds rate. Given the importance of the federal funds rate in US monetary policy, the unique information in the federal funds rate should provide some information about monetary policy shocks. Consequently, extracting the unique information in the funds rate and examining the relation of this information to other US interest rates could improve our understanding of the transmission of monetary policy from the federal funds rate to other interest rates and, thereby, the rest of the economy.

We focus on the effective federal funds rate and 10 other US interest rates with maturities ranging from overnight to 10 years, examining empirically both daily and monthly time series since 1974. Our empirical strategy is based on an

[1] For a discussion of alternative operating procedures used by the Fed to implement monetary policy, see, for example, Meulendyke (1998). For an excellent review of the issues related to empirically identifying monetary policy shocks and gauging their impact on other economic variables, see, for example, Christiano, Eichenbaum and Evans (1999) and Clarida (2001).

[2] This argument is also implicit in Taylor's (1999) historical analysis of US monetary policy.

econometric procedure recently developed by Wen (2001, 2002). This procedure is based on a frequency domain representation of a vector autoregression (VAR). Unlike the conventional structural VAR approach carried out in the time domain, where monetary policy shocks are identified by imposing a specific lag structure or a Wold causal chain on the variables in the VAR (typically by using the Choleski factorization), the identification procedure used here imposes no lag structures. This is an important advantage in this context since in well functioning financial markets the informational advantage of any particular rate is likely to be relatively short lived due to arbitrage, so that the response of interest rates to monetary policy shocks is likely to occur with very small or no lags.

To anticipate the main results of this paper, our empirical analysis suggests that, when monthly (or lower-frequency) data are used, it is not possible to identify any unique information in the federal funds rate relative to other US interest rates. In turn, this finding suggests that in order to identify idiosyncratic shocks to the federal funds rate it is necessary to use data at higher frequency. This results is consistent with Hamilton's (1997) argument that exogenous shocks to monetary policy can only be identified using daily data.

Using daily data, we are able to identify the unique information contained in the federal funds rate, which is found at fairly high frequency. This information appears to be particularly relevant to explain the high-frequency behavior of other US interest rates at the short end of the term structure. However, perhaps not surprisingly, this information appears to be less relevant, if at all, at the long end of the term structure of interest rates. We provide various possible interpretations of these results in terms of the conventional view of monetary policy and of market efficiency considerations.

The remainder of the paper is set out as follows. In Section 2 we describe the econometric techniques used to identify idiosyncratic shocks to the federal funds rate and to examine their impact on other US interest rates. We also discuss the advantages and disadvantages of our econometric procedure relative to conventional VAR estimation methods. Section 3 discusses the data, and Section 4 discusses the results obtained by applying our spectral estimation methods to monthly average data. In Section 5 we report and discuss the empirical results from applying our procedure to daily interest rates data. In Section 6 some of the implications of our analysis are discussed. A final section briefly summarizes and concludes.

## 2. Econometric methodology

The conventional approach for identifying monetary policy shocks involves imposing restrictions in the time domain on the impulse response functions of a vector of time series estimated from structural VARs (e.g., see, *inter alia*, Sims, 1980, 1986; Bernanke and Blinder, 1992; Christiano, Eichenbaum and Evans, 1994, 1999, and the references therein). A structural VAR can be used to trace through the effects of shocks to monetary policy on such variables as inflation, output and the exchange rate and to estimate the importance of monetary policy shocks in explaining particular episodes in macroeconomic history. These approaches identify monetary shocks as ones that impact instantaneously on the variable proxying for monetary policy (say the federal funds rate) but not on other variables in the VAR until some periods later. This and other methods that impose a Wold causal chain with lags are useful only when it is reasonable to assume that the impact from monetary shocks on the monetary proxy variable precede that on other variables. Such an assumption is problematic in the context of interest rates, since lags in the response to monetary shocks among financial variables (especially short-term interest rates) are likely to be short and possibly non-existing.[3]

Another approach for identifying monetary shocks in the time domain involves imposing long-run restrictions so as to distinguish shocks that have permanent effects from shocks that have only transitory effects. This approach, first proposed by Blanchard and Quah (1989) in an attempt to identify supply and demand shocks, is also unapplicable in the context of analyzing and comparing interest rates, because arbitrage and market efficiency would almost certainly imply that all rates contain essentially the same information in the long run, rendering virtually impossible the identification of shocks contained in one rate but not in another.

We employ an econometric approach based on the frequency domain representation of a VAR. Our approach is related to the approach of Blanchard and Quah (1989), but differs from their approach in that we impose identifying restrictions

[3]An alternative approach to examine empirically the role of monetary policy shocks which is attracting increasing attention in the literature involves a forward-looking Taylor rule (FLTR) of the sort suggested by Clarida, Gali and Gertler (1998, 2000). Clarida (2001) illustrates how the FLTR approach can be directly linked to the structural VAR approach, demonstrating how the FLTR approach is consistent with a structural VAR approach with cross-equation restrictions. Therefore, the discussion in this section applies generally to both structural VARs and to the FLTR approach.

not with respect to time but with respect to frequency. The identification of idiosyncratic shocks to the federal funds rate is achieved by finding spectral peaks at specific frequencies in the funds rate that are not shared by the other interest rates, under the condition that the coherence (correlation) between the funds rate and other rates is relatively low at these frequencies. Our working hypothesis is that a spectral peak unique to the federal funds rate reveals idiosyncratic shocks to the funds rate. This hypothesis is valid under two conditions: 1) the spectral peaks are not shared with other interest rates; this eliminates the possibility that the spectral peaks may reflect an endogenous propagation mechanism or dynamic structure of the financial system rather than idiosyncratic shocks to the funds rate, as we assume that all interest rates share the same propagation mechanism in reacting to external news; 2) the coherence (correlation) is low between the funds rate and other rates at the frequencies where unique spectral peaks are located, which eliminates the possibility of reverse "causality".

To be more specific, let $x = (FR, OR)'$, where $FR$ denotes the federal funds rate and $OR$ denotes any other interest rate. We use data in first differences in our investigation, so that the variables in the VAR can be assumed to be jointly stationary. The stationarity assumption of the first difference of $x$ implies the existence of the following structural moving average representation:

$$\Delta x_t = \left(A_0 + A_1 L + A_2 L^2 + ...\right) \varepsilon_t = A(L)\varepsilon_t, \tag{1}$$

where $\Delta$ denotes the first-difference operator; $\varepsilon = (\varepsilon_{1t}, \varepsilon_{2t})'$ is a vector of two orthogonal *iid* shocks with a covariance matrix normalized to identity; $L$ is the lag operator; and $A(L) = \begin{bmatrix} a_{11}(L) & a_{12}(L) \\ a_{21}(L) & a_{22}(L) \end{bmatrix}$ with $a_{ij}(L) = \sum_{k=0}^{\infty} a_{ij}(k)L^k$ for $i, j = 1, 2$. Stationarity of $\Delta x$ also implies that there is a unique Wold-moving average representation of the form

$$\Delta x_t = \left(I + B_1 L + B_2 L^2 + ...\right) \varepsilon_t = B(L)v_t, \tag{2}$$

where $B(L) = \begin{bmatrix} b_{11}(L) & b_{12}(L) \\ b_{21}(L) & b_{22}(L) \end{bmatrix}$, and $var(v) = \Sigma$. This representation can be obtained by first estimating and then inverting the VAR representation of $\Delta X$ in the usual way.

To recover the structural representation (1) from the Wold representation (2), which can be uniquely and consistently estimated from the data, we need to find the mapping

$$A_0 \varepsilon_t = v_t, \tag{3}$$

so that $A_j = B_j A_0$ for each $j$. Condition (3) implies

$$A_0 A_0' = \Sigma, \tag{4}$$

which has only three independent equations that can be used to identify the four elements in $A_0$ due to the symmetric structure of the covariance matrix $\Sigma$. This leaves us with one degree of freedom to impose restrictions on the dynamic effects of the innovations $\varepsilon_t$ on the federal funds rate. We choose to impose the restrictions at particular frequencies on the power spectrum of $FR$.

The power spectra of $\Delta x$ can be obtained by taking the Fourier transform of the two different representations of $\Delta x$ given by (1) and (2). The Fourier transform of (1) is given by

$$F_x(e^{-i\omega}) = \left| A(e^{-i\omega}) \right|^2, \tag{5}$$

where the upper left-hand entry is the spectrum of $FR$ and is given by

$$F_{11}(e^{-i\omega}) = \left| a_{11}(e^{-i\omega}) \right|^2 + \left| a_{12}(e^{-i\omega}) \right|^2. \tag{6}$$

Notice that (6) describes a spectral decomposition of the total variance of $FR$ across different frequencies $\omega \in [0, \pi]$, where the first term is the partial spectrum of $FR$ pertaining to the innovation $\varepsilon_1$, and the second term in (6) is the partial spectrum of $FR$ pertaining to the innovation $\varepsilon_2$.

The Fourier transform of (2) is given by:

$$F_x(e^{-i\omega}) = \left| B(e^{-i\omega}) A_0 \right|^2 = B(e^{-i\omega}) A_0 A_0' B(e^{i\omega}), \tag{7}$$

where $A_0 A_0' = \Sigma$. The spectrum of $FR$ in (7) is given by the upper left-hand entry:

$$\left| [A_0]_{11} b_{11}(e^{-i\omega}) + [A_0]_{21} b_{12}(e^{-i\omega}) \right|^2 + \left| [A_0]_{12} b_{11}(e^{-i\omega}) + [A_0]_{22} b_{12}(e^{-i\omega}) \right|^2, \tag{8}$$

where the first term is the partial spectrum of $FR$ with respect to the innovation $\varepsilon_1$, and the second term is the partial spectrum of $FR$ with respect to the innovation $\varepsilon_2$. It is clear from (8) that in order to recover the structural representation (6) we must uncover the elements $[A_0]_{ij}$ $(i, j = 1, 2)$ in the matrix $A_0$.

Now we assume that $\varepsilon_2$ is an idiosyncratic shock to the federal funds rate and is responsible for generating a spectral peak in the funds rate at frequency $\omega_0$. This implies that $\varepsilon_2$ must have maximum contributions to the variance of $FR$ at the frequency $\omega_0$ where the spectral peak is located. This also implies that the other shock ($\varepsilon_1$) has only minimum contributions to the variance of $FR$ at that particular frequency. We can interpret $\varepsilon_1$ as shocks that are either common to both the funds rate and the other rate, or unique to the other rate. Choosing $[A_0]_{11}$ to minimize the partial spectrum of $FR$ pertaining to $\varepsilon_1$ (the first term in equation (8)) at frequency $\omega_0$ then gives

$$[A_0]_{11} = -[A_0]_{21} \left( \frac{b_{11}(e^{-\omega_0 i}) b_{12}(e^{\omega_0 i}) + b_{12}(e^{-\omega_0 i}) b_{11}(e^{\omega_0 i})}{2 \left| b_{11}(e^{-\omega_0 i}) \right|^2} \right). \tag{9}$$

The system of equations that can be used to identify $\varepsilon_1$ and $\varepsilon_2$ and to solve for the four elements in $A_0$ is given by the identifying restriction (9) and the relation $A_0 A_0' = \Sigma$.[4]

With the knowledge of $A_0$, we can then examine the dynamic effects of the federal funds rate shock $\varepsilon_2$ on the other interest rate in the VAR using representation (7), which decomposes the variances and covariances of the series in $\Delta x$ into two parts: the part due to the federal funds rate shock ($\varepsilon_2$) and the part due the other shock ($\varepsilon_1$).

## 3. Data

Our data set comprises daily time series for 11 US interest rates over the sample period from January 2, 1974 to December 29, 2000. The main interest rate under study is the effective federal funds rate ($FR$), which is a weighted average of all daily transactions for a group of New York federal funds brokers. Federal funds are deposit balances at Federal Reserve banks that institutions (primarily depositories, e.g. banks and thrifts) lend overnight to each other. Deposit balances at the Fed satisfy reserve requirements of the Federal Reserve System.[5] The federal funds rate is calculated by the Federal Reserve Bank of New York and the

[4] See Wen (2001, 2002) for a more detailed and technical treatment of the identification scheme.

[5] Because reserve requirements are binding at the end of the reserve maintenance period, called settlement Wednesday, the federal funds rate tends to be more volatile on settlement Wednesdays. Since February 1984 the reserve maintenance period has been two weeks for all

previous day's rate is made available on the morning of the next business day. The other overnight rate considered in this study is the repurchase or repo rate ($RP$). The $RP$ rate is a weighted average of daily rates on overnight repurchase agreements reported by a survey of all primary government security dealers taken between 8:45am and 9:20am Eastern time the next day.

We also consider the commercial paper rate on financial paper for two different maturities, the 1-month rate ($CP1$) and the 3-month rate ($CP3$). The commercial paper rate is a weighted average of offer rates for companies with AA bond ratings reported to the Depository Trust Company, a national clearinghouse for the settlement of securities trades and a custodian for securities. Three Treasury bill rates are also used, namely the 3-month rate ($TB3$), the 6-month rate ($TB6$), and the 12-month rate ($TB12$). The T-bill rates are secondary market rates, calculated as simple averages of offer rates from a group of primary government security dealers.[6] We also examine three certificate of deposit (CD) rates, namely the 1-month rate ($CD1$), the 3-month rate ($CD3$), and the 6-month rate ($CD6$). The CD rate is calculated as a simple average of dealer offering rates on nationally traded certificates of deposit (secondary market). These CD rates are obtained for the current day around 10am Eastern time. Finally, we use one long-term rate, namely the rate on 10-year Treasury bonds ($T10$). The 10-year rate is a constant maturity rate calculated by the Board of Governors of the Federal Reserve System. All rates, except for $RP$, were taken from the Board of Governors H.15 Statistical Release.[7] The repurchase rate $RP$ was taken from the Board of Governors *FAME* data base.[8]

In addition to daily data, we also used a monthly data set for the same 11 US interest rates and sample period. With the exception of the federal funds rate, the monthly data are business-day averages of daily figures. The federal funds rate is a calendar-day average. We did not re-average these data to the same basis because the data are typically used as reported by the Board of Governors

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institutions. Before 1984 it was one week for most large institutions. For a more detailed discussion of the Federal Reserve's reserve requirements and the microstructure of the federal funds market, see, for example, Taylor (2001). For comprehensive descriptions of the institutional aspects of the federal funds market, see Stigum (1990) and Furfine (1999).

[6] Before October 1996, the Desk called five primary government security dealers on a rotating basis. After that date, the Desk obtained these rates from vendors whose identity is confidential.

[7] More detailed information on these rates can be obtained at the webpage http://fweb.rsma.frb.gov/bks/interest.pdf.

[8] All of the short-term interest rates discussed above are annualized on a 360-day year basis.

and we wanted our empirical results to reflect those that would be obtained with regularly used, publicly available data.

The sample period under investigation – January 2, 1974 to December 29, 2000 – covers 26 years, a period that should be sufficiently long to capture some of the main features of the unknown stochastic process governing the relationship between the federal funds rate and each of the other interest rates examined. Also, the number of observations, $T = 6,693$ for daily data and $T = 324$ for monthly data, is sufficiently large to be fairly confident of the estimation results.[9]

Table 1 reports sample descriptive statistics for all 11 interest rates in our data set (in first difference). The statistics are reported only for the daily data to conserve space. The sample means of the 11 US interest rates are similar and not statistically different from zero. The standard deviation of the federal funds rate is much larger than the standard deviation of each of the other 10 interest rates, including the overnight repo rate. The standard deviation of the 3-month T-bill rate is larger than that of the 3-month commercial paper rate, but slightly smaller than that of the 3-month CD rate. As expected, the variance declines as the term to maturity lengthens[10], and $T10$ has the smallest variance among the rates considered. The sample distributions of each of the interest rates exhibit strong non-normality, primarily due to excess kurtosis.

[9] The raw time series comprised 6,696 observations. However, we deleted three observations prior to beginning the empirical analysis. One observation was deleted at the end of 1985 and two observations were deleted at the end of 1986. At the end of both of these years, the federal funds rate spiked dramatically as banks attempted to 'window dress' their year-end balance sheets. During the last day of 1985 the funds rate nearly doubled from its previous trading level to 13.46 percent. The funds rate again rose dramatically on the last two days of 1986, rising from its previous trading level of about 6.3 percent to 14.35 on December 31 after retreating somewhat from its December 30 level of 16.17 percent. In 1986 the RP rate also rose dramatically. The RP rate rose to 17.1 percent on December 31 1986 from its previous trading level of about 6.2 percent. Thus, to be confident that our empirical results were not due to a few extreme spikes in the data that do not reflect important relationships between the interest rates considered here, these observations were deleted. However, having executed the empirical analysis discussed below with and without deleting these three observations, we found qualitatively identical results.

[10] The only exception is for CD rates as the variances of the 1-, 3- and 6-month CD rates are very close and in fact 1-month CD rate movements appear to be slightly less volatile than movements in both the 3- and 6-month CD rates.

# 4. Identifying unique shocks to the federal funds rate: monthly data

Most studies attempting to identify the response of economic variables to monetary policy shocks use data at monthly or lower frequency (e.g. see Rudebusch, 1995; Christiano, Eichenbaum and Evans, 1996, 1998; Clarida, Gali and Gertler, 2000, and the references therein).[11] The use of relatively low frequency data is motivated by the fact that most macroeconomic aggregates are available only at monthly or lower frequency. Consequently, we began our investigation using monthly data. We found, however, that the power spectra of all monthly interest rates look very similar in that they all have spectral peaks located at the same frequencies. Moreover, the coherence – which measures the degree to which the rates are correlated at a certain frequency $\omega$ – between the federal funds rate and each of the other rates is very high at each of the frequencies where a peak exists. To illustrate this point, Figure 1 shows the spectra of the monthly federal funds rate and 3-month T-bill rate as well as their coherence. The figure is representative of those of the other interest rates examined. There are three spectral peaks in the funds rate (the upper left window). These peaks take place at frequencies $0.11, 0.225$ and $0.365$ respectively. Corresponding to exactly the same frequencies there are also three spectral peaks in the 3-month T-bill rate (the lower right window). Moreover, the coherence function (the upper right window) also exhibits 3 local maxima at these frequencies, with values of about 0.9 at frequencies 0.11 and 0.225, and about 0.57 at frequency 0.365. Such extraordinarily high coherence values at these frequencies suggest that these rates are jointly influenced by common shocks or reflect common endogenous cycles.[12]

The facts that the spectral-density peaks are common to all of the interest rates examined and that interest rates are highly correlated across those peak frequencies suggest that it is difficult to identify the idiosyncratic component (shocks) in any of the interest rates using monthly data using our method. These features of the data are consistent with the efficient markets hypothesis (EMH), which suggests that information that is unique to one rate is quickly spilled over

[11] Christiano, Eichenbaum and Evans (1999) convincingly document that the qualitative inference from using VARs with monthly and quarterly data is essentially the same.

[12] Notice that the coherence is about 0.9 or higher for all frequencies between 0 and 0.13. Given that we are dealing with the first difference of monthly and fairly volatile time series, a coherence value of about 0.5 may be seen as strong evidence of comovement.

to all other rates. Consequently, interest rates appear to move together at low frequencies so that monthly data are not suitable for identifying idiosyncratic shocks to any one of the interest rates considered. Hence, we conclude that higher-frequency data are needed for identifying unique shocks to any one of the interest rates considered.[13] [14]

## 5. Identifying unique shocks in the federal funds rate: daily data

In this section we present the results from analyzing all bivariate models of the funds rate and each of the other 10 interest rates using daily data. The daily federal funds rate has three dominant spectral density peaks at frequencies $\omega = 0.10$, $\omega = 0.225$, and $\omega = 0.415$ respectively. In particular, the maximum peak of the power spectrum is located at $\omega = 0.225$, the second largest at $\omega = 0.415$; together these peaks account for the bulk of variations in the funds rate. In contrast, all other rates, except for the overnight repo rate, have their highest peaks at the zero frequency and do not share common peaks with the funds rate in the high frequency range. These results suggest that the shocks at these frequencies are unique to the funds rate. Comovements between the funds rate and other rates with daily data take place only at business cycle frequencies (80- to 300-week cycle) or lower frequencies. This is illustrated clearly in Figure 2, which presents the coherence between the federal funds rate and each of the other 10 interest rates. The first, and lowest-frequency, peak of the spectral density of the federal funds rate appears to be common to all of the rates. For each rate, the coherence is relatively high at this frequency. This is particularly true for the

[13]Similar conclusions have also been reached by others in the literature (e.g. see Engle and Granger, 1987; Stock and Watson, 1988; Campbell and Shiller, 1991; Hall, Anderson and Granger, 1992; Engsted and Tangaard, 1994).

[14]We did find, however, that the coherence between the funds rate and other rates tends to decline as the term to maturity lengthens. The difference is qualitatively and quantitatively small for the 12-month T-bill rate, but substantial for the 10-year rate, where the coherence is only about 0.35 at $\omega = 0$. Given the coherence between the federal funds rate and the 10-year rate, it might be possible to identify unique information in each of these rates using monthly data. Nevertheless, we found that the analysis of the relationship between the federal funds rate and the 10-year rate using monthly data is qualitatively identical to that using daily data. Therefore, we postpone our discussion of the relationship between the federal funds rate and the 10-year rate to the next section.

repo rate, where the coherence is about 0.6 at $\omega = 0.10$.[15] The second peak in the funds rate (corresponding to a 1-week cycle), however, displays substantially lower coherence with all other rates, including the repo rate. The relatively low coherence between the federal funds rate and these rates at this frequency suggests that this peak is unique to the federal funds rate. The third peak of the spectral density of the federal funds rate (corresponding to a 3-day cycle) exhibits even lower coherence values, suggesting that this peak is also unique to the funds rate. With the exception of the overnight repo rate, the peak coherence between the funds rate and other rates occurs at $\omega = 0$. Consequently, movements at business cycle frequencies (80-week to 300-week cycle) or frequencies near zero are common to all rates.[16] Overall, Figure 2 suggests that the two spectral peaks at frequencies 0.225 and 0.415 are unique to the federal funds rate and, hence, reflect unique shocks to the funds rate.

The relevant question is: Do shocks to the funds rate affect other rates and, if so, to what degree? To answer this question, we employed the spectral estimation method outlined in Section 2. Figure 3 presents the results obtained by imposing the identifying restriction at frequency $\omega = 0.225$ where the highest peak of the funds rate is located. Figure 3 shows the contribution of shocks to the federal funds rate at this frequency to the variance of each of the other interest rates across all frequencies.[17] The top panels of Figure 3 report the total spectrum (black line) of the federal funds rate and its decomposition carried out using a bivariate VAR (the spectrum and its decomposition for the other interest rate in the VAR are presented in the bottom panels accordingly). The spectral estimation method decomposes the total spectrum of an interest rate time series into two parts: the part due to the unique shock to the funds rate ($\varepsilon_2$), and the part due to the other shock ($\varepsilon_1$) that is orthogonal to $\varepsilon_2$. The red line in each window then reflects the contribution of $\varepsilon_2$ (shock to the funds rate) to the total spectrum of an interest rate across frequencies, while the blue line reflects the contribution of $\varepsilon_1$.

It is clear that shocks to the federal funds rate identified using $\omega = 0.225$ explain almost all of the variation in the federal funds rate at all frequencies.

[15] Note that also for the repo rate the coherence shows a very high value at zero frequency, even though it is not the maximum value of the coherence graph.

[16] The coherence also appears to be inversely related to the term to maturity. This is particularly apparent for the 10-year Treasury bond rate where the coherence is essentially zero for $\omega \geq 0.10$.

[17] Note that the variance of a time series is proportional to the total area underneath the spectrum. Hence, the spectrum shows the distribution of the total variance across frequencies.

Moreover, the other shock ($\varepsilon_1$) accounts for almost none of the variation in the federal funds rate at any frequency. The proportion of the variation in other rates explained by shocks to the funds rate varies considerably across rates, however. Shocks to the funds rate at this frequency explain virtually none of the variation in the 10-year rate at any frequency. Indeed, shocks to the funds rate account for very little of the variation of any of the Treasury rates at any frequency. Nevertheless, shocks to the funds rate account for a substantial amount of the variation in the overnight repo rate. Shocks to the funds rate also account for a relatively large proportion of the variance in the commercial paper and CD rate, but only at the 1-month horizon, suggesting that the shorter the term to maturity, the more important are shocks to the funds rate. Hence, shocks to the funds rate at this frequency appear to be relevant only at the short-end of the maturity spectrum.

To conserve space, we summarize the results obtained from imposing the identifying restriction at various frequencies that indicate spectral peaks in the federal funds rate (i.e., $\omega = 0.225$ and $\omega = 0.415$ and at $\omega = 0.10$ and $\omega = 0.0$) in Table 2. The top panel of the table reports the contribution of shocks to the federal funds rate (identified by imposing restrictions at the indicated frequency) to the total variance of each of the indicated rates summed across all frequencies. The bottom panel reports the contribution of shocks to the federal funds rate to the total variance of each of the indicated rates summed only across the business cycle or lower frequencies (i.e., frequencies lower than 80 weeks or 560 days per cycle). For example, shocks to the funds rate at $\omega = 0.225$ account for 42 percent of the variation in $CP1$ near the zero frequency, but only 23 percent of the total variation in $CP1$ across all frequencies.

At the two frequencies of peaks that are unique to the federal funds rate – identified by imposing restrictions at $\omega = 0.225$ and $\omega = 0.415$ – shocks to the funds rate appear to explain relatively little of the variation in other rates either across all frequencies or at the business cycle frequency, except at the short end of the term structure. In particular, funds rate shocks explain a sizable proportion of the variation in $RP$ at all frequencies. Also, for the two one-month rates examined, namely $CP1$ and $CD1$, high-frequency shocks to the funds rate accounts for more than 20 percent of their variation at all frequencies and more than 35 percent of their variation at the business cycle frequency. However, for all of the Treasury rates the contribution of unique shocks to the funds rate is virtually zero. Consistent with the interpretation that unique shocks to the funds rate are important only at the short end of the maturity spectrum, the contribution of the two higher-frequency shocks to the federal funds rate tends to decline as the maturity of the instrument examined lengthens.

The contribution of lower-frequency funds rate shocks – identified by imposing restrictions at $\omega = 0$ and $\omega = 0.10$ – to other rates is much larger. This is expected because these shocks appear to be common to all rates and not unique to the federal funds rate.

For completeness, Table 2 also reports (in parentheses) the results obtained from reversing the order of the variables in the VAR so that the "unique shocks" identified ($\varepsilon_2$) is not associated with the funds rate but to the other interest rate in the VAR. These results are only reported at the zero frequency because with the exception of the overnight repo rate, all of the other rates have their spectral peaks at $\omega = 0$. The results show that shocks identified by imposing restrictions at the zero frequency, regardless of the order of the variables used in the VAR, should be considered common to all interest rates. The contribution of shocks to each of the interest rates to the federal funds rate is relatively small across all frequencies compared with the contribution of shocks to the federal funds rate to each of the other rates; nevertheless, the mutual contributions at the business cycle frequency are virtually identical.[18] This finding suggests that shocks to rates at the business cycle frequency are common to all rates.

Overall, our results support the conclusion that there is little, if any, unique information in interest rates at low frequencies. Low frequency shocks are *largely* common to all US interest rates, consistent with the view that interest rates at different maturities co-move in the long-run in response to the same shocks. Unique shocks to the federal funds rate are high-frequency shocks. These shocks, however, appear to be relevant at the short-end of the maturity spectrum. Such shocks have virtually no effect on rates of instruments with maturities of three months or longer.

## 6. Discussion

The results presented here confirm the conventional wisdom that there is unique information in the federal funds rate not contained in other interest rates. This unique information, however, appears to be identifiable only using high frequency

[18]The numbers are identical up to the second decimal digit.

(daily) data and appears to be associated with high frequency movements in the funds rate. Moreover, the impact of the idiosyncratic shocks identified at those high frequencies appears to be primarily limited to the shorter-end of the term structure of interest rates.

These results are open to several alternative interpretations. First, while we are able to identify shocks that are unique to the federal funds rate, we cannot tell how much of these shocks reflects monetary policy and how much is simply noise. The fact that these idiosyncratic shocks are identified at relatively high frequencies ($\omega = 0.415$ corresponds to a 1-week cycle and $\omega = 0.415$ corresponds to 3-day cycle) could imply, for example, that these shocks are 'composite' shocks reflecting mainly noise in the federal funds market. However, there is no *a priori* reason to rule out the possibility that these high-frequency shocks (i.e., shocks that cause high frequency cycles in the funds rate) reflect monetary policy, as it is clear from Figure 3 that the impact of these high-frequency shocks are not necessarily short-lived: they are capable of explaining the low-frequency movements of the funds rate and the short-term (up to 1-month) interest rates examined.

Second, the fact that the dynamic impact of the funds-rate shocks on other rates appears to be limited to the shorter-end of the term structure of interest rates is not inconsistent with the conventional interpretation of the term structure: this interpretation sees short-term interest rates being driven by exogenous policy actions of the central bank and longer-term rates being driven by the market's expected moving average of the short-term rates. In such a case, the high-frequency effects of unanticipated monetary shocks are averaged out in the longer term rates.

Third, our results can be interpreted as consistent with the efficient market hypothesis (EMH). The EMH implies that even in cases where the Fed's intentions are not immediately known or well understood, the unique monetary policy information reflected in the federal funds rate is quickly reflected in other interest rates, especially the shorter-term rates. Consequently, we observe that shocks to the funds rate tend to have larger impact on the shorter term rate as compared to longer term rates and that it is difficult to identify unique information in any rates using data that are sampled at too low a frequency, such as the monthly frequency.

Our results are also consistent with the idea that the Fed responds systematically to economic fundamentals. Goodfriend (1987) and Barro (1989), *inter alios*, suggest that the role of the Fed is to smooth interest rates. Shocks to the real economy cause interest rates to move. In such circumstances, the Fed acts to smooth the transition of rates to the level that is consistent with economic fundamentals. This argument is based on the belief that it is not the Fed *per se* that is responsible for the low-frequency behavior of interest rates, which are endogenously determined by economic fundamentals. Goodfriend (1991, p. 10) summarizes this view succinctly as follows:

> "[...] it should not be said that a Federal funds rate target change causes a change in market rates since the Fed is merely reacting to events in much the same way as the private sector does. More generally, to the extent that we believe the Fed reacts purposefully to economic events, we should not say that funds rate target changes are ever the fundamental cause of market rate changes, since both are driven by more fundamental shocks."

If the Fed does not move rates *per se*, but rather reacts to events in much the same way as private agents, there is little reason to suspect that the funds rate contains unique information about monetary policy at low or business-cycle frequencies.[19] Consequently, we observe that low-frequency shocks (i.e., shocks that are mainly responsible for low-frequency or business-cycle-frequency movements of the federal funds rate) are common to all rates examined.

Regardless of the interpretation, our analysis establishes that shocks responsible for the low-frequency movements in the federal funds rate are common to many, if not all, other US interest rates. This implies that identifying monetary policy shocks using low frequency data may not be possible.

## 7. Conclusion

A large empirical literature identifies monetary policy shocks using the effective federal funds rate, upon the (implicit or explicit) assumption that the federal funds rate contains some unique information about monetary policy. In this paper we have provided evidence on the existence of this information, in an attempt to add

[19]News about economic fundamentals is known both to market participants and Fed officials. There is no particular reason to believe that policymakers have unique information about economic fundamentals. Woodford (2001), for example, argues that any informational advantage that the Fed may have had in the past (because its "large staff of trained economists and privileged access to government statistical offices") has eroded.

precision to this conventional wisdom. In order to do so, we have investigated the time series behavior of the effective federal funds rate and 10 other US interest rates with maturities ranging from overnight to 10 years using an econometric procedure in the frequency domain that is novel in this context. This procedure complements conventional structural VAR analysis and is particularly suitable in the present application in that it allows us to identify idiosyncratic shocks to the funds rate without assuming any lag structure in the responses of other interest rates to shocks to the funds rate.

Our results have several implications relevant to empirical analyses of monetary policy. First, our results suggest that it is very difficult, if at all possible, to identify monetary policy shocks from analyses of the federal funds rate using data averaged over a month or longer: all interest rates examined in this paper appear to contain the same information when averaged over months. This finding is consistent with Hamilton (1997), who makes a similar point in a slightly different context and concludes that the response to exogenous innovations to monetary policy can only be convincingly obtained by using data at a frequency higher than monthly. This result may be seen by some researchers as also consistent with the view – shared by Goodfriend (1987, 1991), Barro (1989) and others – that the Federal Reserve is not responsible for the low-frequency behavior of interest rates, which are endogenously determined by economic fundamentals. Further, it is possible to interpret this result in terms of market efficiency. If financial markets are efficient, unique information in any interest rate (that is important for other interest rates) can only be expected to be present at fairly high frequencies. When information is fully processed by the market, it is no longer unique to any rate. The faster markets process information and equilibrate, the higher the frequency of the data one needs in order to identify the unique information embedded in a particular interest rate. Our analysis of interest rates at the monthly and daily frequencies supports the notion that financial markets process information quickly and efficiently.

**Table 1. Descriptive statistics: interest rate changes**

| var | max. value | min.value | mean | s.d. | skewness | kurtosis |
|---|---|---|---|---|---|---|
| $\Delta FF$ | 4.68 | -4.70 | -0.03E-02 | 0.40 | 0.37 | 21.28 |
| $\Delta RP$ | 2.95 | -4.10 | -0.04E-02 | 0.28 | 0.15 | 26.73 |
| $\Delta CP1$ | 1.43 | -1.85 | -0.04E-02 | 0.14 | -1.66 | 28.08 |
| $\Delta CP3$ | 1.22 | -1.15 | -0.03E-02 | 0.09 | -1.24 | 34.17 |
| $\Delta T10$ | 0.65 | -1.27 | -0.03E-02 | 0.08 | -0.27 | 10.88 |
| $\Delta TB3$ | 1.34 | -1.10 | -0.03E-02 | 0.12 | 0.23 | 22.63 |
| $\Delta TB6$ | 1.17 | -0.88 | -0.03E-02 | 0.11 | 0.31 | 21.59 |
| $\Delta TB12$ | 0.90 | -0.75 | -0.03E-02 | 0.09 | -0.12 | 17.08 |
| $\Delta CD1$ | 1.27 | -1.51 | -0.05E-02 | 0.12 | -0.12 | 33.03 |
| $\Delta CD3$ | 1.14 | -1.73 | -0.04E-02 | 0.13 | -0.80 | 31.02 |
| $\Delta CD6$ | 1.14 | -2.10 | -0.03E-02 | 0.13 | -1.35 | 30.22 |

**Notes:** $\Delta$ is the first difference operator; s.d. denotes the standard deviation of the series in question. $FF$, $RP$, $CP1$, $CP3$, $T10$, $TB3$, $TB6$, $TB12$, $CD1$, $CD3$ and $CD6$ denote the effective federal funds rate, the repo rate, the 1-month commercial paper rate, the 3-month commercial paper rate, the 10-year Treasury bond rate, the 3-month Treasury bill rate, the 6-month Treasury bill rate, the 12-month Treasury bill rate, the 1-month certificates of deposit rate, the 3-month certificates of deposit rate, and the 6-month certificates of deposit rate.

**Table 2. Spectral variance decompositions**

| All frequencies | | | | |
|---|---|---|---|---|
| var | $\omega = 0$ | $\omega = 0.100$ | $\omega = 0.225$ (max) | $\omega = 0.415$ |
| $RP$ | 0.29 (0.52) | 0.34 | 0.35 | 0.77 |
| $CP1$ | 0.42 (0.28) | 0.33 | 0.23 | 0.11 |
| $CP3$ | 0.39 (0.16) | 0.06 | 0.04 | 0.04 |
| $T10$ | 0.19 (0.01) | 0.03 | 0.00 | 0.00 |
| $TB3$ | 0.40 (0.09) | 0.18 | 0.03 | 0.02 |
| $TB6$ | 0.46 (0.06) | 0.39 | 0.01 | 0.01 |
| $TB12$ | 0.44 (0.04) | 0.22 | 0.01 | 0.01 |
| $CD1$ | 0.52 (0.30) | 0.40 | 0.24 | 0.09 |
| $CD3$ | 0.52 (0.19) | 0.33 | 0.07 | 0.08 |
| $CD6$ | 0.49 (0.12) | 0.09 | 0.03 | 0.05 |

| Business-cycle frequency | | | | |
|---|---|---|---|---|
| var | $\omega = 0$ | $\omega = 0.100$ | $\omega = 0.225$ (max) | $\omega = 0.415$ |
| $RP$ | 0.54 (0.54) | 0.60 | 0.61 | 0.97 |
| $CP1$ | 0.64 (0.64) | 0.54 | 0.42 | 0.23 |
| $CP3$ | 0.62 (0.62) | 0.14 | 0.10 | 0.03 |
| $T10$ | 0.18 (0.18) | 0.03 | 0.00 | 0.00 |
| $TB3$ | 0.50 (0.50) | 0.26 | 0.05 | 0.04 |
| $TB6$ | 0.54 (0.54) | 0.46 | 0.01 | 0.02 |
| $TB12$ | 0.48 (0.48) | 0.25 | 0.00 | 0.02 |
| $CD1$ | 0.68 (0.68) | 0.55 | 0.36 | 0.16 |
| $CD3$ | 0.63 (0.63) | 0.43 | 0.11 | 0.12 |
| $CD6$ | 0.56 (0.56) | 0.04 | 0.03 | 0.06 |

**Notes:** Figures denote the variance contributions of federal funds rate shocks to each of the other interest rates, calculated as discussed in the text; $\omega$ denotes the frequency. Figures in parentheses are variance decompositions obtained when we reversed the ordering of the VAR so that the federal funds rate is the second time series in the VAR and the identifying restriction is imposed on the zero-frequency shocks to the other (first) interest rate. $FF$, $RP$, $CP1$, $CP3$, $T10$, $TB3$, $TB6$, $TB12$, $CD1$, $CD3$ and $CD6$ denote the interest rates, as defined in Section 3 and in the Notes to Table 1.

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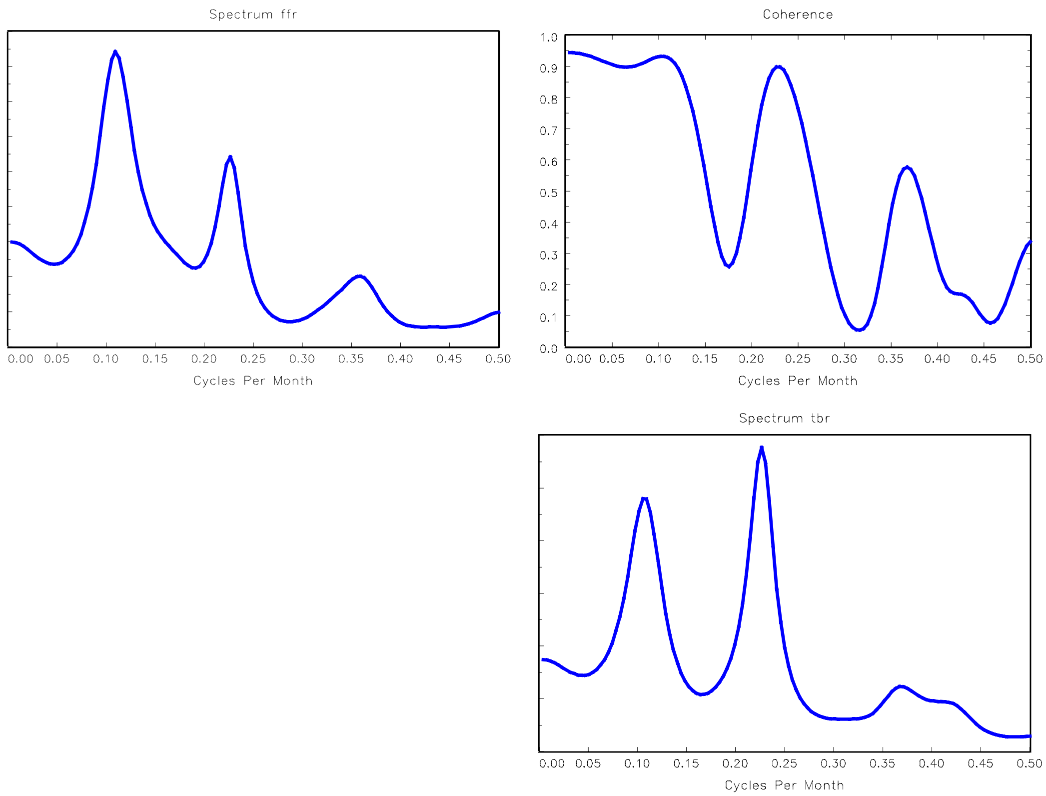


Figure 1. Power Spectrum and Coherence for FR and TB3.

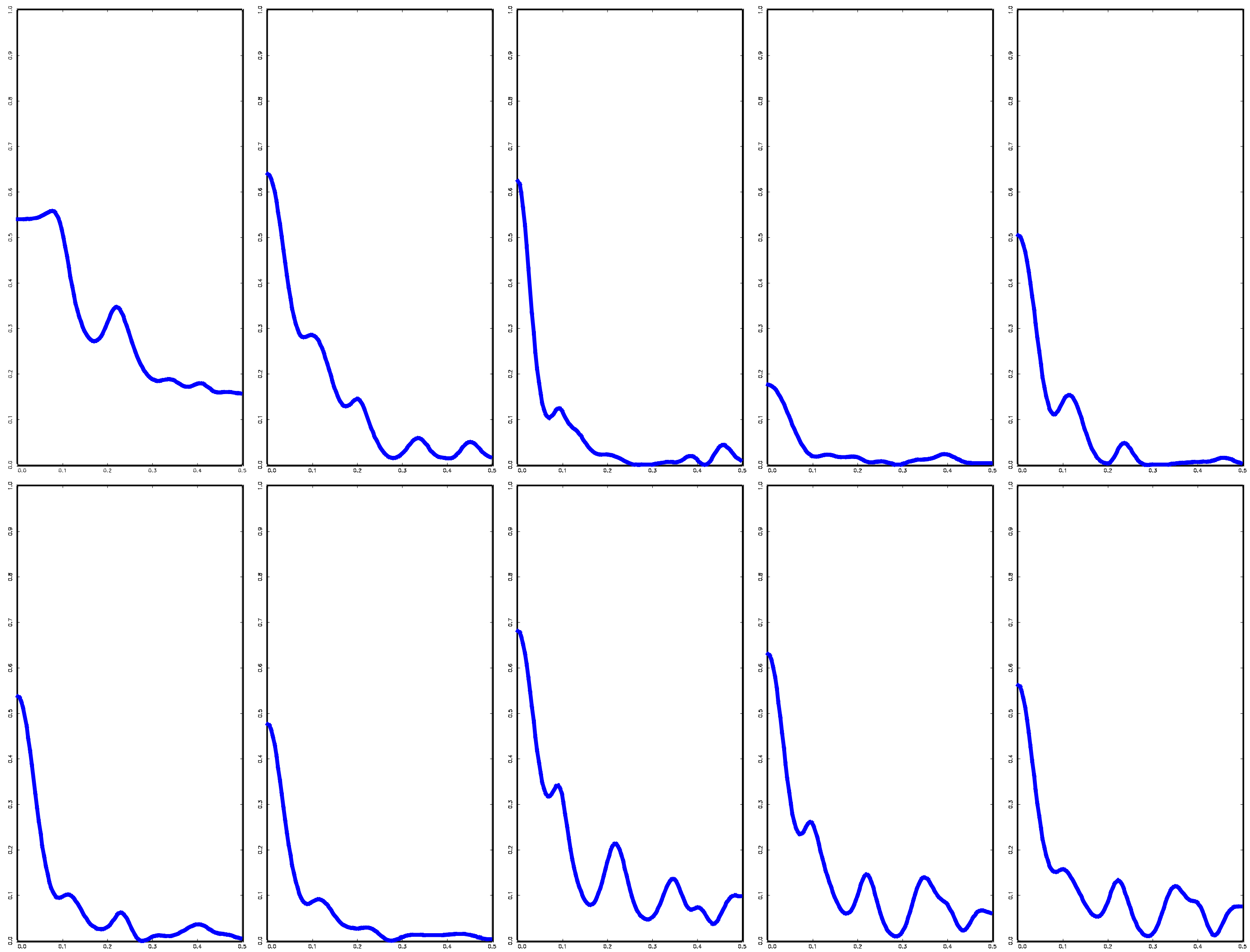

Figure 2. The Coherence Between the FR and Each of the Other Rates at Frequency .225

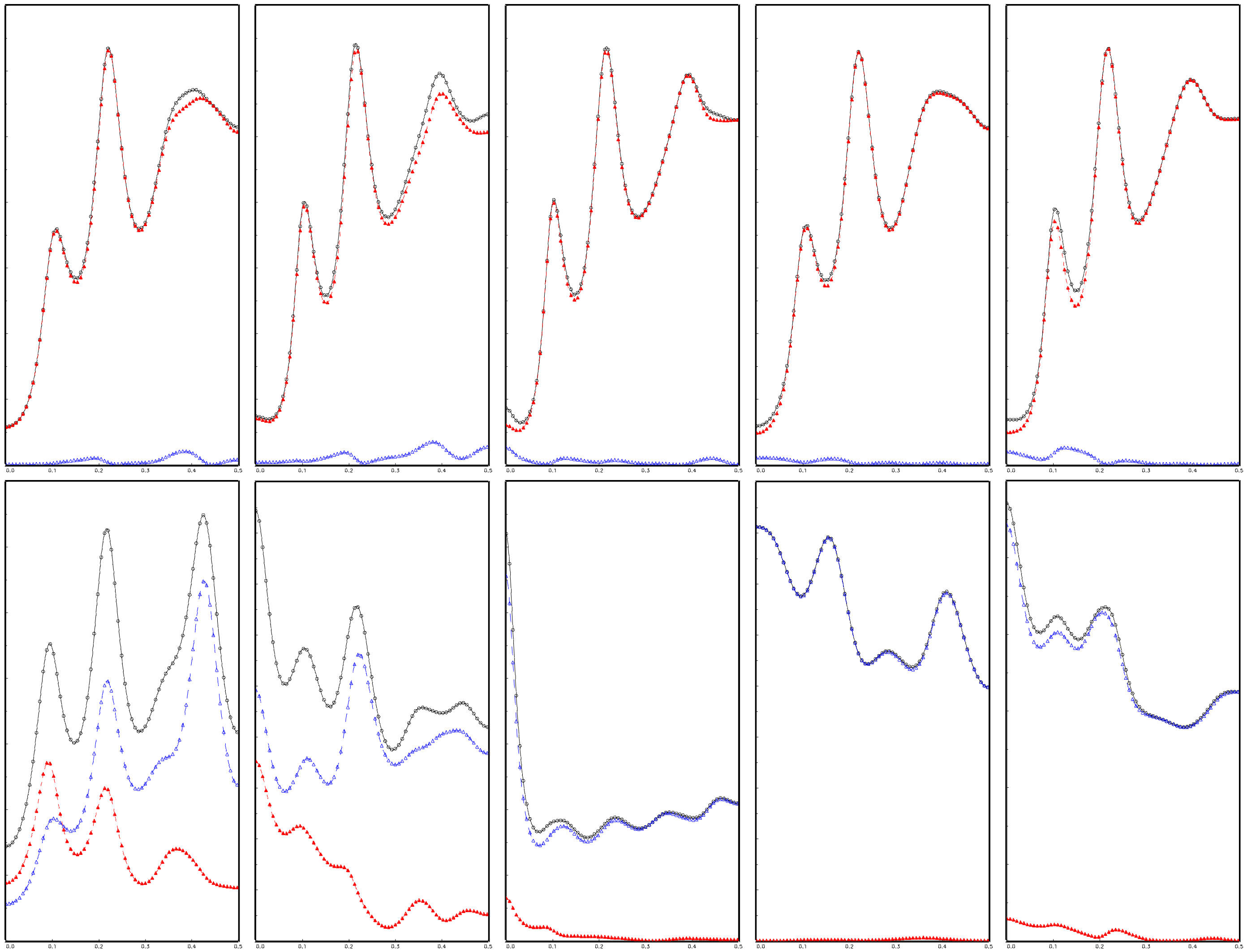

Figure 3. Spectral Decomposition for Different Interest Rates

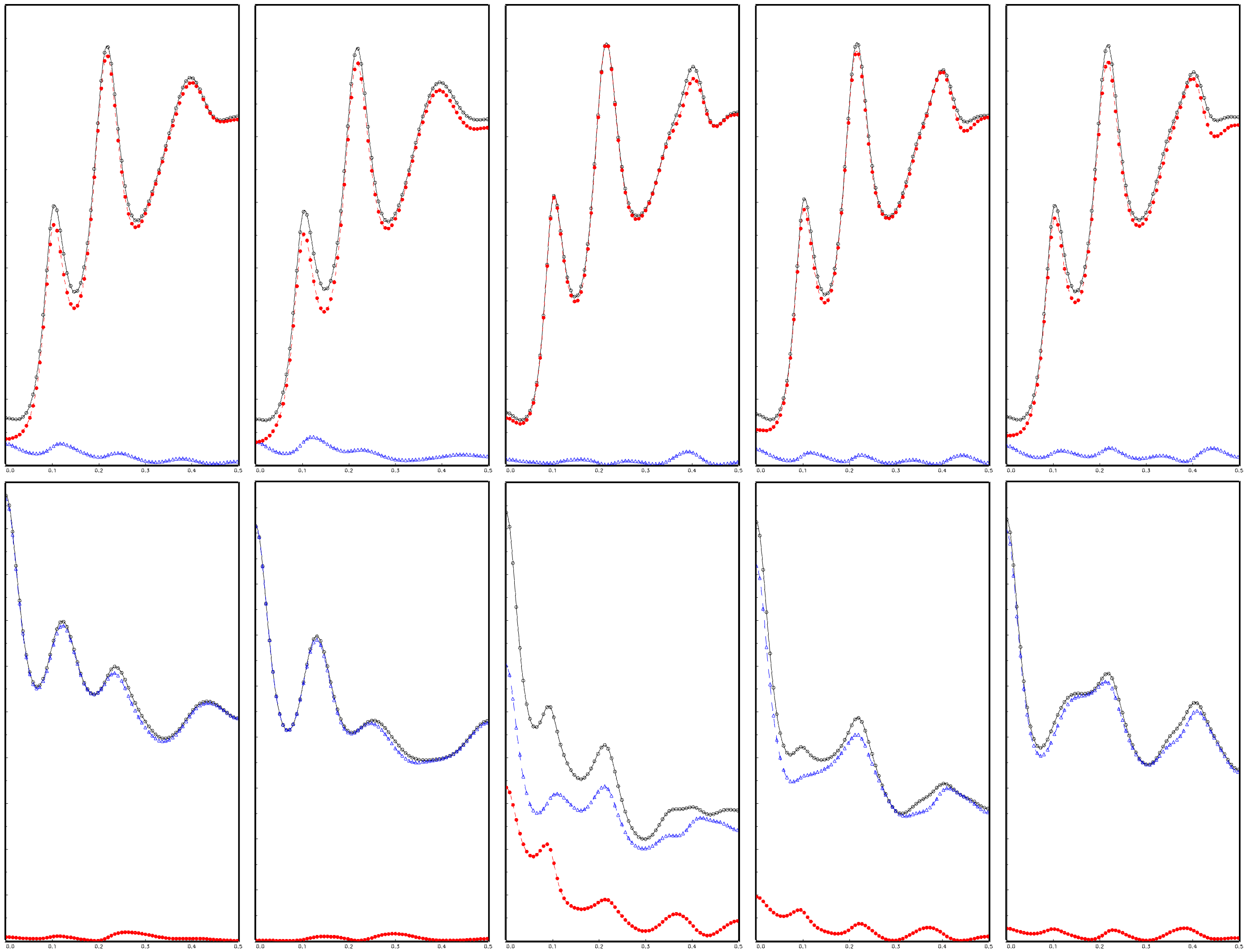


Figure 3 Spectral Decomposition for Different Interest Rates (cont'd)