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Monetary Policy, Term Structure and Asset Return: Comparing REIT, Housing and Stock

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Abstract This paper confirms that a regime-switching model out-performs a linear VAR model in terms of understanding the system dynamics of asset returns. Impulse responses of REIT returns to either the federal funds rate or the interest rate spread are much larger initially but less persistent. Furthermore, the term structure acts as an amplifier of the impulse response for REIT return, a stabilizer for the housing counterpart under some regime, and, perhaps surprisingly, almost no role for the stock return. In contrast, GDP growth has very marginal effect in the impulse response for all assets.

Keywords Monetary policy · Term structure · REITs · House prices · Regime-dependent · Yield curve · Markov regime switching

JEL Classification E5 · G0 · R0

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Introduction

The relationship between the monetary policy changes and the asset markets has attracted a considerable attention in recent years. For instance, among central bankers and scholars, Goodhart (2001) and Bernanke and Gertler (2001) express very different points of view on whether the monetary policy should react to asset price movements. Perhaps a more fundamental question is whether the monetary policy affects the asset markets, and if so, how and how much. Many studies have been devoted to these questions and clearly it is beyond the scope of this paper to review the literature.[1] To complement the literature, this paper focus on investigating the impact of changes in the Federal Funds Rate (henceforth *FFR*) on the returns of house prices and Equity Real Estate Investment Trusts (REITs), respectively.[2] To differentiate from previous research efforts, this paper explicitly introduces two elements in the empirical model: (1) the term structure (or, *the interest rate spread*, or *the slope of the yield curve*) and (2) the regime-switching nature of the dynamical system.

The justifications of including the interest rate spread in the empirical model are easy to see. It is well known that the term structure contains information about future inflation, future real economic activities as well as asset returns.[3] Thus, it may be instructive to include the term structure as a (partly) "forward-looking variable" in the regression without taking any stand on the formation of future inflation or interest rate expectation.[4] Furthermore, theoretically, asset returns and particularly real estate related assets returns, should respond at least as much to the long-term interest rate (or, *the long rate*) as to the short-term interest rate (or, *the short rate*). Yet typically central banks can only influence the short rate directly. Thus, the transmission mechanism of how a monetary policy change leads to the asset market reactions in the presence of an endogenously adjusted term structure can be very interesting. In fact, it is also related to the monetary economics literature. Many studies have shown that money is "neutral" in the long run, in the sense that money growth will

[1] Among others, see Cochrane (2001, 2005), Goodhart and Hofmann (2007), Chang et al. (2010), and the reference therein.

[2] By regulation, REITs are required to invest at least 75% of their assets in real estate and pay the minimum 90% of their taxable earnings as dividends (Chan et al. 2003).

[3] This statement has been confirmed by the data of the U.S. as well as other advanced countries. Among others, see Campbell (1987), Chen (1991), Fama (1990), Ferson (1989), Plosser and Rouwenhorst (1994), Estrella and Mishkin (1997), Estrella and Hardouvelis (1991), and the reference therein. For a review of the more recent literature, see Estrella (2005), Estrella and Trubin (2006), among others.

[4] In the literature of term structure, a lot of efforts have been devoted to verify the "expectation hypothesis." However, Collin-Dufresne (2004) shows that there are several versions of the expectation hypothesis and they are not consistent with one another. Thus, the explicit formulation of the expectation may matter to the final empirical result.

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eventually be matched with proportional price growth (i.e. inflation).[5] Thus, if the central banks cut the short rate and increase the nominal money supply permanently, it may decrease the cost of capital in the short run. At the same time, however, the long run inflation expectation would increase, which in turn push up the long rate. With the short rate decreases and the long rate increases, the interest rate spread would increase, and hence the asset return and real economic activity would be affected. This may be considered as an indirect effect of the monetary policy. We will have further discussion on this point later.

The modelling of the regime switching process can be easily justified as well. It has long been aware that economic time series may be characterized by a Markov regime-switching process, rather than a smooth ARMA process. For instance, Hamilton (1989) shows that the aggregate output in the United States can be characterized by such a process.[6] Regime-switching models have since then been widely used in modelling different classes of asset prices, including stock, option, foreign exchange, interest rate, etc. (among others, see Cai 1994; Bollen et al. 2000; Cheung and Erlandsson 2005; Driffill and Sola 1998; Duan et al. 2002; Froot and Obstfeld 1991; Hansen and Poulsen 2000; Lizieri and Satchell 1997). The literature also suggest that there are significant difference between the REITs listed in the 1990s and those listed before, including the liquidity, size, the degree of focus by property type, financing policy, capital structure, etc. (among others, see Beneveniste et al. 2001; Capozza and Seguin 1998, 1999; Chan et al. 2003; Ott et al. 2005). The conduct of monetary policy has changed over time along different chairmanship of the Fed and during several dramatic episodes of aggregate shocks. Perhaps more importantly, as shown in Chang et al. (2010), a regime switching model is consistent with a scenario *where there is short-run predictability and yet without long-run profitability*, if the regime is persistent. In this paper, our dynamical system follows a regime-switching process, which nests the usual case of single regime as a special case. It enables us to formally test whether the process should be characterized by a single-regime process or a regime-switching one. In addition, it also nests the typical structural break model, where the system can only change the regime once, as another special case. Moreover, we can formally estimate whether the regime in the USA asset market data is indeed persistent.

In terms of the asset markets, this paper would focus on the responses of equity REIT and housing. As a comparison, we will also present the results of stock return in a later section. The importance of REITs has been rapidly increasing in the last 20 years. The increasing securitization of real estate assets has led the total market capitalization of REITs jumped from around

[5] Clearly, it is beyond the scope of this paper to review this large literature. See King and Watson (1994, 1997) and the reference therein.

[6] Since Hamilton (1989), there is a large literature on applying regime-switching process in economics and finance research. For a review of the literature, see Hamilton (1994), among others.

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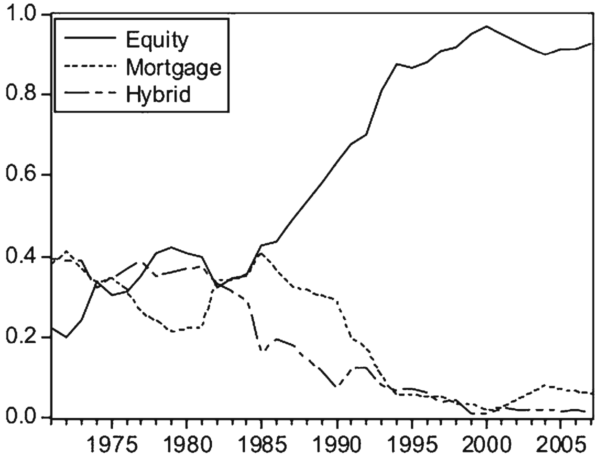

Fig. 1 Market capitalization of various types of REITs as a ratio to total REITs

$0.9 billion in 1975 to $312 billion in 2007.[7] In particular, as Fig. 1 shows, the market capitalization of equity REITs has gained considerable importance in recent years and accounts for more than 90% of total REITs since 1997. Hence, this paper would focus on the equity REIT. As more and more Asian countries (including Japan, South Korea, Singapore, Hong Kong) are developing their REIT markets, the experience of the U.S. REIT market can also serve as an important benchmark for both the academics and policy makers in these Asian countries.[8]

Comparison of the returns between REIT and other assets is not new in the literature. Among others, Glascock et al. (2002a, b), Chan et al. (2005), show that REIT behave more like stocks and less like bonds after early 1990s. This paper builds on their insights and attempts to compare the two returns from a different angle. It is not difficult to see that monetary policy can affect the return of REIT. Interest rate changes may influence how investors discount the value of future cash flows or service flows, and hence the value of real estate assets, commercial real estate (the typical underlying portfolio of REIT) as well as housing. In fact, Chan et al. (2003) decompose the total return of REIT and find that "dividend return" is pretty stable and most of the fluctuations come from the "capital gain return."

On the other hand, there are fundamental differences in the returns on the housing markets (which is a private real estate) and equity REITs (which is a public real estate). For example, most "investors" in the housing market in the United States are individuals who are typically also the occupiers. A very significant share of their wealth are tied to the value of the house. In

[7] According to Datastream, the total US stock market capitalization ("TOTMKUS" which comprises of top 80% of companies in US) is around 15,519.84 billion at the end of 2007. Thus, the total market capitalization of REITs in 2007 accounts for around 2% of the total US stock market capitalization. See also Chan et al. (2003).

[8] Among others, see Ong et al. (2008) and the reference therein.

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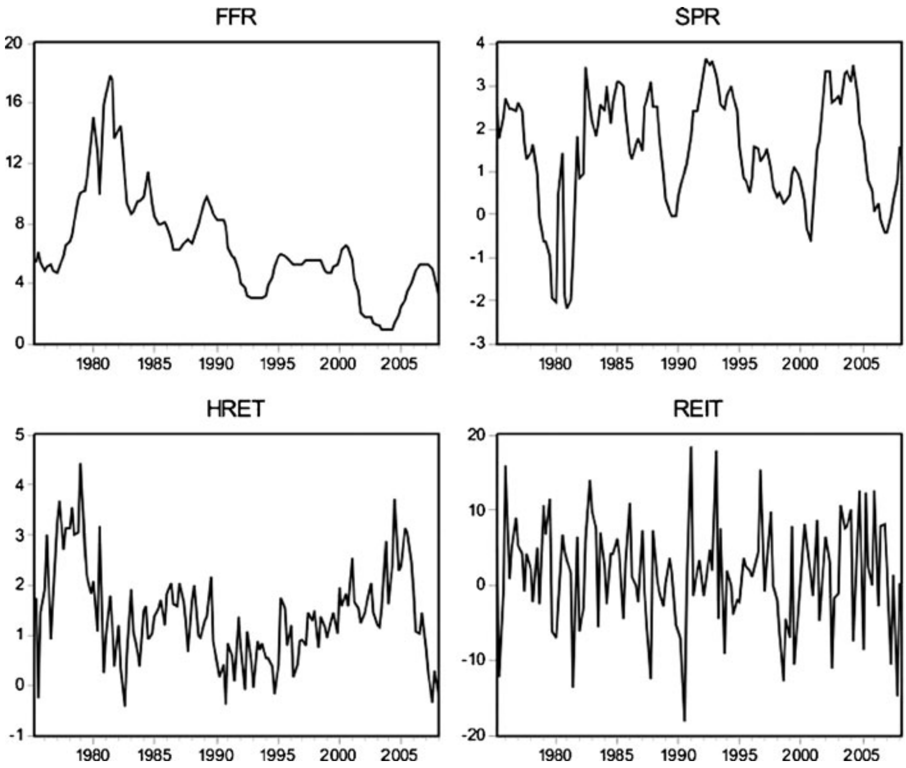

Fig. 2 Federal funds rate (*FFR*), interest rate spread (*SPR*), equity REIT returns (*REIT*), and housing market returns (*HRET*)

contrast, typical investors of REIT are institutional investors and they may have a different preferences for REITs.[9] Furthermore, house price returns are based on residential housing market price index, while the underlying assets of REITs are mostly commercial real estates such as office buildings, shopping centers, and warehouses. Due to these differences, the reactions of REIT return and housing return may indeed be very different. Figure 2 plots the returns of equity REITs and the housing market over time. It is clear that the volatility of equity REITs returns are much larger than that of housing market returns. Table 1 shows the summary statistics of the four variables under investigation, which are the Federal Funds Rates (*FFR*), the housing market returns (*HRET*), the rate of return on equity REITs (*REIT*), and the interest rate spread (*SPR*).[10] Notice that the standard deviation of equity REITs returns are seven times more than that of housing market returns

[9] For instance, see Ciochetti et al. (2002) for empirical evidence. Wang et al. (1995) find that REIT stock with higher percentages of institutional investors tend to perform better.

[10] Throughout this paper, we use nominal return. More discussion on this will be presented in the data section.

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Table 1 Statistical summary of federal funds rate, interest rate spread, housing market returns, and equity REIT returns (1975Q2–2008Q1)

	FFR	SPR	HRET	REIT
Mean	6.464	1.490	1.401	1.519
Median	5.618	1.581	1.345	1.852
Maximum	17.780	3.611	4.425	18.523
Minimum	0.997	−2.182	−0.406	−18.174
Std. Dev.	3.493	1.341	0.947	6.849
Skewness	1.040	−0.604	0.564	−0.182
Kurtosis	4.307	2.904	3.284	3.173
Observations	132.000	132.000	132.000	132.000

FFR denotes the federal funds rate, SPR denotes interest rate spread, HRET means housing market returns, and means equity REIT returns

during the sampling period. In addition, the skewness (in absolute value) for both the term spread and the housing return is above 0.56. The skewness of federal fund rate is even above unity. In addition, the kurtosis of the federal fund rate is above four. All these seem to suggest that a single-regime linear VAR with normally distributed error term might not be able to fit the data very well, and we might need a non-linear econometric model to explain this data set.[11] Table 2 shows that the correlation coefficient of these two returns are only slightly positively correlated.

Next, the transmission mechanisms of monetary policy may be different in the REIT versus housing market.[12] Finally, even within the same market, the response to the monetary policy under difference states of the economy may be different. All these may lead to significantly different response in housing market returns in comparison with REIT returns to changes in monetary policy.

It may be instructive to preview some of the results, which indeed show that the REIT return and housing return behave differently. First, the contemporaneous effect of the spread on either REIT returns or housing market returns is higher than that of federal funds rate in the high volatility regime, but the opposite occurs in the low volatility regime, suggesting that the direct and indirect effect of monetary policy are *regime-dependent*. Second, the contemporaneous effect on REIT returns, either from federal funds rate or the spread, is *much larger* than the effect on housing market returns. Third, the impulse responses of REIT returns to either federal funds rate or the spread are *much larger initially but less persistent* than the responses of housing market returns. Fourth, in response to an innovation in federal funds rate, the

[11] Among others, see Bond and Patel (2003) for further analysis of the higher moment of real estate return.

[12] For example, the impact of policy rate changes on the equity market affects the expected level of future dividends of the firms which can be paid out as dividends for REITs; however, real estate related assets returns should be responding to long-term rate more than to short-term rate, via the influence on general economic activity that feeds through to the demand in the underlying real estate market.

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Table 2 Correlation coefficients (1975Q–2008Q1)

	FFR	SPR	HRET	REIT
FFR	1.000			
SPR	−0.554	1.000		
HRET	−0.055	−0.101	1.000	
REIT	−0.108	0.146	0.211	1.000

responses of housing market returns in the high-volatility regime and the low-volatility one are very different from those of REIT returns. In particular, REIT returns decline substantially in high volatility regime much more than in the low regime, while the responses of housing market returns are smaller in the high volatility regime than in the low regime and in general much smaller than those of REIT returns. Finally, the spread plays a very different role in the transmission mechanism of monetary policy in affecting REITs returns and housing market returns: the spread acts as an *amplifier* for the former, while a *stabilizer* for the latter under some regime. These findings may carry important implications to the conduct of monetary policy and the reactions of the asset markets. More discussion will be followed.

To tie up more closely with the literature, we produce two more sets of results. First, we repeat the exercise with the stock market return. Perhaps surprisingly, we find that the interest rate spread plays no role in the transmission of monetary policy shock to the stock market return. It means that even though REIT is being traded in the financial market, it is still *fundamentally different from stocks* due to its very nature. In addition, we extend our structural VAR system to include the real GDP growth. Most results concerning the asset returns remain unchanged. It demonstrates the robustness of our previous results. It may also have interesting policy implications. We will delay the discussion on these issues to later sections.

Clearly, our paper is related to several strands of literature studying the effect of monetary policy on asset returns and the role of term spread in the transmission of monetary policy. Many works have studied the effect of interest rate variables on the real estate returns. The results from literature seem to be mixed and may suggest some non-linearity. For instance, McCue and Kling (1994) find that interest rates have a very significant influence on equity REIT returns net of stock market influences with a VAR structure. On the other hand, Mueller and Pauley (1995) find insignificant effects on REIT prices from changes in the short and long-term interest rates either in periods when interest rates are high or low. Bredin et al. (2007) find a strong response in both the first and second moments of REIT returns to unexpected federal funds rate changes. Lizieri and Satchell (1997) adopt a threshold autoregressive methodology and find that the relationship between the real rate of interest and property company stock prices for UK is sensitive to high interest and low interest rate regimes. Similarly, a number of papers have shown that the sensitivity of REITs to interest rates is both time-varying and also dependent on the rate used. He et al. (2003) also confirm previous findings showing that REITs are most sensitive to changes in long-term yields and low-grade corporate bonds, and these responses are also time-varying. Tsatsaronis

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and Zhu (2004) also find that the short rate and the spread have very different impact on the housing prices in a cross-country study. Our paper complements the literature by explicitly takes into consideration of the possibility of regime-switching,[13] and how the term spread would affect different asset returns, with an extended data set.

The rest of the paper is organized as follows. Section "The Econometric Analysis" describes the econometric model and gives a statistical summary of the data. Section "Empirical Results" presents the empirical estimation results with the baseline model, which includes the federal funds rate, interest rate spread, and returns, where the returns is either the REIT returns or the housing market returns. Section "Counterfactual Analysis" conducts a counterfactual analysis by shutting off the channel of spread. We also consider a four-variable model, by adding GDP, as a robustness check. Section "Comparison with the Stock Return" considers stock returns, as a comparison with REIT returns. Section "Concluding Remarks" concludes.

The Econometric Analysis

Data

To be comparable to the literature, we employ the U.S. data for our analysis. Since the house price index is available only in quarterly data, other variables originally available in monthly are transformed into quarterly, covering the period of 1975Q1–2008Q1. The basic model includes only four variables, which are *FFR*, *HRET*, *REIT*, and *SPR*. Notice that throughout this paper, nominal returns are used.[14] If we use real asset return, we would need to add the inflation rate as an additional variable. Due to the regime-switching nature of the model, the number of parameters to be estimated will significantly increase and will be a burden given our limited dataset.[15] Also, the inflation rate would be correlated to the short rate and the long rate, which means that adding the inflation rate in the system could create some degree of multicollinearity. More importantly, to calculate the interest spread in real terms, we will need some independent measure for long term inflation expectation, which does not seem to be available. In fact, the literature tend to use the interest rate spread to "extract" long term inflation expectation. Therefore, our benchmark is to have a three-variable system, *FFR*, *SPR*, and one of the real estate return (*REIT* or *HRET*). Since asset returns tend to adjust faster than other macroeconomic

[13]It includes the Hamilton (1989) regime switching model, and the test on the stationarity test for regime-switching model developed by Francq and Zakoian (2001).

[14]Some recent studies of housing market also use nominal prices and returns instead of the real ones, including Himmelberg et al. (2005) and Hott and Monnin (2008), among others.

[15]In spite of this, we will introduce more variables in the analysis in some later sections.

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variables, such as output or capital stock, it may be instructive to focus on a system with only asset returns.[16]

In terms of data construction, the short-term policy rate, i.e. *FFR*, is taken from H.15 statistical release ("Selected Interest Rates") issued by the Federal Reserve Board of Governors. We compute the *HRET* from the housing price index which is taken from the Office of Federal Housing Enterprise Oversight (OFHEO). The *REIT* is taken from the National Association of Real Estate Investment Trusts (NAREIT). For the spread *SPR*, we follow Estrella and Trubin (2006) by choosing the spread between 10-year Treasury bond yield and 3-month Treasury bill rate, and both are released by the Federal Reserve Board of Governors.[17] As for the 3-month Treasury bill rate, since the constant maturity rates are available only after 1982, we use the secondary market 3-month rate expressed on a bond-equivalent basis.[18] Estrella and Trubin (2006) argue that this spread provides an accurate and robust measure in predicting U.S. real activity over long periods of time. Figure 2 plots the time series for these four variables.

As shown by Table 1, the equity REIT returns has about the same mean with the housing market returns, but has a much higher volatility than the housing market returns. The simple correlation coefficients displayed in Table 2 shows that only the federal funds rate is significantly and negatively correlated with the spread, which is around −0.55. The housing market returns are only mildly positively correlated with equity REIT returns. Other pairwise correlation coefficients are in generally low. A more careful investigation of the data will show that these variables are indeed significantly related, and the tool that we employ will be explained in the next section.

The Econometric Model

The econometric model is simple. The structural form of time varying vector autoregression model with lag length p for a process y_t:

$$A_0 y_t = \gamma + A_1 y_{t-1} + A_2 y_{t-2} + ... + A_p y_{t-p} + u_t, \quad (1)$$

where we allow for *all parameters*, including intercept coefficients, autoregressive coefficients, and covariance matrix of stochastic terms to be *contingent on*

[16]The idea that some markets can adjust faster than other markets is not new. See Arrow and Hahn (1971) for a review of the earlier theoretical literature. In addition, asset prices may be more forward-looking than the macroeconomic variables. We will come back to this point in some later sections. See also Dornbusch (1976) for an illustration in the context of an open economy.

For a survey of the sluggish adjustment in the goods market and the labor market, see Taylor (1999), among others.

[17]Treasury securities are also useful because they are not subject to significant credit risk premiums that may change with maturity and over time.

[18]The 3-month secondary market T-bill rate provided by the Federal Reserve System is on a discount basis. We follow Estrella and Trubin (2006) by converting the 3-month discount rate (r^d) to a bond-equivalent rate (r): $r = \frac{365 \times r^d/100}{360 - 91 \times r^d/100} \times 100$.

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the unobservable state variable $s_t \in S$ (to ease the burden of the notations, we suppress the state-dependent subscripts). Vector autoregression model is chosen because it imposes (relatively) less presumptions on the data structure, and it also conveniently parameterize the dynamic interactions within a system.[19] The time varying coefficients capture possible nonlinearities or time variation in the lag structure of the model. The stochastic volatility allows for possible heteroskedasticity of the stochastic terms.

The variables of interest $y_t = (y_{1,t}, y_{2,t}, .., y_{m,t})'$ is a $m \times 1$ vector. The stochastic intercept term $\gamma = (\gamma_1(s_t), \gamma_2(s_t), .., \gamma_m(s_t))'$ captures the difference in the intercept under different states. A_0 is a $m \times m$ state-dependent matrix which measures the *contemporaneous* relationship between variables and the econometric identification of the model is obtained through restrictions on A_0. A_k is a $m \times m$ matrix with each element which is state-dependent $a_k^{(ij)}(s_t)$, $i, j = 1, .., m$, $k = 1, .., p$. The stochastic error term u_t will be explained below.

The corresponding reduced form of the above model can be obtained by pre-multiplying Eq. 1 by A_0^{-1}, which yields:

$$y_t = d + \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + ... + \Phi_p y_{t-p} + \epsilon_t, \tag{2}$$

where $d = A_0^{-1}\gamma$, $\Phi_k = A_0^{-1}A_k$, and $\epsilon_t = A_0^{-1}u_t$, $k = 1, 2, ...p$. Φ_k is a $m \times m$ matrix with each element which is state-dependent $\phi_k^{(ij)}(s_t)$, $i, j = 1, .., m$, $k = 1, .., p$. We further define $d(s_t) \equiv c + \alpha(s_t)$, which will be explained below. The vector of stochastic error term ϵ_t can be further expressed as

$$\epsilon_t = A_0^{-1}u_t = \Lambda(s_t) H^{1/2} v_t(s_t),$$

where H is a $m \times m$ diagonal matrix with diagonal elements σ_j^2, $j = 1, .., m$, $\Lambda(s_t)$ is a $m \times m$ diagonal matrix with diagonal elements $\lambda_j(s_t)$, $j = 1, .., m$,

$$\Lambda(s_t) = \begin{bmatrix} \lambda_1(s_t) & 0 & \cdots & 0 \\ 0 & \lambda_2(s_t) & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \lambda_m(s_t) \end{bmatrix},$$

which captures the difference in the intensity of volatility, and $v_t(s_t)$ is a vector of standard normal distribution, $v_t(s_t) \sim N(0, \Sigma(s_t))$, where the covariance matrix is given by

$$\Sigma(s_t) = \begin{bmatrix} 1 & r_{21}(s_t) & \cdots & r_{m1}(s_t) \\ r_{12}(s_t) & 1 & \cdots & r_{m2}(s_t) \\ \vdots & \vdots & \ddots & \vdots \\ r_{1m}(s_t) & r_{2m}(s_t) & \cdots & 1 \end{bmatrix}. \tag{3}$$

[19] Among others, see Sims (1980) for more discussion on these issues and the potential biases that could arise if single equation approach is adopted instead of the VAR method.

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In this paper, we consider a three-variate time varying $SVAR(p)$ model, i.e., $m = 3$. The three variables of interest are $y_t = (FFR, SPR, RET)'$, where FFR denotes the federal funds rate, SPR is the interest rate spread, and RET denotes either REIT returns ($REIT$) or housing market return ($HRET$).

Given these three variables, we impose restrictions on the elements of A_0 according to theoretical considerations as an identification scheme of the model. A_0 is specified to be a lower triangular matrix:

$$A_0 = \begin{bmatrix} 1 & 0 & 0 \\ a_0^{21}(s_t) & 1 & 0 \\ a_0^{22}(s_t) & a_0^{23}(s_t) & 1 \end{bmatrix}, \tag{4}$$

As shown in Eq. 4, we have imposed a recursive restriction so that $y_{1,t}$ (FFR) affects $y_{2,t}$ (SPR), and both $y_{1,t}$ and $y_{2,t}$ affect $y_{3,t}$ (RET) contemporaneously, but not vice versa. On the other hand, it is still possible for RET to affect FFR and SPR, but with a time lag. Thus, the restriction may not be as stringent as it seems.

Two-State Markov Process

Following the literature of Markov Switching, and being limited by the sample size, we assume that there are only two states, i.e., $s_t \in S = \{1, 2\}$. The procedure of the identification of the regime of the economy for a given period will be discussed below. The Markov switching process relates the probability that regime j prevails in t to the prevailing regime i in $t-1$, $Pr(s_t = j \mid s_{t-1} = i) = p_{ij}$. The transition probability matrix is then given by:

$$P = \begin{pmatrix} p_{11} & 1 - p_{11} \\ 1 - p_{22} & p_{22} \end{pmatrix}.$$

The persistence can be measured by the duration $1/(1 - p_{ii})$, and hence the higher the value of p_{ii}, the higher the level of persistence.

Given that the economy can be either in state 1 or state 2, the term $\alpha_j(s_t)$, $j = 1, .., m$, defined above, captures the difference in the intercept under different states. For convenience, we set $\alpha_j(1) = 0$ for $s_t = 1$, thus $\alpha_j(2)$ measures the difference in the intercept between state 2 and state 1. Furthermore, we set the diagonal element of $\Lambda(s_t)$ at state 1 to be unity, i.e., $\lambda_j(1) = 1$, so that if $\lambda_j(2) > 1$, then the intensity of volatility in state 2 is larger than that in state 1, and vice versa.

Since $v_t(s_t)$ is a vector of standard normal distribution and $\lambda_j(1)$ is set to be one, the variance of $y_{j,t}$, $j = 1, .., m$, at state 1 is σ_j^2, and the variance is $\lambda_j^2(2)\,\sigma_j^2$.

Identification of Regimes

Finally, we discuss the identification of regimes in this model. Since the state of the economy is *unobservable*, we identify the regime for given a time

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period by Hamilton's (1989, 1994) smoothed probability approach, in which the probability of being state s_t at time t is given by $\pi(s_t \mid \Omega_T)$, where $\Omega_T = \{y_1, y_2, ..., y_t, ..., y_T\}$. The idea is that we identify the state of the economy from an ex post point of view, and thus the full set of information is utilized. Notice that we only allow for two regimes in this paper, i.e., $s_t \in S = \{1, 2\}$. Thus, if $\pi\,(s_t = j \mid \Omega_T) > 0.5$, then we identify the economy most likely to be in state j, $j = 1, 2$.

Stationarity of Markov Regime Switching Model

The stationarity test of Markov regime switching model is provided by Francq and Zakoian (2001). To illustrate the idea, take a $VAR(2)$ model as an example. Let

$$\Gamma\,(s_t) = \begin{bmatrix} \Phi_1\,(s_t) & \Phi_2\,(s_t) & 0_3 \\ I_3 & 0_3 & 0_3 \\ 0_3 & 0_3 & 0_3 \end{bmatrix},$$

where I_3 is a 3×3 identity matrix, 0_3 is 3×3 null matrix, and $\Phi_1\,(s_t)$ and $\Phi_2\,(s_t)$ are the autoregression matrices in Eq. 2. We then define the following matrix

$$\Xi = \begin{bmatrix} p_{11} \times (\Gamma\,(1) \otimes \Gamma\,(1)) & p_{21} \times (\Gamma\,(1) \otimes \Gamma\,(1)) \\ p_{12} \times (\Gamma\,(2) \otimes \Gamma\,(2)) & p_{22} \times (\Gamma\,(2) \otimes \Gamma\,(2)) \end{bmatrix}, \tag{5}$$

and let $\rho\,(\Xi)$ be the spectral radius of Ξ . Francq and Zakoian (2001) show that a sufficient condition for second-order stationarity of a Markov switching $VAR(2)$ model is $\rho\,(\Xi) < 1$.

Empirical Results

Equity REIT Returns

We first examine the impact and transmission of monetary policy on equity REIT returns. To begin with, we consider the model selection problem. Recall that in the model 2, we allow for all parameters, including intercepts ($\alpha\,(s_t)$), autoregressive coefficients ($\Phi_k\,(s_t)$), volatilities and correlation coefficients of stochastic terms ($\Lambda\,(s_t)$ and $\upsilon_t\,(s_t)$), to be state-contingent. We first examine whether this model is indeed better than alternative specifications. We compare the model based on Akaike's information criterion (AIC) with other three specifications: (A) only $\alpha\,(s_t)$ and $\Lambda\,(s_t)$ are state-contingent; (B) only $\alpha\,(s_t)$, $\Lambda\,(s_t)$, and $\upsilon_t\,(s_t)$ are state-contingent; and (C) only $\alpha\,(s_t)$, $\Phi_k\,(s_t)$, and $\Lambda\,(s_t)$ are state-contingent. The model 2 is labeled as model (D). Together with the single-regime model where all parameters are non-state-contingent, the results are summarized in Table 3. It is clear that, with lag period chosen to be one ($p = 1$), model D, i.e., Eq. 2, is the best for having the lowest value of AIC. In

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Table 3 AIC values for various three-variable VAR(p) models

VAR model	What are state-contingent	p = 1
Single-regime model	None	10.625
2-Regime model (A)	$c(s_t)$, $\Lambda(s_t)$	9.951
2-Regime model (B)	$c(s_t)$, $\Lambda(s_t)$, $v_t(s_t)$	9.928
2-Regime model (C)	$c(s_t)$, $\Lambda(s_t)$, $\Phi_k(s_t)$	9.945
2-Regime model (D)	$c(s_t)$, $\Lambda(s_t)$, $\Phi_k(s_t)$, $v_t(s_t)$	9.916

the following we report only the estimation results of the single-regime model and the best-performing model 2.

To see whether the choice of lag period $p = 1$ is justified, we will perform two tests. First, we test for the autocorrelation of the residuals. The LM tests reported in Table 4 suggests that the residuals of $SVAR(1)$, for both single-regime model and Markov-switching model, cannot reject the null hypothesis that the residuals are white noise. This result increases the credibility of our model.

Second, we test for the dynamic stationarity of our Markov switching $SVAR(1)$ model using the method proposed by Francq and Zakoian (2001). We calculate the spectral radius of Ξ specified in Eq. 5 and the result shows that $\rho(\Xi) = 0.919 < 1$. This says that our Markov switching $SVAR(1)$ model is second-order stationary. Thus, we will proceed the estimation and conduct the impulse responses with the $SVAR(1)$.

Table 5 reports estimation results of the three-variate SVAR (*FFR, SPR, REIT*) under single-regime model and the Markov switching model 2. Many coefficients are statistically significant, providing support to the validity of the model. It also shows that the performance of the regime-switching model is superior to the linear VAR model through the log-likelihood ratio.

For the Markov switching model, recall that we set the volatility at regime 1 $\lambda_j(1) = 1$, thus the element $\lambda_j(2)$ measures the relative volatility of regime 2 over regime 1. From Table 5, we can see that the estimated values of relative volatility $\lambda_j(2)$ are significantly less than one for $j = 1$ and 2, which means that *for both federal funds rate and the spread the volatility in regime 2 is lower than in regime 1*. On the other hand, $\lambda_3(2)$ is larger than one, but statistically insignificant, which suggests that *for the REIT returns there is no significant difference in volatility across regimes*. Specifically, the value of variance of the federal funds rate is 2.659 (σ_1^2) in regime 1 and 0.241 ($\sigma_1^2 \times \lambda_1^2(2)$). For the spread, they are 0.902 in regime 1 and 0.203 in regime 2. For the REIT returns,

Table 4 LM tests of autocorrelation for VAR(1) model of FFR, SPR, and REIT

k	Single-regime model	Model D (two-regime model)
3	7.549	12.029
6	9.794	11.098
9	7.809	12.122

The null hypothesis of LM test is that there is no autocorrelation for residuals up to order k. The statistic follows the χ^2 distribution with 9 degrees of freedom. The value of χ^2 distribution with 9 degrees of freedom at 5% significance level is 16.919

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Table 5 The estimation results for FFR, SPR, and REIT

Parameter	VAR model		Markov switching model (model D)			
	Single regime		Regime 1		Regime 2	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
c_1	0.302	0.334	3.767[b]	1.507	3.767	1.507
$\alpha_1(2)$					−3.761[b]	1.600
$\phi_1^{(11)}$	0.957[a]	0.047	0.690[a]	0.113	0.977[a]	0.045
$\phi_1^{(12)}$	−0.060	0.075	−0.457[b]	0.192	0.036	0.047
$\phi_1^{(13)}$	0.030[b]	0.012	0.094[b]	0.043	0.007	0.008
σ_1^2	0.923[a]	0.298	2.659[b]	1.208	2.659[b]	1.208
$\lambda_1(2)$					0.301[a]	0.066
c_2	0.077	0.216	−1.302	0.895	−1.302	0.895
$\alpha_2(2)$					1.578[c]	0.956
$\phi_1^{(21)}$	0.015	0.030	0.132[c]	0.068	−0.021	0.034
$\phi_1^{(22)}$	0.903[a]	0.049	1.013[a]	0.116	0.896[a]	0.044
$\phi_1^{(23)}$	−0.019[b]	0.008	−0.077[a]	0.026	−0.003	0.006
σ_2^2	0.425[a]	0.099	0.902[a]	0.326	0.902[a]	0.902
$\lambda_2(2)$					0.474[a]	0.088
c_3	−0.740	3.074	6.537	8.206	6.537	8.206
$\alpha_3(2)$					−5.319	8.702
$\phi_1^{(31)}$	0.098	0.317	−0.395	0.668	−0.258	0.395
$\phi_1^{(32)}$	1.083	0.659	0.939	0.855	0.840	0.651
$\phi_1^{(33)}$	0.007	0.078	−0.086	0.177	−0.012	0.039
σ_3^2	44.874[a]	5.617	36.089[a]	6.093	36.089[a]	6.093
$\lambda_3(2)$					1.127	0.127
r_{12}	−0.782[a]	0.066	−0.846[a]	0.081	−0.652[a]	0.073
r_{13}	−0.148[b]	0.072	−0.380[a]	0.148	−0.132	0.103
r_{23}	0.033	0.079	0.074	0.203	−0.075	0.108
p_{11}	0.956[a] (0.030)					
p_{22}	0.991[a] (0.007)					
$\ln L$	−683.219		−616.436			

Values in parenthesis are standard deviations. Moreover, the null hypothesis for scale parameter is $\lambda_i(2) = 1$

[a]Represent the significance at 1%

[b]Represent the significance at 5%

[c]Represent the significance at 10%

it is 36.089 in regime 1 and 45.838 in regime 2. Thus, no matter which regime, REIT returns has the highest volatility.

Figure 3 plots the estimated smoothed probabilities for regimes 1 and 2 respectively. The left panel shows the probabilities of the economy being in regime 1 (i.e. high volatility regime) at a given period. The right panel mirrors the left panel, showing the probabilities of being in regime 2.

The Markov switching model here identifies two regimes for this monetary policy tool: a high volatility regime (regime 1) and a low volatility regime

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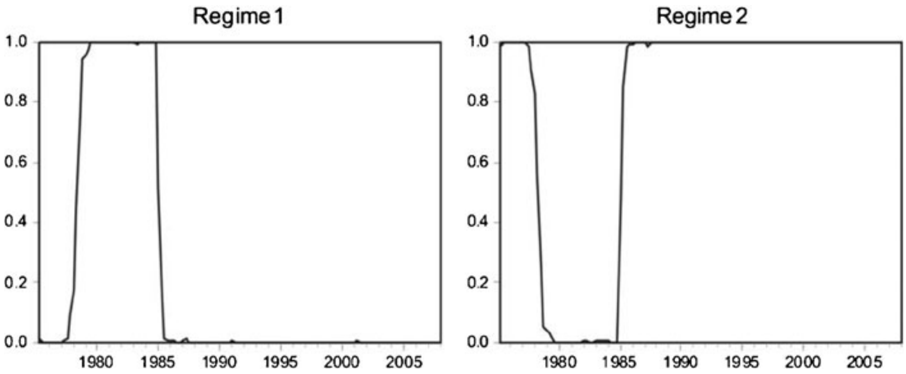

Fig. 3 Smoothed probabilities for SVAR(1) model of (FFR, SPR, REIT)

(regime 2). The high volatility regime accounts for 20.45% of the total sample periods, while the latter 79.55%. Based on these two regimes, only the period 1978Q3–1985Q1 is identified as the high volatility regime (regime 1).[20] This period coincided with the aftermath of the first and the second oil crises, and P. Volcker being appointed as Chairman of the Federal Reserve.[21]

The transition probability matrix is estimated to be

$$P = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} = \begin{pmatrix} 0.956 & 0.044 \\ 0.009 & 0.991 \end{pmatrix},$$

which means that both regimes are actually very persistent. In other words, it may not be easy to predict the timing of the regime-change. It is also consistent with the notion of short run predictability without long run profitability. Loosely speaking, the market is efficient in the long run.

The matrix A_0 measuring the contemporaneous relationship between variables for the single-regime model is estimated to be

$$A_0 = \begin{bmatrix} 1 & 0 & 0 \\ 0.5309 & 1 & 0 \\ 3.1235 & 3.9404 & 1 \end{bmatrix}. \tag{6}$$

[20] One may be tempted to remove the data prior to 1985Q2 and thus focus on a single-regime case. First, we did not know the high volatility regime is concentrated in one period (1978Q3–1985Q1). Second, the early period (1975Q2–1978Q2) still belongs to the regime 2. If we remove all the data before 1985Q2, the estimation of the regime 2 parameters will become less precise, some may even be mis-labelled as insignificant. Perhaps more importantly, as we will see in the next section, the high-volatility regime for housing return is very different from that of the REIT. Thus, it may still be wise to use the full sample to estimate the regime-switching model, rather than to artificially cut off some earlier periods and estimate a linear VAR model.

[21] Among others, Goodfriend and King (2005) and Goodfriend (2007) provides a summary of the history of monetary policy during that period.

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The estimated result of A_0 can then be more conveniently expressed as the following to show the contemporaneous effects among variables,

$$FFR_t = 0 \times SPR_t + 0 \times REIT_t + ...$$

$$SPR_t = -0.5309 \times FFR_t + 0 \times REIT_t + ...$$

$$REIT_t = -3.1235 \times FFR_t - 3.9404 \times SPR_t + ...$$

This says that the spread contemporaneously declines by 0.5309% for 1% increase in the federal funds rate, and the contemporaneous effect of spread on REIT returns (3.9404%) is higher than that of federal funds rate on REIT returns (3.1235%).

As for the regime switching model, the regime-dependent transition matrices for regimes 1 and 2 are the following,

$$A_0(1) = \begin{bmatrix} 1 & 0 & 0 \\ 0.4927 & 1 & 0 \\ 4.1106 & 5.4990 & 1 \end{bmatrix}, A_0(2) = \begin{bmatrix} 1 & 0 & 0 \\ 0.5995 & 1 & 0 \\ 4.3389 & 4.1928 & 1 \end{bmatrix}. \quad (7)$$

There is an interesting difference between these two models. A comparison of Eqs. 6 and 7 reveals that the contemporaneous effect of the spread higher than that of federal funds rate on REIT returns which we found in the single-regime model occurs here only in regime 1 (high volatility regime), i.e., 5.4990% over 4.1106%. In regime 2 (low volatility regime), on the contrary, the contemporaneous effect of the spread on REIT returns (4.1928%) is lower than that of federal funds rate on REIT returns (4.3389%) .

We then conduct impulse responses for the $SVAR(1)$ model. Throughout this paper, as in many papers, the vertical axis measures the percentage change of the variable relative to its own steady state value. The convention is that a value of unity means 100% of its steady state value. In Fig. 4, the solid line represents results from single regime model, and two dotted lines represent results when the economy is in regime 1 (high volatility), and regime 2 (low volatility). An immediate observation is that the dynamics of impulse responses in high volatility regime are much more volatile than that in low volatility regime. Next, for either regime 1 or regime 2, REIT returns

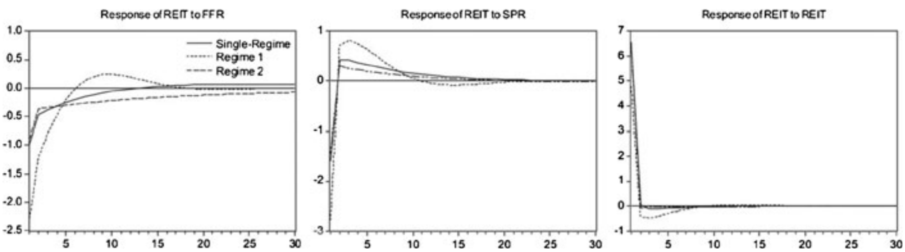

Fig. 4 Impulse responses of REIT for (FFR, SPR, REIT)

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Table 6 AIC values for various three-variable VAR(p) models

VAR model	p = 1	P = 2
Single-regime model	6.120	6.084
Model A (two-regime model)	5.403	5.059
Model B (two-regime model)	5.402	4.972
Model C (two-regime model)	6.330	4.907
Model D (two-regime model)	5.308	4.781

The three variables are FFR, SPR, and HRET

respond to innovations in spread more strongly initially but less persistent than innovations in federal funds rate. Also, under the low volatility regime, which constitutes about 80% of the sampling period, the impulse response of the REIT return to an innovation in REIT return itself quickly dies out in two quarters, which seems to be consistent with the view that the REIT market is very efficient in “digesting and absorbing” the news of itself.

Housing Market Returns

We now turn to the impact and transmission of monetary policy on housing market returns. Again, we first consider the model selection problem. As before, we compare the general model 2 with other alternatives with lag period chosen to be one ($p = 1$) and two ($p = 2$). Table 6 reports the results. It is clear that the model 2 with a lag period of $p = 2$, labeled Model D, is the best for having the lowest value of AIC.

As in the case of REIT, we will use two tests to justify the choice of lag period $p = 2$. As in the case of REIT return, we first test for the autocorrelation of the residuals. For both the single-regime model and Markov-switching model, the LM tests reported in Table 7 suggest that the residuals of $SVAR(2)$ cannot reject he null hypothesis that the residuals are white noise. Now we test for its dynamic stationarity by computing the spectral radius of Ξ specified in Eq. 5. We find $\rho(\Xi) = 0.888 < 1$, which says that the model is second-order stationary.

Table 8 reports estimation results of the three-variate SVAR (*FFR, SPR, HRET*) under single-regime model and the Markov switching model 2. Again, it shows that the Markov switching model performs better. The estimated

Table 7 LM tests for autocorrelation for VAR(p) model of FFR, SPR, and HRET

k	Single-regime model		Model D (two-regime model)	
	p = 1	P = 2	p = 1	P = 2
3	11.784	13.238	10.755	5.550
6	20.819	14.992	21.362	15.476
9	5.933	7.648	6.633	6.606

The null hypothesis of LM test is that there is no autocorrelation for residuals up to order k. The statistic follows the χ^2 distribution with 9 degrees of freedom. The value of χ^2 distribution with 9 degrees of freedom at 5% significance level is 16.919

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Table 8 The estimation results for FFR, SPR, and REIT

Parameter	VAR model		Markov switching model (model D)			
	Single regime		Regime 1		Regime 2	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
c_1	−0.360	0.332	−0.535	1.606	−0.535	1.606
$\alpha_1(2)$					0.136	1.593
$\phi_1^{(11)}$	1.068[a]	0.215	0.662[c]	0.385	1.763[a]	0.142
$\phi_1^{(12)}$	−0.095	0.205	−0.556	0.458	0.320[b]	0.143
$\phi_1^{(13)}$	0.377[b]	0.167	1.145[c]	0.667	0.070	0.059
$\phi_2^{(11)}$	−0.092	0.226	0.260	0.356	−0.754[a]	0.144
$\phi_2^{(12)}$	0.145	0.210	0.554	0.422	−0.219	0.149
$\phi_2^{(13)}$	−0.084	0.115	−0.016	0.270	0.074	0.064
σ_1^2	0.836[a]	0.287	2.343[a]	0.664	2.343[a]	0.664
$\lambda_1^{(21)}$					0.218[a]	0.030
c_2	0.483[b]	0.224	1.648	1.161	1.648	1.161
$\alpha_2(2)$					−1.098	1.152
$\phi_1^{(21)}$	0.129	0.138	0.323	0.261	−0.558[a]	0.086
$\phi_1^{(22)}$	1.127[a]	0.138	1.170[a]	0.310	0.930[a]	0.092
$\phi_1^{(23)}$	−0.117	0.103	−0.381	0.353	−0.014	0.049
$\phi_2^{(21)}$	−0.128	0.139	−0.358	0.247	0.511[a]	0.080
$\phi_2^{(22)}$	−0.280[a]	0.136	−0.442	0.305	−0.108	0.090
$\phi_1^{(23)}$	−0.065	0.077	−0.270	0.200	−0.042	0.050
σ_2^2	0.401[a]	0.093	1.050[a]	0.361	1.050[a]	0.361
$\lambda_2(2)$					0.290[a]	0.055
c_3	0.242	0.212	3.619[a]	1.544	3.619[a]	1.544
$\phi_3(2)$					−3.602[b]	1.517
$\phi_1^{(31)}$	−0.052	0.107	−0.228	0.187	0.158	0.185
$\phi_1^{(32)}$	−0.078	0.168	−0.351	0.242	0.011	0.171
$\phi_1^{(33)}$	0.486[a]	0.098	−0.193	0.161	0.600[a]	0.100
$\phi_2^{(31)}$	0.052	0.115	0.076	0.191	−0.140	0.180
$\phi_2^{(32)}$	0.151	0.163	−0.048	0.269	0.118	0.145
$\phi_2^{(33)}$	0.256[a]	0.086	−0.075	0.276	0.184[b]	0.084
σ_3^2	0.483[a]	0.067	0.464[a]	0.152	0.464[a]	0.152
$\lambda_3(2)$					0.917	0.190
r_{23}	−0.787[a]	0.062	−0.900[a]	0.138	−0.420[a]	0.108
r_{13}	−0.128	0.178	−0.047	0.818	−0.138	0.147
r_{23}	−0.018	0.181	−0.048	0.723	−0.030	0.145
p_{11}	0.919[a] (0.085)					
p_{22}	0.972[a] (0.039)					
$1\text{n}L$	−374.572		−259.535			

Note: Values in parenthesis are standard deviations. Moreover, the null hypothesis for scale parameter is $\lambda_i(2) = 1$

[a]Represent the significance at 1%

[b]Represent the significance at 5%

[c]Represent the significance at 10%

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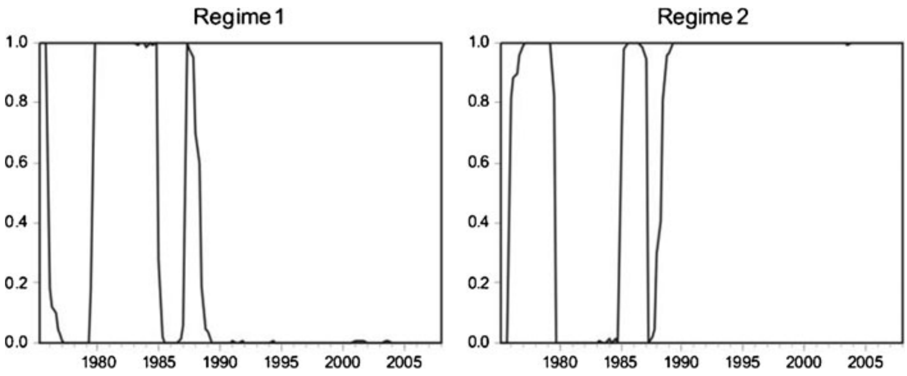

Fig. 5 Smoothed probabilities for SVAR(2) model of (FFR, SPR, HRET)

values of relative volatility $\lambda_j(2)$ are significantly less than one for all j (in fact, they are numerically less than 0.3), meaning that for the volatilities of all three variables under regime 2 are significantly lower. In terms of the absolute magnitude, the volatility of housing market returns are far less than those of REIT returns. [22]

The left panel of Fig. 5 plots the estimated smoothed probabilities for regime 1 (i.e. the high-volatility regime) and the right panel shows the probabilities of being in regime 2 (i.e. the low-volatility regime). The high volatility regime accounts for 21.97% of the total sample periods, a little bit higher than the previous subsection. Three time periods are identified as having high volatilities: 1975Q2–1975Q4, 1979Q4–1984Q4, and 1987Q2–1988Q2. The second time period (1979Q4–1984Q4) closely overlaps with the period identified as high volatility regime when REIT returns was under investigation (1978Q3–1985Q1). Yet housing returns and REIT returns are different. The REIT returns display low volatility in the other two periods for housing returns to display high volatility. The first one (1975Q2–1975Q4) was related to the aftermath of the first oil crisis, and the third one (1987Q2–1988Q2) coincided with the 1987 stock market crash.[23]

The transition probability matrix is estimated to be

$$P = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} = \begin{pmatrix} 0.919 & 0.081 \\ 0.028 & 0.972 \end{pmatrix},$$

which means both regimes are very persistent, as in the case of REIT. In addition, the low volatility regime is more persistent than in high volatility

[22] The value of variance of the federal funds rate is 2.343 (σ_1^2) in regime 1 and 0.111 ($\sigma_1^2 \times \lambda_1^2(2)$). For the spread, they are 1.050 in regime 1 and 0.088 in regime 2. Finally, the housing market returns is 0.464 (σ_3^2) in regime 1 and 0.390 (($\sigma_3^2 \times \lambda_3^2(2)$) in regime 2.

[23] Clearly, it is beyond the scope of this paper to review the literature on the 1987 stock market crash. Among others, see Schwert (1990).

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regime. The matrix A_0 measuring the contemporaneous relationship between variables for the single-regime model is estimated to be

$$A_0 = \begin{bmatrix} 1 & 0 & 0 \\ 0.5451 & 1 & 0 \\ 0.2829 & 0.3407 & 1 \end{bmatrix}.$$

Similar to the case of REIT returns, the contemporaneous effect of the spread on housing market returns (0.3407%) is higher than that of federal funds rate on housing market returns (0.2829%).

As for the regime switching model,

$$A_0(1) = \begin{bmatrix} 1 & 0 & 0 \\ 0.6024 & 1 & 0 \\ 0.2118 & 0.3167 & 1 \end{bmatrix}, A_0(2) = \begin{bmatrix} 1 & 0 & 0 \\ 0.3746 & 1 & 0 \\ 0.3431 & 0.2252 & 1 \end{bmatrix}.$$

Note that the contemporaneous effect of the spread on housing market returns (0.3167%) is higher than that of federal funds rate on housing market returns (0.2118%) in the high volatility regime, but the opposite occurs in the low volatility regime. This exhibits a similar pattern to the case of REIT returns. The difference is that the contemporaneous effect on REIT returns, either from federal funds rate or the spread, is much larger than the effect on housing market returns.

Figure 6 shows the impulse response of the *SVAR*(2) model. As before, the solid line represents results from single regime model, and two dotted lines represent results when the economy is in regime 1 (high volatility), and regime 2 (low volatility). Several interesting observations are in order. First, the impulse responses of housing market returns to either federal funds rate or the spread are *smaller in value but much more persistent* than the responses of REIT returns. This seems to be sensible as REIT is being traded in a centralized market ("exchange") while housing units are traded in a very decentralized manner, through search and bargaining. Hence, policy would have more persistent effect in the housing market. Second, in response to an innovation in federal funds rate, the responses of housing market returns in regimes 1 and 2 are very different from those of REIT returns. In particular, recall that Fig. 4 shows that REIT returns decline much more substantially

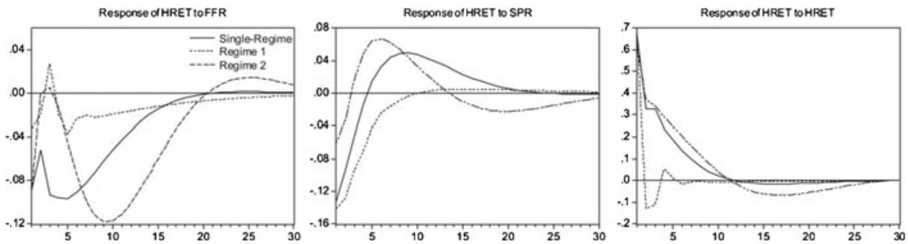

Fig. 6 Impulse responses of HRET for (FFR, SPR, HRET)

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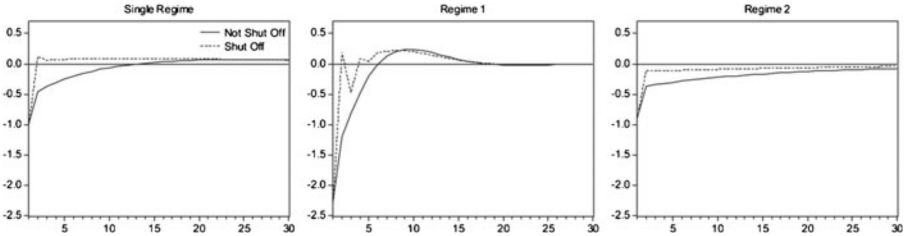

Fig. 7 Impulse responses of REIT to innovations in FFR when the effect of SPR is shut off (FFR, SPR, REIT)

in regime 1 than in regime 2. But in Fig. 6 the responses of housing market returns exhibits a pattern opposite to those of REIT returns. Interestingly, the impulse response of the housing return to its own innovation during the regime 1 effectively dies out after six quarters, while the same response under regime 2 lasts more than 20 quarters.

Counterfactual Analysis

The results in the previous sections reveal that the monetary shock affect the real estate returns (REIT and housing) through two channels. On top of the "direct channel" (from *FFR* directly to *REIT* or from *FFR* directly to *HRET*), a monetary policy change would also affect the term spread *SPR*, which in turn affect the real estate returns (the "indirect channel"). To assess the relative importance of the direct versus the indirect channels, we conduct a counterfactual analysis by shutting off the effect of the spread on returns. Specifically, we set to zeros both the contemporaneous response of returns to spread, $a_0^{23}(s_t)$ in Eq. 1, as well as any lagged response of returns to spread given by $a_k^{23}(s_t)$, $k = 1$ for responses of REITs and $k = 1, 2$, for housing returns in Eq. 1 which govern the influence of lagged spreads on returns, fixing the covariance matrix of the structural errors u_t at its baseline value. Since we focus on the impulse response of an innovation of the FFR, freezing all other shocks to be zero throughout the experiment, this counterfactual exercise effectively eliminates the marginal impact of spread on returns (REITs and HRET, respectively) and highlight the direct channel only.

Figures 7 and 8 show that the (conditional) impulse responses of returns on REITs and housing market returns, respectively, to innovations of the federal funds rate with and without shutting off the spread channel.[24] Figure 7 shows that shutting off the spread channel to REIT returns dwarfs the impact on

[24]Throughout this paper, it is assumed that the dynamic system always stays in the same regime when the impulse response exercise is conducted. The results in the previous sections show that for both REIT and housing returns, the regimes are very persistent. Thus, this assumption may not be as strong as it seems.

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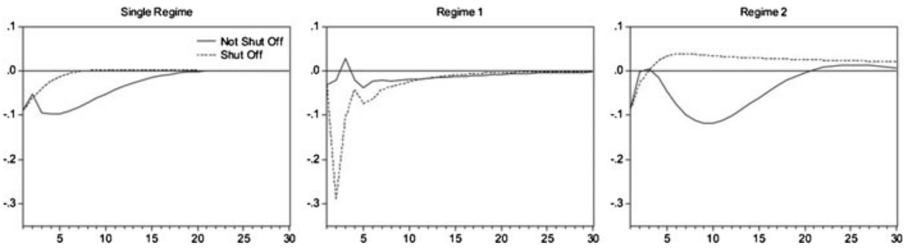

Fig. 8 Impulse responses of HRET to innovations in FFR when the effect of SPR is shut off (FFR, SPR, HRET)

the response of REIT returns to a federal funds rate shock both in terms of magnitude and persistence, whether under the single-regime or two-regime econometric model. The means that *interest rate spread amplifies the effect of monetary policy on the REIT returns*.

The case for the housing return is very different. Figure 8 shows that the response to the federal funds rate in regime 1 exhibits a volatility several times larger than the case when the spread channel is shut off. This suggests that *the spread dampens the effect of monetary policy on housing market returns* particularly in the high volatility regime. In regime 2, however, the effect is different. The impulse response with the full effect exhibits almost like a cycle for more than 20 quarters. With the spread channel shut off, the response becomes smaller but also more persistent. This demonstrates that the spread plays a very different role in the transmission mechanism of monetary policy in affecting different asset returns and also under different regimes.

What is the intuition behind this result? It may reflect the difference in financing of the housing and REIT market. First of all, when the short-term rate decreases following an expansionary monetary policy, the stimulation on the aggregate demand will raise both returns of housing and REITs. Then, as discussed in the introduction, the rise in the long run inflation expectation due to the expansionary monetary policy will push up the long rate, leading the interest rate spread to increase. The rises in the long term rate and the spread tend to suppress house prices due to a higher discount rate, or a higher borrowing cost. This is because many households in the United States finance the mortgage with a 30-year fixed rate mortgage (we will get back to this point later). Hence, an increase in the term structure directly translate into an increase in the financing cost. Therefore, the spread appears as a stabilizer for the housing returns.

On the other hand, since underlying assets of equity REITs are mostly commercial real estates, the returns would be more sensitive to business cycle. It is possible that the potential customers (i.e. renters) of those commercial real estate are heavily dependent on the short term rolling-over loan for finance, which would have significant effect on their business scale, including the amount of commercial real estate rental. Therefore, an expansionary monetary policy not only leads to a decrease in the short rate, but may also encourage

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them to switch to a higher proportion of short term financing, which tend to make them even more sensitive to further changes in the short rate in the future. And as discussed earlier, the literature finds that an upward yield curve tends to be associated with a rise in economic prospect. Therefore, this further stimulates the returns of REITs and thus the spread acts as an amplifier.

Robustness Check

Recall that the benchmark econometric model concerns only the interactions among asset returns. It may be justified on the ground that asset markets in general adjust faster than the real economy.[25] On the other hand, it is sensible to ask whether the additional consideration of some macroeconomic variable will alter the results. For instance, changes in monetary policy would affect output which then feedbacks to the asset returns, and therefore we have to control for the effect of monetary policy on output in order to characterize the behavior of REIT and housing market returns. In addition, real estate returns are linked to the macroeconomy and business conditions (Ling and Naranjo 1997; Liu and Mei 1992), and term spread has been identified to have considerable predictive power on future economic activity (Laurent 1988; Fama and French 1989; Estrella and Hardouvelis 1991; Estrella 2005; Rosenberg and Maurer 2008).[26] However, due to complexity of our model, adding more variables would significantly increase the number of parameters to be estimated. Therefore, we can only consider four-variate models to check the robustness of our results. Since aggregate consumption is well known to be "too smooth" to explain asset returns,[27] we return to the real output for our robustness check. Specifically, we estimate the models (*FFR, SPR, GDP, REIT*) and (*FFR, SPR, GDP, HRET*) following the procedure outlined above, where *GDP* represents the growth rate of the aggregate output in real terms.[28]

Figures 9 and 11 presents the identified regimes for the four-variate models. As shown in Fig. 9, the four-variate model identifies the regime 1 (high

[25] Among others, see Dornbusch (1976) for an illustration.

[26] For example, Rosenberg and Maurer (2008) confirm term spread to be a leading indicator of recession, and the expectations component, rather than term premium, of the term spread is important in explaining the role of term spread in predicting recession. Laurent (1988) uses the yield curve as an indicator of monetary policy, and finds it statistically associated with the subsequent pace of output growth. Estrella and Hardouvelis (1991) find that the yield curve performed well in predicting aggregate GNP, consumption, investment, and recessions.

[27] There is a large empirical literature behind this fact. Among others, see Cochrane (2001, 2005) for a review.

[28] Notice that real GDP is non-stationary. Thus, we follow the literature to use the real GDP growth as the additional variable in our regression. Due to the space limit, here we present only figures of identified regimes and impulse responses. The estimated results of parameter values for these two models are omitted to save space. They are available upon request. Furthermore, a caveat for estimating the model with housing market returns (*FFR, SPR, GDP, HRET*) is that the AIC determines the model to have two lags, as in the three-variate model; however, with two lags the total number of parameters to be estimated amounts to 94. We therefore allows only one lag while estimating this model.

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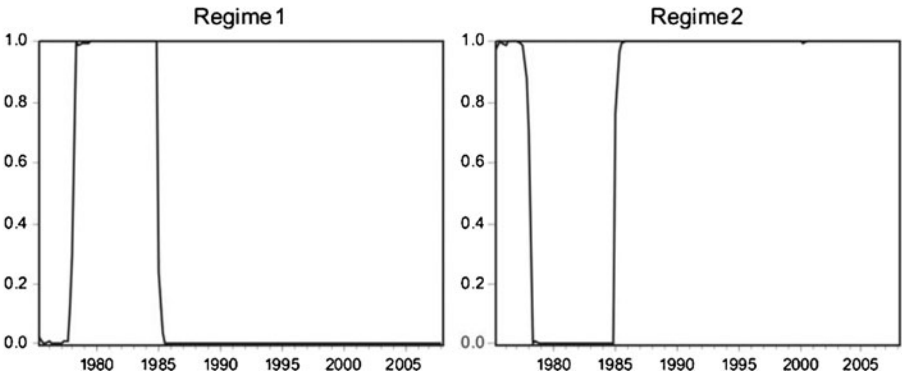

Fig. 9 Smoothed probabilities for SVAR(1) model of (FFR, SPR, GDP, REIT)

volatility regime) with only one quarter lead when compared with the three-variate model for REIT returns. The high volatility regime accounts for 20.45% of the total sample periods, identical to the three-variate model (Fig. 10). For the housing market returns in Fig. 11, the high volatility regime

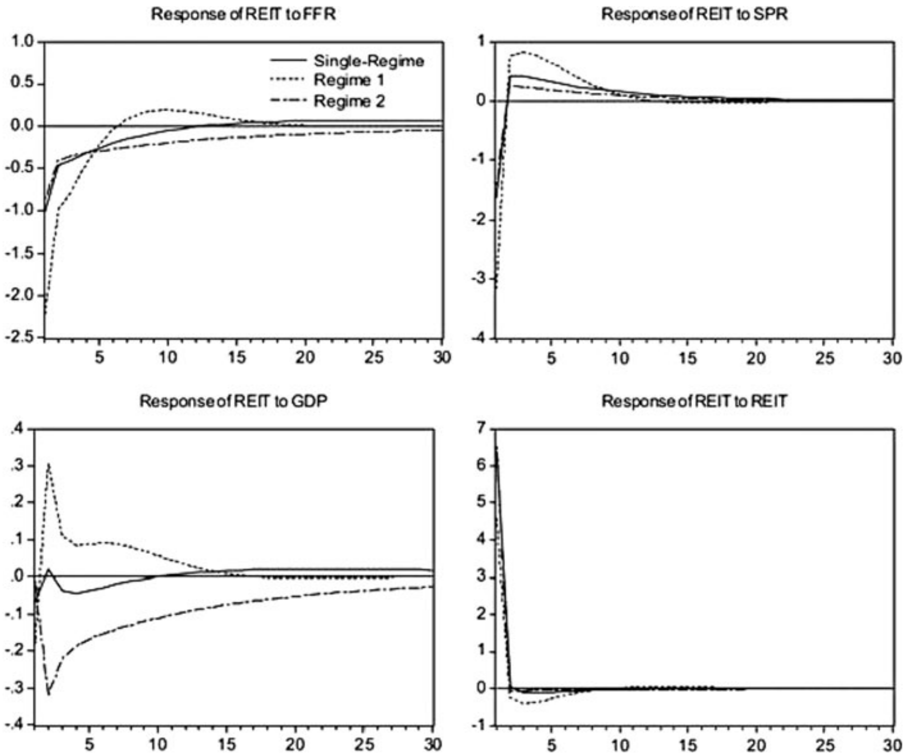

Fig. 10 Impulse responses of REIT for (FFR, SPR, GDP, REIT)

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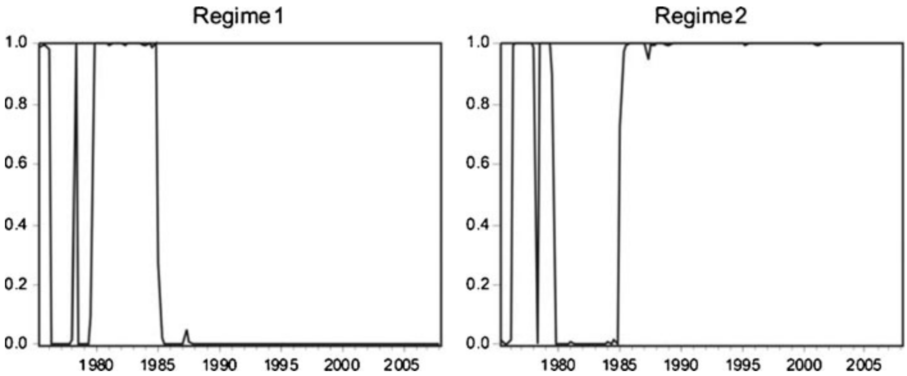

Fig. 11 Smoothed probabilities for SVAR(1) model of (FFR, SPR, GDP, HRET)

accounts for 18.93% of the total sample periods, only a little bit lower than that in the three-variate model.

The patterns of impulse responses in Figs. 10 and 12 are also very similar to the three-variate models in Figs. 4 and 6, for the response of REIT and HRET

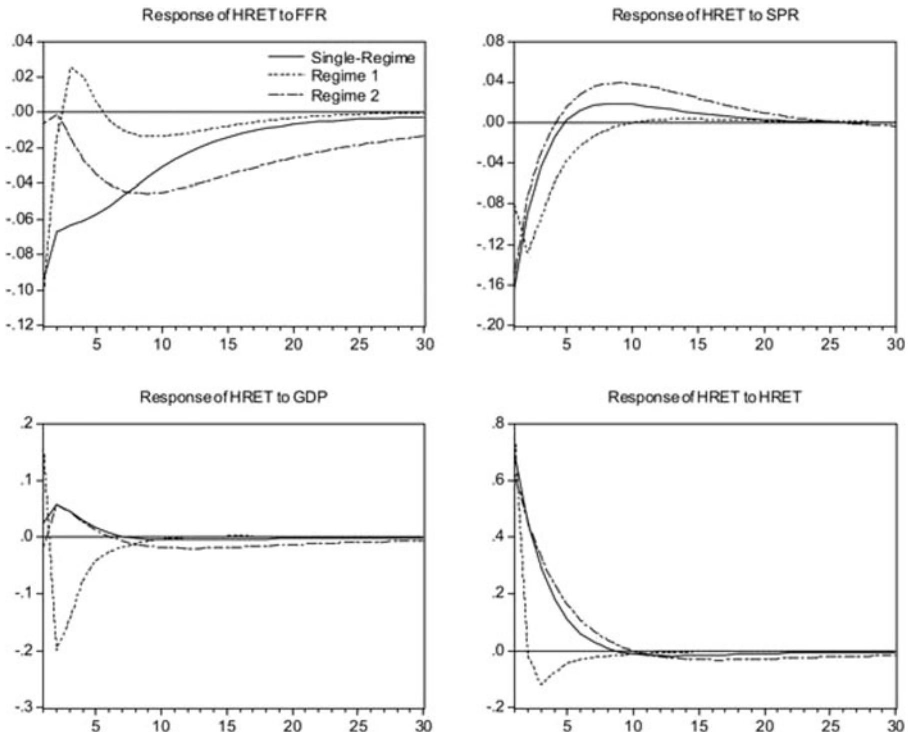

Fig. 12 Impulse responses of HRET for (FFR, SPR, GDP, HRET)

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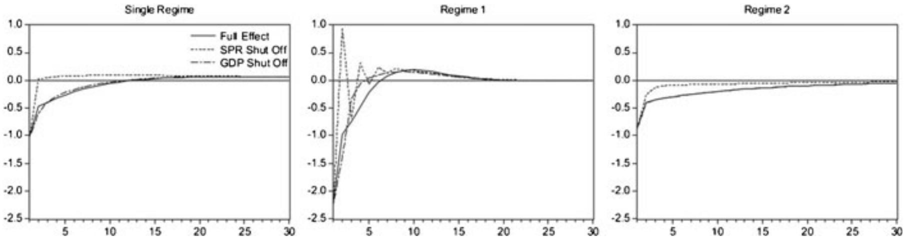

Fig. 13 Impulse responses of REIT to innovations in FFR when the effect of SPR or GDP is shut off (FFR, SPR, GDP, REIT)

respectively to a change in federal funds rate. Furthermore, the patterns of impulse responses after shutting off the effect of spread are also very similar between the three-variate and four-variate models, we thus omit the figures to save space.[29] In sum, all of our results remain intact when GDP is added to our three-variate model.

To further strengthen our results, we repeat our counterfactual analysis. Figure 13 compares the impulse responses of REIT to innovations in FFR under three different scenarios: the full effect, the case when the SPR channel is shut off, and the case when the GDP channel is shut off. It is clear that in the case of single regime, the case when the GDP channel is shut off is remarkably similar to the case of the full effect. In fact, for the case of regime 2 (low volatility regime), the two impulse responses are so similar that the difference is almost invisible. On the other hand, it is still true that SPR acts as an amplifier, as the impulse response of the case when the SPR channel being shut off has a small magnitude and is less persistent.

We repeat the same exercise on housing return and report the results in Fig. 14. Again, for both the single regime case as well as the case of regime 2, the two impulse responses (the full effect and the case when the GDP channel is shut off) are very similar. The results on the REIT return and the housing return confirm the intuition that asset market adjust faster than the real economy (or *being more "forward-looking"*) and therefore the impulse responses to the innovation of monetary policy are very similar with and without the GDP.[30]

When we allow for regime-switching, we confirm an earlier finding. Under regime 1, the impulse response of HRET when the SPR channel is shut off

[29]The results will be available upon request.

[30]It does not mean that GDP is unimportant. For instance, Telmer and Zin (2002) find that in a dynamic general equilibrium model with incomplete financial market, pricing kernels that are simple functions of equilibrium prices (or returns), provide good proxies for 'actual' pricing kernels that are typically higher dimensional functions of disaggregate information. Thus, a structural asset pricing model with a strong theoretical base can be consistent with reduced-form specifications which, in practice, tend to 'perform' better.

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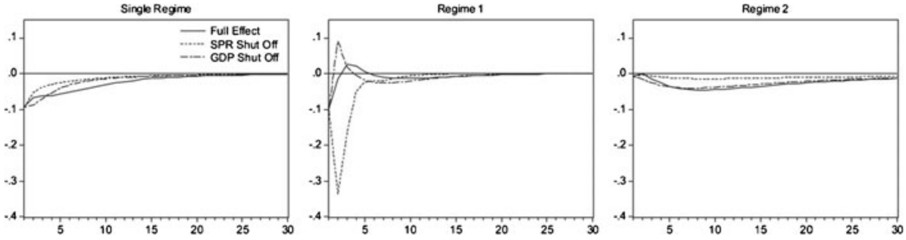

Fig. 14 Impulse responses of HRET to innovations in FFR when the effect of SPR or GDP is shut off (FFR, SPR, GDP, HRET)

exhibits a level of volatility which is at least three times of the case when the GDP channel is shut off, and is at least nine times for the full effect. In other words, the interest rate spread does serve as a stabilizer under the high volatility regime, even after the effect of GDP is also taken into considerations.

Comparison with the Stock Return

Earlier literature on the REIT such as Glascock et al. (2002a, b) and Chan et al. (2005), find that REIT behave more like stocks and less like bonds after early 1990s. With a slightly updated dataset and with a very different econometric tool, it may be interesting to compare the behavior of the stock return and to confirm whether REIT is indeed like stock. To address these concerns, we use the S&P 500 index from Datastream and estimate a series of models. The first one is (*FFR, SPR, SRET*), where *SRET* represents the stock returns. It is exactly our basic model discussed earlier, with real estate return replaced by stock return. Due to the space limit, we can again only report the results graphically and the details are available upon request. Figure 15 shows that for the stock return, the high volatility regime occurs basically in the late 1970s

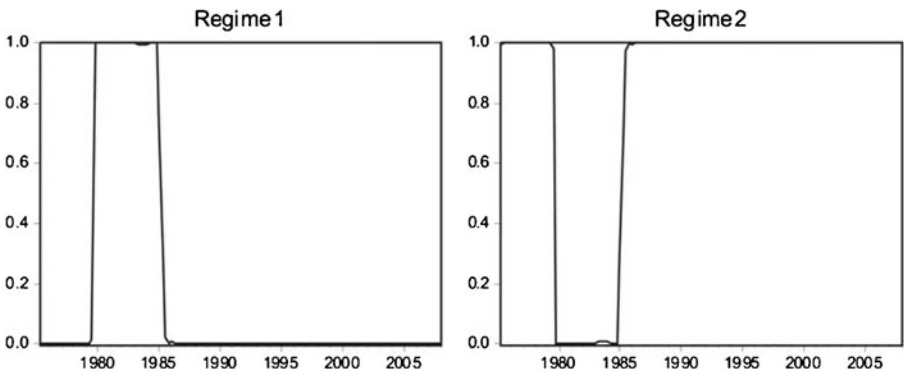

Fig. 15 Smoothed probabilities for SVAR(1) model of (FFR, SPR, SRET)

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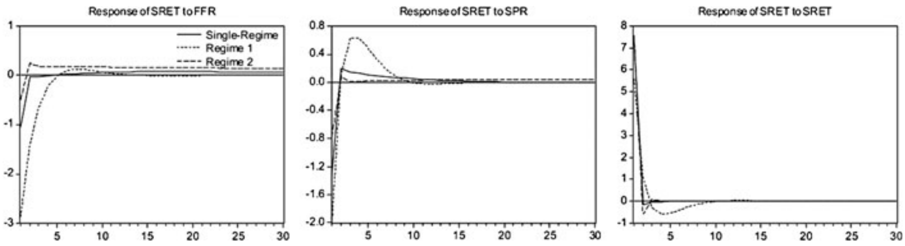

Fig. 16 Impulse responses of SRET for (FFR, SPR, SRET)

and early 1980s, which is similar to that of REIT. Figure 16 shows the impulse responses of stock return to different innovations. It seems to suggest that in the face of the innovations of FFR and the stock return itself, the impulse responses tend to have a large initial reaction but then die out pretty quickly. This pattern of stock return, again, is similar to that of REIT.

We also conduct the counterfactual analysis to compare the full effect and the case when the interest rate spread channel is shut off. Perhaps surprisingly, Fig. 17 shows that the difference between the two cases is very small, implying that the spread plays almost no role in the transmission mechanism of monetary policy. On this regard, stock return is *very different* from both REIT and housing return.

To complete the comparison, we estimate a second model, which is (*FFR, SPR, GDP, SRET*). In other words, we attempt to provide a robustness check for the results of the stock return. Figure 18 shows that the introduction of the GDP into the dynamical system does not significantly affect our identification of the regimes. The difference between Figs. 15 and 18 are very minor. Figure 19 displays the impulse responses of the stock return for different types of innovation.

Again, we conduct the counterfactual analysis of shutting down a certain channel and compare those impulse response with that of the full effect. Figure 20 shows that whether shutting off the spread or the GDP channel

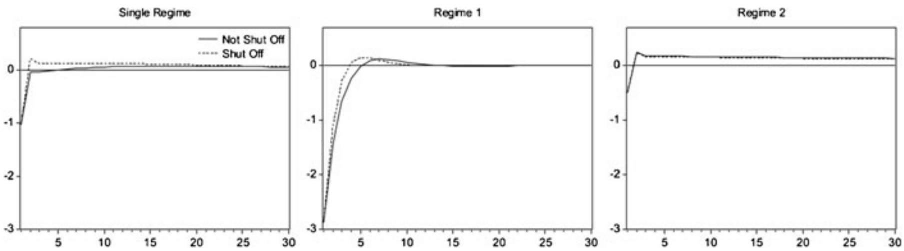

Fig. 17 Impulse responses of SRET to innovations in FFR when the effect of SPR is shut off (FFR, SPR, SRET)

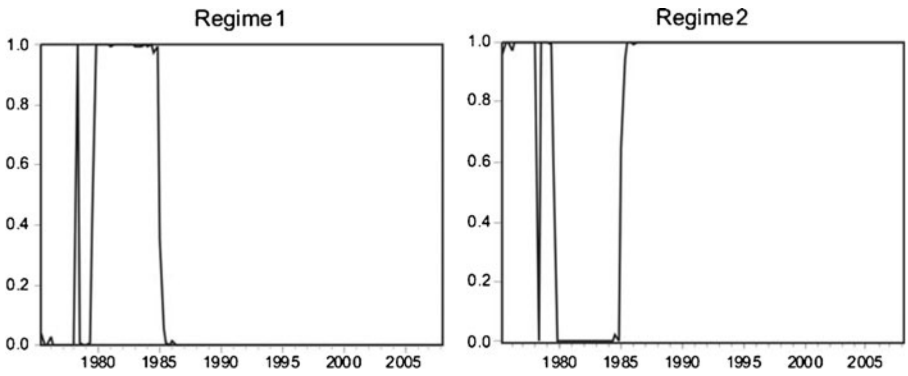

Fig. 18 Smoothed probabilities for SVAR(1) model of (FFR, SPR, GDP, SRET)

makes very little difference under all regimes. The implications are clear. As in the case of REIT and housing, the introduction of GDP is not important. It also confirms the finding that the spread does not play any role of the transmission mechanism of the monetary policy.

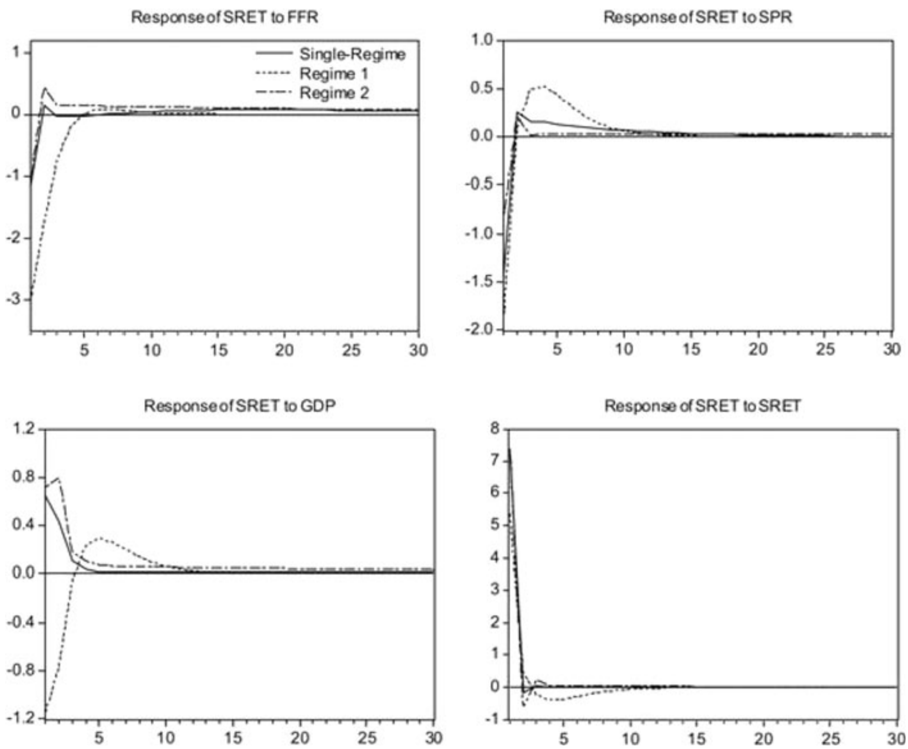

Fig. 19 Impulse responses of SRET for (FFR, SPR, GDP, SRET)

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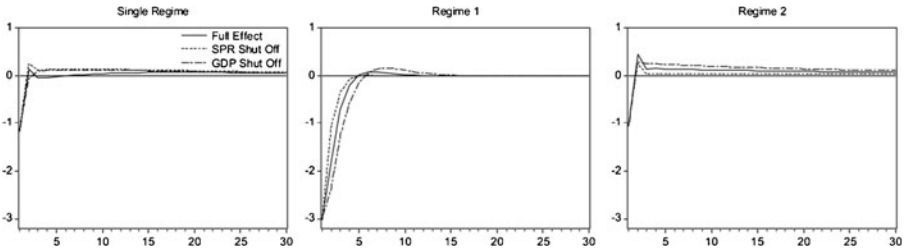

Fig. 20 Impulse responses of SRET to innovations in FFR when the effect of SPR or GDP is shut off (FFR, SPR, GDP, SRET)

Concluding Remarks

This paper examines the impact of changes in the main monetary policy instrument in the United States, the Federal Funds Rate, on Equity REITs, housing, and stock returns respectively, to study the transmission mechanism of monetary policy to the asset markets. The relatively superior performance of the econometric model with all parameters being regime-dependent suggests a strong *non-linearity* in the response of asset returns (equity REIT returns and housing market returns) to federal funds rate and the interest rate spread. We also find that, in response to either federal funds rate or the spread, housing market returns react less significantly but more persistently than REIT returns. Furthermore, the dynamics of housing market returns between the high and the low regimes are very different from those of REIT returns. Finally, the interest rate spread seems to amplify the effect on REIT returns but dampen the effect on housing market returns in response to an innovation of the federal funds rate. In sharp contrast, the interest rate spread plays virtually no role in transmitting monetary shock to the stock return. These results seem to suggest that different assets indeed behave very differently and that monetary policy *can at the same time stabilize and de-stabilize* different segments of the real estate market. Thus, policy makers may need to be very careful in using monetary policy that aims to stabilize the real state market.

In addition, we find that the introduction of the real GDP growth have little impact on the estimation, confirming the notion that asset markets tend to adjust much faster, or being more "forward looking" than the real economy. We also confirm the earlier findings that in some aspects, the stock return and the REIT return are similar. On the other hand, we find that the interest rate spread plays almost no role in the transmission mechanism of monetary policy for the stock return, which is very different from both REIT and housing.

Clearly, this paper have several limitations and can be extended in several ways. First, we have followed the monetary policy literature (survey by Christiano et al. 1999) in the identification of shocks. More specifically, we have assumed that the monetary policy reacts to the asset market only with a time lag. This may not be true. In the appendix, we study an alternative hypothesis suggested to us. Although we have not found any supporting evidence for that hypothesis, we still can not rule other possibilities. Moreover, if the central bank has an objective function and actively responds to the situation of the economy and the asset markets, the current framework may be inadequate. One may consider to follow the footsteps of Sargent et al. (2006), among others, to adopt a Bayesian learning framework to model the interactions among the policy maker, the real economy and the asset markets.

Second, our current approach has assumed that there are only two regimes, replacing each other stochastically throughout the whole sampling period. One may argue that there could be a third regime. In particular, the increasing securitization and leveraging in the period 2000–2005 may differ from all previous periods. Unfortunately, we do not have enough data points to estimate a three-regime structural VAR model and whether it out-performs the current two-regime counterpart. Furthermore, the period 2000–2005 is simply too short to estimate a linear VAR model. In the Appendix, we can only estimate an "extended period," namely, from year 2000 to 2008 and we find that the impulse responses during that sub-period in fact behaves differently from the whole sample. At this point, we can only await future research to have a more throughout investigation of the possibility of introducing yet another regime, or to adopt a better econometric framework and longer time series that would be available.

In terms of extension, the current study focuses on the aggregate data and the future research can naturally switch to the analysis to the micro-data. Recall that the finding that *interest rate spread amplifies the effect of monetary policy on the REIT returns*, and yet *dampens the effect of monetary policy on housing market returns* in high the volatility regime. Thus, a possible extension of this study is to repeat the analysis on firm-level data. We can then verify whether such "amplifying effect" appears in all REIT, or REIT listed in a certain period of time, or REIT with certain characteristics. In addition, the analysis here can be applied to other countries and verify whether the results from the U.S. data can be generalized. Researchers can also await for longer time series and then introduce more control variables, as well as additional features of the regime switching model, such as time-dependent switching probabilities. Moreover, the empirical work here also provide some "stylized facts" relating the monetary policy, term structure, housing return and stock return. These facts have yet to be modelled in existing dynamic equilibrium models, and should hence leave a challenge to the theorists.[31]

Acknowledgements We are grateful to Shaun Bond, Wing Hong Chan, Jim Shilling, seminar participants of (alphabetical order) AREUEA meeting, Bank of International Settlements, City University of Hong Kong, DePaul University REIT symposium, and especially an anonymous referee, for many helpful comments and insights, and City University of Hong Kong, UGC Earmark Grant (Code: CityU 144709) for financial support. The usual disclaimer applies.

[31] Among others, see Emiris (2006) and Leung and Teo (2008), and the reference therein.

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Appendix

This appendix attempts to address the concerns of some alternative interpretation of the model as well as the data.

First, it has been suggested to us that

> *But one story is: when the economy is booming, income are high, and households are more likely to be able to finance the purchase of housing. This raises the liquidity of housing. When housing is more liquid, many people are willing to be buyers and sellers. As a result, more transactions take place. But as more transactions take place, lenders charge lower interest rates... The lower interest rate spread causes even more buyers to enter the market, reinforcing the greater liquidity and causing prices to rise. But, as I understand it, a transmission mechanism of this sort is ruled out by the authors by the way in which the VAR is specified...*

We are very grateful to this suggestion. Yet when we try to test this alternative hypothesis, we face some difficulty. We lack measures of the housing market liquidity as well as transaction volume of the housing market for the same sampling period. Thus, we can only look at a "reduced form" of the hypothesis, which is a negative correlation between the income (or GDP) and the term spread (SPR). Below is what we find:

Please allow us to explain. We first study the correlation between the GDP (i.e. GDP growth rate, as the level is non-stationary) and the term spread for the full sampling period. The correlation seems to be very small (0.152 as shown in the first row of Table 9). We then use our regime-switching VAR model to identify the periods in which the economy is in "regime 1" (i.e. the high volatility regime) and the periods in which the economy is in "regime 2." We then divide the sample into two sub-samples: the "regime 1 sub-sample" and the "regime 2 sub-sample." We compute the correlation between the two variables for each of these sub-samples. Again, the correlations are small (0.156 and 0.151).

One can argue that while the (unconditional) correlation is low, the conditional correlation (or "partial correlation" can be high). To investigate such a possibility, we run a regression of GDP on the FFR and HRET first, and get the residual term u(t) as the "conditional GDP growth" (please see Table 10 for more details). We then compute the correlations between the "conditional GDP growth" and the SPR under the full sample, the regime 1 subsample and

Table 9 The correlation coefficient between GDP growth and SPR

	Full sample	Regime 1	Regime 2
Correlation ρ (GDP, SPR)	0.152	0.156	0.151
Conditional correlation ρ (u_t, SPR)	0.098	−0.144	0.159

Note: The regimes are classified by the model of (FFR, SPR, HRET)

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Table 10 The estimates results for simple regression

	Full sample	Regime 1	Regime 2
a_0	0.837*** (0.173)	2.064*** (0.730)	0.640*** (0.170)
a_1	−0.024 (0.019)	−0.102* (0.056)	−0.005 (0.026)
a_2	0.062 (0.069)	−0.184 (0.273)	0.104* (0.061)

Note: The simple regression is GDP $= a_0 + a_1$ FFR $= a_2$ HRET $= u_t$. Values in parenthesis are standard deviations

* represent the significance at 10%

*** represent the significance at 1%

the regime 2 subsamples. The results are shown in the second row of Table 9. Again, the correlations are very low. Thus, given our very limited proxies, we have not been able to find evidence to support this alternative theory.

Clearly, a key variable, the transaction volume variable, is missing. We would re-visit this issue in our ongoing research with a different dataset and hopefully we will be able to deliver a more satisfactory answer in the future.

Second, in terms of the identification restriction, it is the same one used in the monetary policy literature (among others, see the survey by Christiano et al. 1999). It actually allows the real estate return to affect the FFR and SPR with time lags. The only restriction is that the effect is one-directional contemporaneously. For less restrictive identification assumption, one needs to adopt the Bayesian methodology (see Leeper et al. 1996, for more elaborations). Our impression is that while some researchers welcome the Bayesian method, some seem to have reservations. Therefore, we attempt to pursue with the "classical econometrics" method (which may be less controversial) and hence inevitably adopt the currently used identification assumption.

Third, there is a suggestion concerning the financial intermediation.

> *Further, is the potential for adverse selection so much greater in the housing market relative to the REIT market, thereby explaining why house prices are less significantly but more persistently impacted by changes in monetary policy than are REIT returns?*

This is a very interesting suggestion. Without the corresponding micro-level data, we are unable to make much progress for this hypothesis though. We only have a simple observation at this point, which is that adverse selection could lead a market to shrink, as in the case of "Lemon" in the classical paper of Akerlof (1970). *Yet the mortgage market actually expands between year 2000 and 2005. Why did not the financial intermediations further ration the credit when the adverse selection problem became more severe?* Thus, it seems that a more complete theory demands not only the adverse selection of the residential mortgage demand, but also the supply, i.e. the behavior of the financial intermediaries. We are currently working towards that direction. Again, we are very grateful to this inspiring insight.

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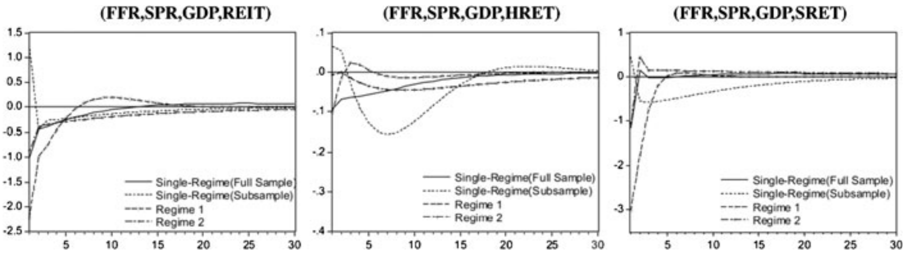

Fig. 21 Impulse responses of asset return to innovations in FFR

The fourth concern is related to the recent crisis.

Given that the originate-to-securitize process had unintended consequences in the US housing market during the 2000–2005 period, do we really expect the effects of monetary policy to be same across the authors' entire sample period?

Again, this is a very good point. Unfortunately, even when we restrict the attention to the single regime (i.e. linear) VAR model with 4 variables, we find that we need to estimate 96 parameters with 6 years of data (for the parameters in the dynamic equation as well as the variance-covariance matrix), which is insufficient! Thus, we extend the period to 2000–2008, which is barely enough for the estimation of a linear four-variate VAR model. Needless to say, since the model in the paper is a regime-switching VAR model with much longer time series, the results may not be directly comparable. Figure 21 provides a visualization of the impulse responses. In the case of REIT (the left hand side), it is clear that the 2000–2008 sub-sample are very different. For the "full sample" case, or the periods under regime 1, or those under regime 2, a positive innovation of FFR will lead to a drop in the REIT return. It seems natural as an increase in the interest rate tends to depress asset returns. In fact, it is also what happened to the housing return (HRET) and the stock return (SRET).

However, for the 2000–2008 sub-sample, the initial response is an increase in the REIT return, followed by a decrease, even when the GDP is controlled. In fact, it is clear that it is also the case for housing return (HRET) and stock return (SRET). So, the 2000–2008 period is indeed "abnormal." How can this happen? At this point, the only explanation we can provide is a "signaling type story." Assume that the central bank wants to prevent the market from "overheating." And assume that people believe that the central bank has some private information about the future economic growth. In that case, when an increase in the interest rate is a signal that the economy will grow even more in the future, and this stimulates even more investment in all assets, and lead to an increase in the returns. When the people discover that it is not the case, investors are disappointed and the asset returns over-shoot (in this case, drop below the steady state value).

Clearly, this "explanation" is *very preliminary* and we hope that our future research can address this issue in a more satisfactory manner.

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