The Information Content of the NCREIF Index

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Abstract This paper examines the dynamic behavior of the National Council of Real Estate Investment Fiduciaries (NCREIF) index. NCREIF total return and appreciation indexes are smooth and exhibit strong autocorrelation and autoregressive heteroscedasticity. We test the information transmission from the NAREIT index to the NCREIF index. In our VAR analysis, the NAREIT index returns Granger cause the returns of the NCREIF indexes. In our ARCH information transmission analysis, the NCREIF indexes are observed to incorporate information spillover from the NAREIT indexes in both the mean and variance of the index returns. The ARCH dynamics between the NCREIF and NAREIT indexes suggest a nonlinear relation between the two indexes.

In recent years a large volume of literature has focused on using the National Council of Real Estate Investment Fiduciaries (NCREIF) index to examine real estate market fundamentals. The NCREIF index is used frequently as a benchmark with which to assess the performance of various real estate submarkets and indexes. Investment management performance and compensation are also frequently benchmarked to the NCREIF index. Consequently, the NCREIF index has become one of the most frequently used real estate benchmarks in the real estate market.

The NCREIF institutional commercial real estate return data series, which represent returns of privately held commercial real estate, demonstrate relatively low volatility and relatively predictable cycles. In contrast, the prices and returns of securitized real estate investment trusts (REITs) typically exhibit a random walk and behave similarly to the stock market. The relation between the two, the unsecuritized and the securitized commercial real estate markets, has been an intriguing subject to real estate investors.

Most studies on the securitized equity real estate market focus on the relation between REITs and common stocks, and the predictability of REIT returns.[1] They generally find that equity REITs are cointegrated with the broad stock market.

Because of the high degree of liquidity, the pricing of securitized real estate reflects constant information updates and anticipation of the current and future real activity. This degree of liquidity, however, is unavailable to unsecuritized real estate, such as commingled funds. Return series on privately held real estate are impacted by infrequent appraisals, are often labeled as smoothed, and hence, do not update information as quickly. Recent studies of NCREIF, for example, attempt to refine the measurement of return indexes, and interpret the significance of various measures.[2] The relation between the unsecuritized and the securitized commercial real estate markets, however, largely remains a puzzle.

The returns of both unsecuritized and securitized equity real estate markets are largely driven by cash flows or rents from fixed rent and relatively long-term leases (e.g. five years or longer). Intuition suggests that the same fundamental factors in the market influence both of these sectors. The two markets, however, are also strikingly different. One key difference between them is liquidity; the more liquid securitized equity market updates information much more frequently. Therefore, the underlying assumption that equity REIT pricing contains information relevant to the unsecuritized real estate market becomes intuitively appealing.

In the finance literature, it has been widely studied and supported that stock returns directly reflect investor expectations of future market fundamentals.[3] On the other hand, changes in stock returns can also have a direct impact on the consumption decisions of individuals and the investment decisions of firms, and thus cause changes in market fundamentals. Balvers, Cosimano, and McDonald (1990) report that lagged real stock returns can significantly affect current real activity, while current real activity helps to explain subsequent real stock returns. Gallinger (1994) provides further evidence on bi-directional causality and contemporaneous causality between real stock returns and real activity. Applying the same conceptual framework to equity real estate, one can easily conjecture a similar relation between the public and private sectors. If the securitized and unsecuritized real estate markets respond to the same set of market fundamentals, the information conveyed in the highly liquid REIT prices should be observed and reflected in the NCREIF returns. An open question is whether appraisers are observing REIT returns or just the same economic factors, but lag in their response to these factors. We also address the question of whether REIT investors observe the periodical changes in the NCREIF indexes and update their own expectations, based on these observations.

Information transmission between markets is an important research subject related to market efficiency (e.g., King and Wadhwani, 1990; and Wu, Li, and Zhang, 2005). In this paper, we test the information transmission from REITs to NCREIF. This test addresses two important issues. First, it examines whether the appraisal-based index captures dynamic market information. Second, it investigates how appraisers learn from market information. Significant evidence of information spillover from REITs to NCREIF is consistent with the informational efficiency hypothesis: the appraisers update property valuation with equity market information. However, this information update does not represent an arbitrage

opportunity because the NCREIF index itself is not a traded asset. Overall, our evidence suggests that private real estate appraisers and investors in securitized real estate respond to the same information with respect to economic fundamentals. The response by appraisers appears to follow the response by REIT investors and thus, the change in REIT pricing.

There is a growing interest in academia on the relation between REITs and unsecuritized real estate. For example, Giliberto (1990) analyzes the correlation and the residuals of the cross-sectional regression models and shows a weak relation between equity REIT returns and conventional real estate returns. Myer and Webb (1993) conduct vector autoregression (VAR) analyses and Granger causality tests using data from 1978 to 1990. They find an intertemporal relation between REIT returns and unsecuritized real estate returns, as well as a significant Granger causality of REIT returns to most of real estate indexes. Both studies highlight the importance of such research and call for more extensive investigation in this area. The real estate market, including both the REIT and non-REIT sectors, has experienced rapid changes since the early 1990s. Improved research technology also provides us with tools to advance the study of this topic.[4]

This paper extends the existing research on the NCREIF index and its relation with the securitized equity real estate market. First, we examine a set of explanatory variables for the NCREIF and REIT indexes. Second, we conduct VAR analysis on the NCREIF and REIT indexes. We find that the REIT index Granger causes the NCREIF index. The unique contribution of this paper is our investigation of the autoregressive heteroscedasticity of the NCREIF index and the information transmission from REITs to the NCREIF index. The returns of the NCREIF total index exhibit autoregressive conditional heteroscedasticity and receive information transmission from the REIT market in both the mean and variance. Under an innovative design, this paper exhibits the dynamic relation between the public and private real estate sectors, and how the less liquid private real estate market responds to market information reflected in the more liquid, public real estate market. It also suggests that it is effective to introduce to real estate market research an advanced econometric method such as the information transmission model.

The remainder of this paper is organized as follows. Section 2 describes the data. Section 3 examines a set of explanatory variables on the NCREIF indexes. Section 4 conducts the VAR analysis on the NCREIF index and its relation with the REIT market. Section 5 investigates the autoregressive conditional heteroscedasticity and information transmission of the NCREIF indexes. Section 6 discusses the difference between the NCREIF and NAREIT indexes and plausible causes for the causality. Finally, Section 7 summarizes the paper.

Data

Although June 17, 1982 marks the official beginning of NCREIF, the NCREIF index traces back to 1978. The value of the NCREIF index was set to 100 for the

fourth quarter of 1977. We use the full quarterly sample that dates from the fourth quarter of 1977 to the fourth quarter of 2001. The index family includes the NCREIF total index, appreciation index, and income index. For a comparative study of NCREIF indexes, we use the three matching equity REIT return indexes from the National Association of Real Estate Investment Trusts (NAREIT): total return index, price return index, and income return index.

The descriptive statistics of the above six indexes are summarized in Exhibit 1. The returns of the NCREIF total and appreciation indexes exhibit large excess kurtosis, which indicates a deviation from the normal distribution. The NAREIT total and price returns are distributed close to a normal distribution, with smaller skewness and kurtosis. The income returns to the NCREIF index are very stable, reflected by a small standard deviation, and negative skewness and kurtosis. In contrast, the distribution of the NAREIT income index returns is far from a normal distribution.

As widely observed, NCREIF indexes are smooth. The returns of the three NCREIF indexes exhibit strong positive autocorrelation up to 12 lags (The first six lags are reported in Exhibit 2). The autocorrelation coefficients of the NAREIT index returns are not significant, consistent with the EMH of securitized commercial real estate.

In addition to the AR process, the return series may also exhibit seasonality. A general contention is that securitized real estate, like stocks, exhibits a first quarter effect. It is conceptually plausible that the real estate market is not as active in the winter relative to other quarters. In order to disentangle the effects of the AR process, we also report in Exhibit 2 the partial autocorrelation of the indexes. It is shown that the NCREIF indexes exhibit positive and significant partial autocorrelations in the first four lags, consistent with their generally observed seasonality.[5] Additionally, real estate prices in the winter may be relatively low

Exhibit 1 | Descriptive Statistics of the Return Series

	Mean	Std Dev	Skewness	Kurtosis
NCREIF Total	2.319	1.744	−1.026	3.813
NCREIF Appreciation	0.369	1.674	−1.035	3.988
NCREIF Income	1.949	0.193	−0.293	−1.029
NAREIT Total	3.503	6.888	0.197	0.544
NAREIT Price	1.353	6.721	0.228	0.724
NAREIT Income	2.131	1.511	7.115	56.90

Notes: Reported are the statistics of the returns to the NCREIF and NAREIT indexes for the period 1978–2001.

Exhibit 2 | Autocorrelation and Partial Autocorrelation

	Autocorrelation						Partial Autocorrelation					
	Number of Lags											
	1	2	3	4	5	6	7	8	9	10	11	12
NCREIF Total	.68	.69	.60	.73	.48	.44	.68	.41	.11	.42	−.36	−.22
NCREIF Appreciation	.66	.66	.58	.71	.46	.41	.66	.40	.11	.44	−.35	−.22
NCREIF Income	.93	.89	.86	.84	.77	.72	.93	.26	.01	.14	−.33	−.01
NAREIT Total	.06	.05	−.05	−.02	−.03	−.01	.06	.02	−.06	.01	−.02	−.03
NAREIT Price	.10	.07	−.12	−.04	−.02	−.02	.10	.03	−.13	.02	−.01	−.05
NAREIT Income	.04	−.01	.03	−.03	.02	−.03	.04	−.00	.02	−.02	.02	−.03

Notes: Reported are the autocorrelation and partial autocorrelation of the returns to the NCREIF and NAREIT indexes for the period 1978–2001.

and hence, the indexes may demonstrate abnormal returns in the first quarter of the year. However, we examine the data and find no significant quarter effects on the series.

Determinants of the Index Returns

The information content of the indexes, in the context of the general economy and equity markets, is of major interest. The real estate market is closely related to the state of the economy. In a growing economy, businesses expand and demand more commercial real estate. In a slowing economy, businesses contract and commercial real estate may experience excess supply, increasing vacancies, and sluggish rents. Hence, the income to commercial real estate is closely linked to the general economy and other macroeconomic variables, such as the short-term interest rate and the interest rate credit or term spread. These monetary variables reflect investor expectation of short-term and long-term economic growth, and are useful explanatory variables for the general equity market.

The interest rate is the traditional proxy that captures the state of investment opportunities (Chen, Roll, and Ross, 1986; and Ferson and Harvey, 1991). Merton (1973) and Cox, Ingersoll, and Ross (1985) have developed models in which interest rates are state variables. Fama and French (1993) identify the term spread and credit spread as two bond-market risk factors. Changes in interest rates may influence margin requirements and short-selling constraints. This implies that trading activity may be related to changes in short-term interest rates. Increases in the long-term Treasury bond yield and the credit spread may also cause investors to reallocate their assets between equity and debt. In order to account for these effects, we include the changes in the term spread, the credit spread, and the short-term interest rate as explanatory variables.

In addition, REITs are usually regarded as equity of small capitalization, which strongly correlates with the general equity market. We conduct regressions on each series using the model:

$$R_t = a_0 + a_1 GDP_t + a_2 SP_t + a_3 CSPREAD_t + a_4 TSPREAD_t$$
$$+ a_5 FEDRATE_t + b\varepsilon_{t-1} + \varepsilon_t. \tag{1}$$

Notation of the variables:

R: Quarterly return series of NCREIF or NAREIT.

GDP: Quarterly growth rate of the Gross Domestic Product.

SP: Quarterly return rate of S&P composite stock index.

$CSPREAD$: Credit spread = yield on BAA rated bonds − yield on 10-year Treasury bonds.

TSPREAD: Term spread = yield on 30-year Treasury bonds − effective rate on federal funds.

FEDRATE: Effective rate on federal funds.[6]

The regression results are reported in Exhibit 3.[7] The NCREIF total and appreciation return indexes respond positively to GDP growth and the stock market. In addition, these two indexes are positively related to the short-term interest rate (*FEDRATE*), while the income index responds to it negatively. The income return of NCREIF does not respond to other independent variables. Interestingly, the NAREIT indexes have a somewhat different relation with these explanatory variables. The cointegration of the securitized commercial real estate market and the stock market is observed. The coefficient of the S&P 500 index returns is significant at the 1% level for both the NAREIT total and price return series. However, similar to the results for the NCREIF income return series, the NAREIT income series does not show a significant relation to the S&P 500 index returns. Intuitively, the interest rate term spread reflects investor confidence in the long-term health of the economy. It has a positive relation with the NAREIT total and price returns. The short-term interest rate, as a proxy for opportunity cost, also has a positive correlation with the NAREIT total and price indexes. The

Exhibit 3 | Explanatory Variables for the Quarterly Index Returns

	Intercept	GDP	SP	CSPREAD	TSPREAD	FEDRATE	R^2
NCREIF Total	0.982	0.361*	0.046*	−0.167	−0.223*	0.128	0.301
	(0.613)	(0.206)	(0.028)	(0.260)	(0.121)	(0.077)	
NCREIF Appreciation	−1.207**	0.351*	0.043*	−0.140	−0.183	0.154**	0.321
	(0.584)	(0.196)	(0.026)	(0.248)	(0.115)	(0.074)	
NCREIF Income	2.189***	0.011	0.003	−0.027	−0.041***	−0.026***	0.201
	(0.077)	(0.026)	(0.004)	(0.033)	(0.015)	(0.010)	
NAREIT Total	−1.734	−1.591*	0.653***	−1.414	1.306**	0.905***	0.299
	(2.851)	(0.871)	(0.122)	(1.140)	(0.565)	(0.340)	
NAREIT Price	−3.518	−1.031	0.675***	−1.730	1.393**	0.797**	0.318
	(2.750)	(0.841)	(0.118)	(1.100)	(0.545)	(0.328)	
NAREIT Income	1.883**	−0.553**	−0.036	0.362	−0.122	0.092	0.173
	(0.715)	(0.218)	(0.031)	(0.286)	(0.142)	(0.085)	

Notes: Reported are the regression results on the quarterly returns to the NCREIF and NAREIT indexes. The explanatory variables are GDP, returns to the Standard & Poor's index, credit spread (*CSPREAD*), term spread (*TSPREAD*), and the Federal Reserve fund rate (*FEDRATE*). Estimation errors are reported in the parentheses below parameters.
*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

regression models exhibit a fairly high goodness-of-fit. It is noteworthy that the NAREIT income return does not demonstrate a significant relation with any independent variables except the GDP growth rate.

Vector Autoregressive Analysis

The relation between the NCREIF and NAREIT indexes remains an intriguing subject. Intuitively, the commercial real estate equity market should be more efficient in pricing. If this is true, the NAREIT index should lead the NCREIF index. Since the NAREIT and NCREIF indexes may have cross and auto correlation in their residuals, VAR is an appropriate methodology to tackle this statistical complexity and examine the underlying relation between these two series. For each pair of the NCREIF and NAREIT indexes, we construct the following model:[8]

$$
\begin{aligned}
NCREIF_t = {} & a_0 + \sum_{i=1}^{p} b_i NCREIF_{t-i} + \sum_{i=1}^{p} c_i NAREIT_{t-i} \\
& + a_1 GDP_{t-1} + a_2 CSPREAD_{t-1} \\
& + a_3 TSPREAD_{t-1} + a_4 FEDRATE_{t-1} + \varepsilon_{1,t}, \qquad (2) \\
NAREIT_t = {} & \alpha_0 + \sum_{i=1}^{p} \beta_i NCREIF_{t-i} + \sum_{i=1}^{p} \gamma_i NAREIT_{t-i} \\
& + \alpha_1 GDP_{t-1} + \alpha_2 CSPREAD_{t-1} \\
& + \alpha_3 TSPREAD_{t-1} + \alpha_4 FEDRATE_{t-1} + \varepsilon_{2,t}
\end{aligned}
$$

where $\begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} \sim N(0, \Sigma)$.

Following Myer and Webb (1993), we examine the VAR model for four time lags, i.e., $p = 4$. In Exhibit 2, we see that the partial autocorrelations of the NCREIF indexes are positive and significant in the first four lags, supporting our use of four lags in the VAR model.[9] Exhibit 3 presents the explanatory variables for the quarterly index returns. Based on the VAR analysis, we conduct Granger causality tests to investigate the possible linear causality between the NCREIF and NAREIT total return indexes. Exhibit 4 reports the Granger causality test results. The null hypothesis of the first test is that the NAREIT total return index does not Granger cause the NCREIF total return index. Technically, it is equivalent to testing that the parameter estimates of the four lags of the NAREIT index, in explaining the NCREIF index, are jointly zero. The Granger causality Wald statistic follows a χ^2 distribution of degree of freedom equal to the number of restrictions. In this case, the test has four degrees of freedom. Reported in Panel A, the statistic for the first

test is 12.39 with a power value of 0.015. At the 5% significance level, this statistic rejects the null hypothesis that the NAREIT total return index does not Granger cause the NCREIF total return. On the other hand, we cannot meaningfully reject the hypothesis that the NCREIF index does not Granger cause the NAREIT index. In Panel B, we report the parameter estimates of the VAR analysis. The NCREIF

Exhibit 4 | VAR Analysis on NCREIF Total Return Index and NAREIT Total Return Index

Panel A: Granger Causality Wald Test			
Test	χ^2	DF	Prob$>\chi^2$
NAREIT not cause NCREIF	12.39	4	0.015
NCREIF not cause NAREIT	5.55	4	0.256

Panel B: Regression Estimates		
	NCREIF Total	NAREIT Total
Intercept	0.490	−4.661
	(0.481)	(3.367)
$NCREIF_{t-1}$	0.206**	−1.288*
	(0.094)	(0.661)
$NCREIF_{t-2}$	0.198**	0.832
	(0.096)	(0.671)
$NCREIF_{t-3}$	0.069	−0.603
	(0.098)	(0.683)
$NCREIF_{t-4}$	0.573***	0.674
	(0.095)	(0.668)
$NAREIT_{t-1}$	0.028*	0.140
	(0.016)	(0.109)
$NAREIT_{t-2}$	0.029*	−0.077
	(0.016)	(0.111)
$NAREIT_{t-3}$	0.011	−0.043
	(0.016)	(0.114)
$NAREIT_{t-4}$	0.039**	−0.067
	(0.016)	(0.110)
GDP_{t-1}	0.201*	1.739**
	(0.117)	(0.820)
$CSPREAD_{t-1}$	−0.222	−0.693
	(0.186)	(1.302)
$TSPREAD_{t-1}$	0.014	0.967
	(0.096)	(0.668)
$FEDRATE_{t-1}$	−0.113**	0.488
	(0.053)	(0.368)

Panel C: The Univariate Model Diagnostics

Dependent	R^2	F-Test		Normality Test	
		F Value	Prob>F	χ^2	P-value
NCREIF Total	0.746	18.11	<.0001	354.26	<.0001
NAREIT Total	0.165	1.22	0.286	0.78	0.675

Notes: The dependent variables in the vector autoregressive analysis are the quarterly returns to the NCREIF and NAREIT total return indexes. Four lags of the independent variables and the first lag of GDP, credit spread (CSPREAD), term spread (TSPREAD), and the Federal Reserve fund rate (FEDRATE) are included as the explanatory variables. Estimation errors are reported in the parentheses below the parameters.
*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

index exhibits strong and positive autocorrelation. This autocorrelation is partially attributed to the "smoothness" of the index and the "smoothing" techniques of NCREIF appraisers. We also see that the NCREIF total index was positively related to the past realization of the NAREIT total index. The coefficient estimates of the first and second lags are significant at the 10% level, while the coefficient of the fourth lag is significant at the 5% level. Intuitively, the NCREIF index also responds positively to the last quarter GDP growth, significant at the 10% level, but negatively to the short-term interest rate, significant at the 5% level. This suggests that appraisers do monitor and incorporate information from the public equity real estate market and other economic variables into the pricing of the NCREIF assets. In contrast, the NAREIT total return index does not exhibit a significant economic relation with the realization of the NCREIF index, nor with its own past returns. Nevertheless, it is positively related to the past quarter GDP growth at the 5% level. This supports the informational efficiency hypothesis for the securitized real estate market.

To examine the robustness of the VAR analysis, we apply univariate regression models on the NCREIF total return index and the NAREIT total return index separately. Results are reported in Panel C of Exhibit 4. The coefficient of determination is 74.6% for the NCREIF regression. The F-test tests the null hypothesis that all the parameters are jointly zero. It is rejected for the NCREIF regression at the 1% significance level. In this panel, we also report the Bera-Jarque normality test on the regression residuals. The Bera-Jarque statistic is calculated based on skewness and kurtosis, which follows a χ^2 distribution. A low

p-value of this statistic rejects normality in the residuals [see Bera and Jarque (1982) for details]. From the results, we see clearly that the null hypothesis is rejected for the NCREIF index but not for the NAREIT index. These results are consistent with the VAR univariate regression results, and thus, further support the EMH of the securitized real estate market. This diagnosis of the univariate regressions is consistent with the VAR regression results. However, the rejection of the Bera-Jarque normality test on the NCREIF total returns suggests that the VAR model may not fully capture the characteristics associated with the NCREIF index. Hence, ARCH tests may provide more information.

We further conduct the above tests over the NCREIF appreciation index and the NAREIT price index. The relation between these two series is similar to that between the two total return indexes reported in Exhibit 4. The Wald test suggests Granger causality from the NAREIT price index to the NCREIF appreciation index, but not in the other direction. The univariate regression diagnostic once again rejects the normality of the NCREIF index. The NCREIF appreciation index incorporates information from the past realization of the index itself, the NAREIT price index, and other macro variables.

Because of the problems related to the infrequency of "serious" appraisals, we rerun the preceding VAR analyses using annual returns as a robustness check. While there is a loss in the degrees of freedom in moving from quarterly to annual data, the Granger causality tests on the annual data are qualitatively similar and confirm the reported tests on the quarterly data. The null hypotheses that annual equity NAREIT returns do not Granger cause annual equity NCREIF returns and the annual total NAREIT returns do not Granger cause annual total NCREIF returns are both rejected at the 5% confidence level. Consistent with the results using quarterly data, there is no significant Granger causality from annual equity and total NCREIF returns to their NAREIT counterparts.[10]

Overall, the VAR analyses support that the NCREIF total return index and appreciation index contain information from the securitized equity real estate market and the general economy. However, the non-normality of the NCREIF index returns suggests that further analyses may be needed. In the next section, we examine the autoregressive conditional heteroscedasticity of the NCREIF appreciation index.

Autoregressive Conditional Heteroscedasticity

High frequency financial data usually are observed with autoregressive conditional heteroscedasticity (ARCH). The rationale for ARCH comes from a contention that information may arrive in clusters leading to periods of high volatility following periods of low volatility [see Engle (1982) and Bollerslev, Engle, and (1995) for a survey on ARCH). In an efficient market, information arrives in a random pace and pattern, such that ARCH should not exist. The equity market is regarded to be efficient in the long run. Hence, the ARCH effect in the equity market fades as the frequency of data decreases.

Time-varying return volatility is an important feature of financial markets, which alone establishes an interesting issue in studying the time series behavior of the general stock market and REITs. There are several reasons why researchers focus on time-varying return volatility (Lin, Engle, and Ito, 1994). First, the volatility of asset prices exhibits clustering. Second, theory suggests that market volatility is related to the rate of information flow (Ross, 1989). The predictability of volatility may be due to the regularity of the autocorrelated arrival rate of information. Finally, autocorrelation in price volatility is associated with the dispersion of beliefs. Shalen (1993) constructs a two-period noisy rational expectation model and finds that belief dispersion can be a factor contributing to the positive correlation between consecutive absolute price changes. Heterogeneous prior beliefs induce trading on new information arrivals, which leads to price change. Traders revise their beliefs upon their observation of a new price, which leads to continuous trading and price changes, contributing to volatility clustering. It is important to examine whether the volatility is correlated in different market sectors in order to understand the speed of the market adjustment to new information.

In ARCH models, the variance of financial returns is self-dependent. In the NCREIF appraisal process, ARCH may suggest the amplitude of price update clusters. We first examine the following standard ARCH model applied to the NCREIF and the NAREIT index returns:

$$R_t = \mu + \theta R_{t-1} + \varepsilon_t$$

$$h_t = c + \alpha \varepsilon_{t-1}^2. \qquad (3)$$

$$\varepsilon_t | \phi_{t-1} \sim N(0, h_t)$$

The ARCH results are reported in Exhibit 5. Consistent with the previous analysis, the NCREIF total and appreciation returns both exhibit strong positive autocorrelation. To investigate the existence of ARCH, we conduct the Lagrange Multiplier (LM) test for the qth order ARCH disturbances proposed by Engle (1982). The LM statistics have an approximate χ_q^2 distribution assuming that disturbances are white noise. A significant LM statistic (low p-values) will suggest autoregressive conditional heteroscedasticity up to the first p lags. The statistics for four lags and p-values (in parentheses) are reported. The LM tests of the fourth order show that the white-noise hypothesis on the NCREIF total and appreciation returns are both rejected at the 1% significance level. The LM statistics of higher orders (not reported) are also significantly high. These results suggest that ARCH is a legitimate feature of the NCREIF total return and appreciation indexes. In contrast, the LM statistics of the NAREIT total and price returns are insignificant, suggesting no ARCH effects in their return disturbances.

We further examine the ARCH of NCREIF total return and appreciation indexes. Theory suggests that information along with liquidity drives the market.

Exhibit 5 | Simple ARCH

	μ	θ	c	α	AIC	Likelihood	LM(1)	LM(4)
NCREIF Total	0.574**	0.753***	1.307***	0.187	316	−153.19	3.135*	20.542***
	(0.261)	(0.082)	(0.242)	(0.267)			(0.077)	(<0.0001)
NCREIF Appreciation	0.087	0.736***	1.347***	0.144	315	−153.46	2.038	20.333***
	(0.157)	(0.087)	(0.229)	(0.270)			(0.154)	(<0.0001)
NAREIT Total	2.820***	0.061	49.346***	0.106	630	−311.144	0.115	1.639
	(0.808)	(0.118)	(8.418)	(0.145)			(0.735)	(0.802)
NAREIT Price	0.636	0.101	46.430***	0.096	624	−308.00	0.151	1.564
	(0.770)	(0.115)	(8.050)	(0.162)			(0.698)	(0.815)

Notes: The dependent variables in the regressions, Equation (3), are the quarterly returns to the NCREIF total, NCREIF appreciation, NAREIT total, and NAREIT price indexes, respectively. Lagrange Multiplier tests of the first order, LM(1), and fourth order, LM(4), are reported in the last two columns. Estimation errors are reported in the parentheses below the parameters.
*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

Information is assimilated into prices and hence is contained in realized returns. The mean and variance of returns represent the frequency of information arrival and the magnitude of information. Many interesting questions thus arise: What information do appraisers incorporate in their appraisal processes? Do they adjust their appraisals with market information (such as REIT returns), or do they cluster large appraisal changes (ARCH)? It is believed that appraisers (facing incomplete information, costly search, and varying expectations) more slowly update their valuation estimates (see Quan and Quigley, 1991). One key information item that appraisers need while updating their appraisals is the current discount rate for commercial real estate (which reflects market supply and demand and opportunity cost). The public equity real estate market, represented by the NAREIT indexes, is an efficient and timely information source for the discount rate. Hence, it is plausible that appraisers make use of price information in the public equity market to supplement their incomplete information An alternative interpretation is that appraisers and participants in public equity markets are updating their estimates or expectations with respect to economic factors. That the public equity market leads private equity appraisals suggests that (1) the public equity market is faster to update valuations based on changes in fundamentals or (2) the infrequency of appraisals of private real estate suggests a lag (or longer lag) in the adjustment of valuations relative to those for public equities. To answer these questions and test related hypotheses, we run a modified ARCH (2,1) model with information spillovers in both the mean and variance equations for NCREIF total and appreciation returns, respectively. The information transmission model is constructed as follows:

$$R_t = \mu + b_1 f_{t-1} + b_2 f_{t-2} + \theta_1 R_{t-1} + \theta_2 R_{t-2} + \varepsilon_t$$

$$h_t = c + \alpha \varepsilon_{t-1}^2 + \beta f_{t-1}^2 \qquad (4)$$

$$\varepsilon_t | \phi_{t-1} \sim N(0, h_t)$$

Here R_t refers to the NCREIF total (or appreciation) return, and f_t refers to the NAREIT total (or price) returns. This model examines the first-order ARCH and second-order AR terms of the NCREIF index. The first-order variance transmission and second-order mean transmission from the matching NAREIT index are also incorporated in the NCREIF index. Exhibit 5 presents the results from this information transmission analysis. The left (right) panel reports the regression results on the information transmission from the NAREIT total (price) index to the NCREIF total (appreciation) index. In addition to the strong autocorrelation, the NCREIF total (appreciation) returns are significantly correlated with the past realization of NAREIT total (price) returns. The NCREIF total returns respond positively to the NAREIT total returns of the two preceding quarters, significant at the 5% level. The NCREIF appreciation returns respond to the NAREIT price returns of the two preceding quarters, significant at the 5% level.

Furthermore, with the inclusion of NAREIT information, the ARCH coefficient of the NCREIF total index is as high as 0.625, significant at the 1% level. The ARCH coefficient of the NCREIF appreciation index is as high as 0.831, significant at the 1% level. The variance spillover from the NAREIT total index to the NCREIF total index is 0.009. The variance spillover from the NAREIT price index to the NCREIF appreciation index is 0.013. Both are significant at the 5% level. Thus the information transmission from NAREIT indexes to NCREIF indexes is evident in both mean and variance, which suggests nonlinear information transmission.

Exhibit 6 reports the AIC statistics, the log likelihoods, and the likelihood ratio statistics. The AIC statistics in the information transmission model are smaller

Exhibit 6 | Information Transmission Analysis

	NAREIT Total to NCREIF Total	NAREIT Price to NCREIF Appreciation
μ	0.844***	0.223*
	(0.284)	(0.129)
b_1	0.013	0.012
	(0.017)	(0.015)
b_2	0.034**	0.028**
	(0.014)	(0.012)
θ_1	0.356***	0.332***
	(0.102)	(0.099)
θ_2	0.271***	0.261***
	(0.102)	(0.079)
c	0.422***	0.280
	(0.144)	(0.173)
α	0.625***	0.831***
	(0.205)	(0.258)
β	0.009**	0.013**
	(0.004)	(0.006)
L-test	27.64	27.58
	(0.000)	(0.000)

Notes: The dependent variables are the quarterly returns to the NCREIF total and NCREIF appreciation return indexes in the two separate regressions, Equation (4), respectively. The information transmission reported is from the NAREIT total to NCREIF total, and NAREIT price to NCREIF appreciation indexes. For the NAREIT Total to NCREIF Total, the AIC = 294 and log likelihood = −139.37; for NAREIT Price to NCREIF Appreciation, the AIC = 295 and log likelihood = −139.67. The likelihood test is reported in the bottom row. Estimation errors are reported in the parentheses below the parameters.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

than the AIC statistics in the simple ARCH model expressed in (3) for each series. This suggests that the information transmission models are a better fit for the data. In essence, the simple ARCH model is a restricted version of the information transmission model, which assumes no spillover from the other series in both the mean and variance equations. Hence, the likelihood ratio test is a useful method to compare the goodness-of-fit of the two models. Denote the parameter set of the information transmission model Θ_0 and denote the parameter set of the simple ARCH model Θ_1, which is a subset of Θ_0. The likelihood test is constructed as $\Delta = 2 \times (L(\Theta_0) - L(\Theta_1))$ and Δ follows a $\chi^2(4)$ distribution, where $L()$ is the log-likelihood function. The p-values are reported in parentheses. The likelihood ratio tests strongly prefer the information transmission model relative to the simple ARCH model.

As a robustness check, we examine the above relation between the two indexes in different return and variance regimes: when the past return of the NAREIT index is higher or lower than the average, respectively; when the square of the past NAREIT index return is higher or lower than the average, respectively. We run the following regression:

$$
\begin{aligned}
R_t &= \mu + b_1 f_{t-1} + b_2 f_{t-2} + b_3 Dummy \times f_{t-1} \\
&\quad + b_4 Dummy \times f_{t-2} + \theta_1 R_{t-1} + \theta_2 R_{t-2} + \varepsilon_t \\
h_t &= c + \alpha \varepsilon_{t-1}^2 + \beta f_{t-1}^2 \\
\varepsilon_t | \phi_{t-1} &\sim N(0, h_t)
\end{aligned}
\tag{5}
$$

In the top panel of Exhibit 7, the dummy is set to 1 if the past return of NAREIT (f_{t-1}) is no more than the average of NAREIT returns and zero otherwise. The coefficient on the down-turn information transmission for the two-quarter lag ($f_{t-2} \times Dummy$) is positive and significant at the 10% level for the NCREIF total index; it is positive and significant at the 1% for the NCREIF appreciation index. The coefficient of f_{t-2} is no longer significant for either index. In the lower panel of Exhibit 7, the dummy is set to 1 if the past return of NAREIT (f_{t-1}) is greater than the average of NAREIT returns and zero otherwise. The coefficient on the up-market information transmission ($f_{t-2} \times Dummy$) of the two-quarter lag is negative and significant for either NCREIF total or NCREIF appreciation. Meanwhile, the coefficient of f_{t-2} retains the significance for either index. These results show that the information transmission from NAREIT to NCREIF remains significant after controlling for the trend of NAREIT. More interestingly, the results suggest that the appraisals underlying the NCREIF index reflect downturns of the NAREIT index more strongly than the upturns.

In order to check the robustness of the results against the volatility change of NAREIT, we run the following model:

Exhibit 7 | Robustness Check

	NAREIT Total to NCREIF Total	NAREIT Price to NCREIF Appreciation
Dummy = 1 if $f_{t-1} \leq E[f_{t-1}]$		
f_{t-1}	0.031	0.032
	(0.023)	(0.023)
f_{t-2}	−0.018	−0.024
	(0.024)	(0.026)
$f_{t-1} \times$ *Dummy*	−0.013	−0.020
	(0.041)	(0.048)
$f_{t-2} \times$ *Dummy*	0.061*	0.071***
	(0.033)	(0.031)
f_{t-1}^2	0.011***	0.012**
	(0.004)	(0.006)
Dummy = 1 if $f_{t-1} > E[f_{t-1}]$		
f_{t-1}	0.018	0.011
	(0.004)	(0.036)
f_{t-2}	0.042***	0.046***
	(0.016)	(0.015)
$f_{t-1} \times$ *Dummy*	0.013	0.021
	(0.041)	(0.049)
$f_{t-2} \times$ *Dummy*	−0.060**	−0.070***
	(0.033)	(0.031)
f_{t-1}^2	0.011***	0.012**
	(0.004)	(0.006)

Notes: The dependent variables are the quarterly returns to the NCREIF total and NCREIF appreciation return indexes in the separate regressions, Equation (5), respectively. The information transmission reported is from NAREIT total to NCREIF total, and NAREIT price to NCREIFT appreciation indexes. A dummy variable is included to control for the possible asymmetric information transmission. Estimation errors are reported in the parentheses below the parameters.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

$$R_t = \mu + b_1 f_{t-1} + b_2 f_{t-2} + \theta_1 R_{t-1} + \theta_2 R_{t-2} + \varepsilon_t$$

$$h_t = c + \alpha \varepsilon_{t-1}^2 + \beta f_{t-1}^2 + \gamma Dummy \times f_{t-1}^2 \qquad (6)$$

$$\varepsilon_t | \phi_{t-1} \sim N(0, h_t)$$

We first set *Dummy* to be 1 if f_{t-1}^2 is greater than its average, and zero otherwise. In a separate regression, we set *Dummy* to be 1 if f_{t-1}^2 is greater than twice its average, and zero otherwise. In each regression, the coefficient estimate for the

Dummy term is insignificant and all other parameter estimates (not reported for brevity) are close to the results in Exhibit 6. Overall, the information transmission is robust with respect to the mean and variance shifts in NAREIT returns.

A Comparative Look at NCREIF and NAREIT

Several studies have compared the returns of the NCREIF and NAREIT indexes, controlling for their differences (e.g., Chan, Erickson, and Wang, 2003; Pagliari, Scherer, and Monopoli, 2003; and Riddiough, Moriarty, and Yeatman, 2005). These works have taken painstaking efforts, using varied approaches, to control for differences such as leverage, property-type, and appraisal smoothing. There are two major differences between NCREIF and NAREIT that may cause different time-series behavior of the two indexes. First, NCREIF is reported as returns to assets while NAREIT focuses on returns to equity. Hence, NAREIT returns are leveraged. Over the 1981–2001 period, the average loan-to-value ratio is nearly 40% (Pagliari, et al., 2003). Second, the two indexes have different property mixes and the mixes of the two indexes change over time (Riddiough, et al., 2005).

Leverage would affect the size of REIT returns but not the direction of the change. Also, if averaging across REITs, leverage changes little over time. So it is likely that controlling for leverage would not affect our preceding analysis results that REITs lead NCREIF. How would the property mix affect the lead-lag relation between the REIT and NCREIF indexes? If the lead-lag relation between the two indexes is caused, at least partially, by the different property mixes of the two indexes, it must imply that certain property classes lead other property classes and the NAREIT index weighs more on these leading property classes than the NCREIF index. From the literature, there has been no indication of this possibility. Myer and Webb (1993) examine the causality between their self-constructed REIT index and the overall NCREIF index and its sub-indexes by property type on a data sample spanning from 1978 to 1990. Their results show that the REIT index Granger causes the overall NCREIF index. They also find that the REIT index Granger causes the Office, Retail, Research and Development, and Warehouse sub-indexes separately. However, none of the sub-indexes by type, nor the overall index of NCREIF Granger causes the REIT index. This suggests that the REIT index's lead is caused by something other than its property mix.

Using firm-level financial data obtained from Compustat, FactSet, and the REIT Handbook, Riddiough, Moriarty, and Yeatman (2005) construct REIT and NCREIF total return indexes of annual frequency from 1980 to 1998. Their REIT index is adjusted for partial-year and leverage effects to match the property mix of the NCREIF index. Based on data provided by Tim Riddiough, we reconstruct quarterly series of REIT and NCREIF total returns for the period 1980–1998, following the method of Riddiough et al. We include the same firms in the same sample years as Riddiough et al. We use quarterly returns of each firm's debt and preferred stock and update quarterly return of each firms' common stock, as done in the study of Riddiough et al. These authors developed a weighted method to

calculate returns that are based on the average valuations of the respective assets throughout each year. Hence, we use the same weights provided by Riddiough to calculate the return on assets of each REIT firm, the return rates of each sub-index by property class, and the return rates of the REIT and NCREIF total return indexes. Our reconstructed quarterly series of REIT index returns are thus free from partial year and leverage effects and they match the property mix of our quarterly series of NCREIF index returns, as documented in Riddiough et al.

Using these two return series, we reexamine the Granger causality between the REIT and NCREIF indexes, and information transmission from the REIT index to the NCREIF index. We first run VAR regression (2) including first sixth lags of the two independent variables. Reported in Panel A of Exhibit 8, the results show that the REIT index returns Granger cause NCREIF index return at the 5% confidence level. Granger causality from the other direction is not significant. We then run the ARCH regression (4) on the reconstituted NCREIF index with information transmission from the reconstituted REIT index, and report the key estimates in Panel B of Exhibit 8. The coefficient of the REIT return a half year earlier (b_2) is positive and significant at the 5% level. This suggests a significant half-year lead of the REIT index relative to the NCREIF index. The coefficient of the square of the past quarter REIT return (β) is positive and significant at the 1% level. This suggests that the volatility of the REIT return is significantly related to the magnitude of the NCREIF index return in the next quarter. The results also show positive autocorrelation of the NCREIF index returns, consistent with preceding analysis. Overall, the reexamination using the reconstituted indexes suggests a significant information transmission from the REIT index returns to the mean and variance of the NCREIF index returns, which is consistent with our preceding analyses. This implies that the reported lead-lag relation between the REIT and NCREIF indexes is not likely caused by the financial leverage of individual REITs, nor by the differential property mix of the two indexes.

The appraisal smoothing of the NCREIF indexes is the third major difference, which might be an explanation of our results. Researchers have developed methodologies to de-smooth appraisal-based indexes to generate revised indexes that are more closely related to economic and market movements (i.e., Geltner, 1991, 1993). More recently, Fu (2003) estimates the lagging errors of the NCREIF indexes due to known sources (such as partial adjustment of the observed index to the latent appreciation return and the seasonality in reappraisal quality), and includes exogenous predictive variables in a state-space model. By construction, a revised index from this methodology is more closely related to market movements.

Smoothing may be a drawback to the NCREIF index while volatility may be a drawback to the NAREIT index. However, we do not argue that one is superior to the other. Different mechanisms are used to construct each of the two indexes because they are used to value different assets. The NCREIF index is for a group of privately held real estate investments, which are long term and generally have low liquidity. Such long-term real estate investments are less sensitive to market fluctuation and short term returns.

Exhibit 8 | Granger Causality Tests and Information Transmission Analysis Using Reconstructed Quarterly REIT and NCREIF Indexes

Panel A: Granger Causality Wald Test

Test	χ^2	DF	Prob$>\chi^2$
REIT not cause NCREIF	13.95	6	0.030
NCREIF not cause REIT	6.44	6	0.378

Panel B: Information Transmission Regression

	REIT Total to NCREIF Total
b_1	−0.050
	(0.077)
b_2	0.044**
	(0.019)
θ_1	0.474***
	(0.082)
θ_2	0.238**
	(0.085)
β	0.157***
	(0.023)

Notes: The dependent variables in the VAR are the quarterly returns to the reconstructed REIT and NCREIF total return indexes. Four lags of the independent variables and the first lag of GDP, credit spread (*CSPREAD*), term spread (*TSPREAD*), and the Federal Reserve fund rate (*FEDRATE*) are included as the explanatory variables. Reported are the Granger causality Wald test and the estimates of the information transmission parameters. Estimation errors are reported in the parentheses below the parameters.
*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

The NCREIF index produces lower returns and lower volatility compared to the NAREIT index. Over 1981–2001, REITs generate an average return of 13.47% with volatility of 14.66%, while the NCREIF index generates returns of 8.43% with volatility of 5.91% (Pagliari, Scherer, and Monopoli, 2003). Pagliari et al. find that, the restated NCREIF returns after controlling for appraisal smoothing, property mix difference, and financial leverage, are not significantly different from that of NAREIT. Clearly, the higher returns and volatility of NAREIT are related to the higher financial leverage for NAREIT and the appraisal smoothing of NCREIF.

Overall, the NCREIF and NAREIT indexes are different. This study focuses on the dynamic relation between the appraisal-based NCREIF and the market-based

NAREIT indexes. Not surprisingly, we find that NAREIT leads NCREIF and this information transmission is presently controlling for the autoregressive conditional heteroscedasticity of the two indexes. Identification of the differences between the two indexes is not the subject of our study. However, the differences between the two, in particular the appraisal smoothing, may be a likely explanation for the causality we find. Appraisal updates are infrequent while appraisers learn from the trading market. Appraisers are not required to respond as quickly to market information and market movements as equity investors. They usually rely on sales and appraisal records in the past several quarters. In addition, agency theory suggests that appraisers are risk averse and are slow to respond to new market information. Therefore, appraisals are likely to be more market trailing rather than market leading.

Conclusion

We examine the dynamic behavior of NCREIF total, appreciation, and income return indexes over the period of 1977–2001. Consistent with previous studies, we find strong autocorrelation in these indexes. NCREIF indexes are smooth partially due to the lagging in their price updates. NCREIF total and appreciation indexes are significantly and positively related to GDP growth rate and stock market returns.

In the ARCH analysis, we find that the relation between the NCREIF and NAREIT indexes is non-linear. NCREIF total and appreciation returns exhibit strong autoregressive conditional heteroscedasticity. Moreover, NCREIF total and appreciation returns receive information transmission from the NAREIT indexes in both the mean and variance of returns. This suggests that the appraisals, which drive the NCREIF index, appear to incorporate information from the securitized real estate market.

The general result of the paper is that appraisal-based returns lag NAREIT returns and there is a causality effect implying that NAREIT returns provide ''information flow'' into the appraisal-based returns. This suggests that appraisers use REITs as a proxy for performance. Of course they do look at other things (previous appraisals, changes in the local market, etc.). But it raises an interesting question. Did the REIT market lead property asset prices higher in the early 2000s? It was during this time that people discussed the disconnection between the asset and the space markets. Space market fundamentals were poor (high vacancy, lackluster rent growth, etc.) yet investors paid top dollar for properties. The answer, of course, is that the huge rotation of capital into real estate was first evident in the public securities market, which processes information more quickly.

Endnotes

[1] For example, see Chan, Hendershott, and Sanders (1990), Ling and Naranjo (1999), Ling, Naranjo, and Nimalendran (2000), and Okunev, Wilson, and Zurbruegg (2000).

[2] See Young and Graff (1996), Geltner and Goetzmann (2000), Pagliari, Scherer, and Monopoli (2001), and Hendershott and MacGregor (2005). Taking a slightly different approach, Shilton (2000) tests the cointegration of the ACLI and NCREIF indexes.

[3] See Geske and Roll (1983), Kaul (1987), Fama (1990), and Li and Born (2006) for example.

[4] Recent studies such as Bond, Karolyi, and Sanders (2003), Chiang and Lee (2004), Riddiough, Moriarty, and Yeatman (2005), Bertin, Kofman, Michayluk, and Prather (2005), Sirmans, Friday, and Price (2006), Chiang and Lee (2007), and Li, Mooradian, and Yang (2007) utilize newly developed methodologies to examine the return and risk of REITs and private real estate.

[5] The negative partial autocorrelations beyond the fourth lag also imply mean reversion in appraisals.

[6] Published by the Federal Reserve System.

[7] We study the NCREIF and NAREIT markets under a general asset pricing framework using traditional economic and monetary factors (i.e., Chen, Roll, and Ross, 1986). We also consider inflation in our study. Inflation proxied by the consumer price index (CPI) is highly negatively correlated with *GDP*, *FEDRATE*, and *CSPREAD*. Including *CPI* in Equation (1) does not add significant power to the regression, while subjecting the regression to collinearity. When we consider real return rates of the indexes (nominal rates minus the inflation rate), regression results are consistent with those reported in the paper.

[8] The lag S&P 500 is insignificantly related to both NAREIT and NCREIF index returns as shown in the earlier regression. In order to avoid loss of degree of freedom, we exclude this term in Equation (2).

[9] We also run VAR analyses using more lags (such as six), yielding qualitatively similar results. Additional lags exhibit neither significant explanatory power on the dependent variables nor add power in the regressions. In order to avoid the loss in degrees of freedom, we report VAR results using four lags.

[10] Results are not reported but available upon request.

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