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Does Property Transaction Matter in the Price Discovery of Real Estate Markets?

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This study examines whether property transaction affects the price discovery process in real estate markets. Prior literature shows that price discovery generally first takes place in the securitized public real estate investment trust (REIT) market. We conjecture that property transaction provides novel information to the direct real estate market and can change the dynamics between public and private real estate returns. We employ a unique dataset of property transactions to construct "transaction windows" and specifically examine the causality between public and private real estate markets around these periods. We form firm-level pairs of public and private price series, and estimate the normalized common factor loadings per Gonzalo and Granger (1995) by using a vector error-correction model. Our findings show that a significant proportion of price discovery happens in the private market instead of the public REIT market. Our results are robust to investments of different property types and different lengths of transaction windows. Overall, the findings in this study imply that property acquisition and disposition provide crucial information to the private real estate market and induce a reverse causality between the public and private markets.

Keywords
REIT, Direct Real Estate, VECM, Price Discovery

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1. Introduction

The relative performance and efficiency of the public and private real estate markets have been a topic of interest in the real estate literature. While private real estate can provide significant diversification benefits in a portfolio setting (e.g., Hoesli et al. 2004; Brounen et al. 2010), the liquidity is low and transaction costs are high with the direct ownership of real estate properties. On the other hand, public securitized real estate markets, such as real estate investment trusts (REITs), offer investors a low-cost alternative to invest into the real estate market, yet the prices of real estate securities may be affected by noise traders or investor sentiment and may deviate from the fundamentals (e.g., Clayton and MacKinnon 2001a; Gentry et al. 2004; Lee et al. 2013). Although studies have shown that a short-run correlation between public and private real estate markets is relatively low (e.g., Sagalyn 1990; Mueller and Mueller 2003; Brounen and Eichholtz 2003) and that the public real estate market more resembles the general stock market (e.g., Goetzmann and Ibbotson 1990; Wang et al. 1995; Ling and Naranjo 1999), the long-run co-integration between these two markets is particularly strong (e.g., Geltner and Kluger 1998; Liow 2003; Liow and Li 2006; Ang et al. 2013). With regard to the price determination in the public and private real estate markets, earlier studies (e.g., Gyourko and Keim 1992; Barkham and Geltner 1995; Eichholtz and Hartzell 1996; Chau et al. 2001; Geltner et al. 2003) that have examined the long-run lead-lag relation between these two markets have predominantly agreed that the public market leads the private market, thus implying that new information is first incorporated into securitized real estate prices before it is reflected in the private market. Although studies (e.g., Myer and Webb 1993; Clayton and MacKinnon 2001c; MacKinnon and Al Zaman 2009; Yavas and Yildirim 2011) have shown that the dynamics of public and private markets have changed over time, recent studies (e.g., Oikarinen et al. 2011; Hoesli and Oikarinen 2012; Yunus et al. 2012) continue to suggest that the public market leads the private market, but not the other way around.

In this study, we examine whether information revealed in the private market is still pertinent for making inferences in prices for the public real estate market. In particular, we focus on property transaction information as it provides novel information to the private real estate market and can change the dynamics between public and private real estate returns. We employ a unique dataset of property transactions from January 1st 2001 to December 31st 2013 and construct "transaction windows" to specifically examine the causality between public and private real estate markets around these periods. We use the daily property transactions on individual real estate firms to form synchronized public and private price pairs around these transaction windows, and not by regular calendar time as in the prior literature. This allows us to estimate the relationship between the public and private real estate markets with respect to the information generated by property transactions in the underlying spot market. We first establish a long-run cointegration relationship between the public and private real estate markets by using the Johansen cointegration test. We then estimate the normalized common factor loadings per Gonzalo and Granger (1995) of the public and private real estate markets with the vector error-correction model (VECM). Our findings are in agreement with prior studies and document that the public and private real estate markets are highly cointegrated in the long run. More importantly, we show significant contributions to price discovery from the private real estate market. By using the synchronized public and private price pairs around transaction windows of a lead-lag of 25 days (i.e., 25 days before and after a recorded property transaction date), we find that the common factor loadings of the private real estate markets relative to the public real estate markets range from 81% to 94% across various property type investments, thus indicating that information predominantly flows from the private to the public real estate market at times when firms make acquisition and disposition decisions. We show that the contribution to price discovery in the private real estate market is more apparent for larger and glamour real estate firms. We also find that private real estate prices lead public real estate prices both before and after the financial crisis. As our findings could be sensitive to the length of the transaction windows chosen, we define the transaction windows with different number of lead-lag days around the property transaction dates. Our results are robust to the alternative definitions of transaction windows.

We contribute to the literature by providing novel evidence on the price discovery between the public and private markets. Understanding the information flow of the public and private real estate markets is very important for investors and will affect the timing of investments in these two markets. Most prior studies, with the exception of Tuluca and Myer (2000), show that the public real estate market leads the private market. Our study shows that under circumstances when significant events occur in the private real estate market, the information flow can be reversed and transmitted from the private to the public real estate market. The implication of our findings is that news in the private market could be as important as public market signals for investors. We focus on property transactions for the following reasons: first, property transactions represent some of the most significant events in a real estate firm with direct bearing on firm valuation. Hence, news of property acquisition and disposition should be efficiently incorporated into the net asset values (NAVs). Second, property transactions occur infrequently and these events are less likely to be affected by daily market shocks that are unrelated to the fundamentals which affect property market prices. Our other contribution with this study is to gauge the price discovery and the long-run cointegration relationship between the public and private real estate markets at the firm-level by utilizing a unique dataset of property transactions. The majority of studies (e.g., Ling and Naranjo 2003; Pagliari et al. 2005; Riddiough et al. 2005; Oikarinen et al. 2011) compare returns in the public markets with private markets at the market index level. We follow Yavas and Yildirim (2011) and conduct our analysis at the firm-level, thus enabling us to examine variations across firms with different property type investments. By focusing on periods with property transaction data, we also provide a new angle to test the relative contribution to price discovery between the public and private real estate markets. Our research is related to the broader finance literature, such as Cao et al. (2005), who find that the trading volume of equity options before takeover announcements significantly increases and indicates that the options market should be particularly informative ahead of material events before the equity market opens. Our results show that the private real estate market can also be informative relative to the securitized public market when there are material events that bear significant consequences on real estate entities.

The remainder of the paper is organized as follows: in the next section, we provide a review of the literature which examine the correlations between the public and private real estate markets. We outline our research methodology in Section 3 and describe the data and descriptive statistics in Section 4. We present the empirical analysis and results in Section 5. We provide some concluding remarks in the last section.

2. Literature Review

A long line of real estate literature has explored the relationship between the public and private real estate markets. Extensive studies are conducted to understand the divergence of public real estate prices from private market fundamentals. For instance, Clayton and MacKinnon (2001b) explore the determinants of the premiums of NAVs in real estate investment trust (REIT) pricing and find that the premiums are correlated with REIT size, debt to equity ratio as well as liquidity. Gentry et al. (2004) show that REIT premiums reflect more than investor sentiment, as REITs tend to have high levels of insider and institutional ownership. A recent study by Lee et al. (2013) shows that sentiment effect remains the dominant factor in explaining the premiums in Singaporean REITs.

With regard to the correlations between the public and private markets, Mueller and Mueller (2003) show that there are low correlations between the public and private real estate markets and propose the inclusion of both investments in a mixed-asset portfolio. Brounen and Eichholtz (2003) examine the relationships between the private property market and the securitized public market with common stock markets in the U.S. and the U.K. They find that there is a common component that underlies both the private and public real estate markets. However, the correlations between the two markets remain very low and the correlation coefficient is far from one.

Many studies argue that even though the short-term correlations between the public and private real estate markets are low, the two markets ought to converge in the long-term since they represent the same underlying property assets. By constructing REIT-based pure-play portfolios, Geltner and Kluger

(1998) show there is a close link between the public and private markets. Liow (2003) examines the cointegration between the two markets and shows that they do not drift apart from each other. Liow and Li (2006) extend Liow (2003) to the Asian-Pacific real estate markets and obtain similar findings. Pagliari et al. (2005) indicate that the public and private real estate markets display a long-run synchronicity. Oikarinen et al. (2011) find a long-run cointegration relationship between the securitized and direct real estate markets, but only direct real estate is found to adjust towards the cointegration relation. In incorporating economic fundamentals and sector-level data for the U.S., U.K. and Australia, Hoesli and Oikarinen (2012) suggest that the public and private real estate markets remain tightly linked in the long-run. Stefek and Suryanarayanan (2012) focus on the core real estate in the U.K. market, analyze data that span more than two decades, and demonstrate a tight link between the public and private real estate markets in the U.K. after accounting for appraisal smoothing and lead-lag relationships. In order to avoid bias that results from appraisal smoothing, Boudry et al. (2012) use transaction-based price indexes; that is, MIT transaction based indexes (TBIs), and find that REITs and their underlying direct real estate market are cointegrated in the U.S. market. Yunus et al. (2012) examine the international markets and discover that in addition to the U.S. and U.K. markets, Australia and Netherlands also exhibit long-run relationships between the public and private real estate markets. Ang et al. (2013) study the long-run commonality between the two markets and find that the common real estate factor is highly autocorrelated, thus reflecting the cyclical nature of real estate. Moreover, in the long-run, both public and private real estate vehicles exhibit similar characteristics. Casni and Vizek (2014) study the long-run cointegration relationship between the equity and real estate prices in thirty developed and emerging economies, and find that real estate equity and direct real estate prices are closely correlated, synchronized, and codependent in the long-run. The level of long-run codependence hinges on the level of national income and the structure of financial markets.

Several studies have documented the dynamic nature of the correlations between the public and private markets. Myer and Webb (1993) state that inter-temporal REIT returns are much more strongly related to direct real estate returns than the returns on stocks or closed-end funds. Clayton and MacKinnon (2001c) document that the relationship between REIT returns and direct real estate returns has changed over time. By examining data that spanned from 1978 to 1998, they find that, during the 1990s, REITs began to exhibit a more direct link to real estate returns. MacKinnon and Al Zaman (2009) make a similar conclusion in that the correlation between REITs and direct real estate is time-varying. The correlation between them increases with horizon, but never exceeds 0.54.

Most studies support the notion that public real estate returns lead private real estate returns. Early studies by Gyourko and Keim (1992), Barkham and Geltner (1995), Eichholtz and Hartzell (1996), Chau et al. (2001) and Geltner et al. (2003) claim that securitized real estate returns tend to lead direct private real estate returns. In order to address the possibly biased estimation of the short-run dynamics, Oikarinen et al. (2011) include the transaction-based NCREIF Index in the analysis and conclude that REIT returns dominate private real estate returns. Accounting for economic fundamentals and leverage, Hoesli and Oikarinen (2012) use sector-level indices and find that the REIT market predicts the direct real estate market. Yunus et al. (2012) suggest that the public market leads the private market, but not the other way round, by using Granger causality testing. In addition to accounting for property-type and leverage, Oikarinen et al. (2013) consider the impact of escrow lags on the reported lead-lag relations between the public and private markets and find that REIT returns lead private real estate returns.

While it is generally believed that the securitized real estate market takes the dominant role in price discovery as it is more liquid and therefore incorporates new information more quickly and efficiently than the direct real estate market, the latter may lead the public market. Yavas and Yildirim (2011) use a dynamic conditional correlation generalized autoregressive conditional heteroskedasticity (DCC GARCH) model to illustrate that the correlations between the public and private real estate markets are time-varying. Although price discovery generally takes place in the securitized public market, they show that such a lead-lag relationship may change across firms and property type. By examining five assets, including T-bills, bonds, stocks, and both public and private real estate, Tuluca and Myer (2000) find that these five assets are nonstationary and cointegrated, and that the two real estate markets have a long-term equilibrium relationship with the private real estate market, possibly leading the securitized real estate market. They attribute their contrasting findings to the theory of an efficient market. As defined by Ross (1987), a market is efficient if there is a lack of arbitrage opportunities. According to this definition, the private real estate market can be regarded as an efficient market because of illiquidity.

3. Research Methodology

3.1 Johansen Cointegration

The primary objective of this study is to investigate the long-run dynamics between the securitized real estate market and underlying direct property market on the relative magnitude of price discovery attributable to the two given markets around property transaction events. The augmented Dickey Fuller (ADF) unit root test is first employed as a preliminary tool to ensure that the price series are non-stationary. We then use the Johansen cointegration rank test to establish the cointegration relation between public and private real estate market prices. The Johansen formulates likelihood ratio (LR) statistics for the number of cointegration relationships as LR statistics for determining the rank of Π: the trace and maximum eigenvalue statistics, shown in Equations (1) and (2) respectively.

$$LR_{trace}(r_0) = -T\sum_{i=r_0+1}^{n} \ln(1-\hat{\lambda}_i) \quad (1)$$

$$LR_{max}(r_0) = -T\ln(1-\widehat{\lambda_{r_0+1}}) \quad (2)$$

While the trace statistic tests the null hypothesis $H_0(r_0)\colon r = r_0$ vs. $H_1(r_0)\colon r > r_0$, the maximum eigenvalue statistic tests the null hypothesis $H_0(r_0)\colon r = r_0$ against the alternative hypothesis $H_1(r_0)\colon r = r_0 + 1$. In this study, we apply the trace test statistics to determine the number of cointegration vectors (r). If $rank(\Pi) = r_0$ then $\hat{\lambda}_{r_0+1}, \cdots, \hat{\lambda}_n$ should all be close to zero and $LR_{trace}(r_0)$ should be small since $\ln\left(1-\hat{\lambda}_i\right) \approx 0$ for $i > r_0$. In contrast, if $rank(\Pi) > r_0$ then some of $\hat{\lambda}_{r_0+1}, \cdots, \hat{\lambda}_n$ will be nonzero (but less than 1) and $LR_{trace}(r_0)$ should be large since $\ln\left(1-\hat{\lambda}_i\right) \ll 0$ for some $i > r_0$.

3.2 Price Discovery

In finance, there are two popular common factor models that are used to investigate the mechanics of price discovery: information shares (IS) (Hasbrouck 1995) and permanent-transitory (PT) (Gonzalo and Granger 1995). Both models are primarily derived from the VECM. By following the recent literature on price discovery (e.g., Giannikos et al. 2013; Man et al. 2013), we adopt the PT procedure proposed by Granger and Gonzalo (1995) to estimate our model in order to examine the long-run dynamics between public and private real estate markets.

The VECM (p) model with the cointegration rank $r(\leq k)$ is written as:

$$\Delta y_t = \Gamma_1\Delta y_{t-1} + \Gamma_2\Delta y_{t-2} + \Gamma_3\Delta y_{t-3} + \cdots + \Gamma_k\Delta y_{t-k} + \alpha\beta' y_{t-1} + \epsilon_t \quad (3)$$

where Γ_i are (2×2) square matrices of the coefficients for the lagged differences, α is the error correction (or equilibrium adjustment) matrix, β is the cointegration vector which represents the long-run relationship between the elements of Δy_t, and e_t denotes the vector regression residual.

We empirically estimate the VECM with the following:

$$\Delta Price_{m,n,t} = \alpha_1 Z_{m,n,t-1} + \sum_{j=1}^{p} \tau_{1j}\Delta Price_{m,n,t-j} + \sum_{j=1}^{p} \varphi_{1j}\Delta NAV_{m,n,t-j} + \epsilon_{m,n,t} \quad (4)$$

$$\Delta NAV_{m,n,t} = \alpha_2 Z_{m,n,t-1} + \sum_{j=1}^{p} \tau_{2j}\Delta Price_{m,n,t-j}$$

$$+\sum_{j=1}^{p} \varphi_{2j}\Delta NAV_{m,n,t-j} + \delta_{m,n,t} \quad (5)$$

where $\Delta Price_{m,n,t}$ and $\Delta NAV_{m,n,t}$ are the changes in the REIT prices[1] and NAVs of firm n of property type m in period t, respectively. $Z_{m,n,t-1} = Price_{m,n,t-1} - \beta NAV_{m,n,t-1}$ is the long-term relationship between changes in the price and NAVs, $\epsilon_{m,n,t}$ and $\delta_{m,n,t}$ are independent and identically distributed (i.i.d.) innovations.

The focus of the price discovery model in Gonzalo and Granger (1995) is on the error correction process. The model estimates the common factor weights that reflect the permanent contribution to the common factor (efficient price). The common factor weights are derived from error correction coefficients, α_1 and α_2, in the two markets. By following the approach of Gonzalo and Granger (1995), the respective contribution from REITs and direct real estate property to price discovery is defined by the following ratios found in Gonzalo and Granger (GG) (1995):

$$GG_{reits} = \frac{\alpha_2}{\alpha_2 - \alpha_1} \quad \text{and} \quad GG_{NAV} = \frac{\alpha_1}{\alpha_1 - \alpha_2} \quad (6)$$

The ratio denotes the portion of the contribution to price discovery. The sum of GG_{reits} and GG_{NAV} equals to 100%. According to Upper and Werner (2007), the point estimate for a common factor loading can be negative, as the coefficients on the error correction terms are of the same sign in both equations of the VECM. They suggest that only one market adjusts toward the equilibrium, while another market moves away from it. To put it another way, this happens when all adjustments are made by only one market.[2] The lag length is selected based on the Hannan-Quinn (HQ) information criteria as suggested by Johansen et al. (2000). Most of the previous studies of price discovery between public and private property markets investigate the lead-lag structure of prices by (1) co-integration (Liow and Li, 2006; Hoesli and Oikarinen, 2012), or (2) DCC (Yavas and Yildirim, 2011). The GG model of price discovery enables us to compute the GG ratio, a direct estimate of the unique contribution of each market after accounting for the cointegration equilibrium relation. We believe that the GG model is appropriate for our study because the private property market is illiquid compared to the public stock market where REITs are listed. Other price discovery models, such as that in Hasbrouck (1995) requires intraday/high frequency transaction data in both markets. Our data frequency is limited to daily observations of REIT prices and NAV estimates for each firm.

[1] Price represents the dividend adjusted price of a REIT.
[2] Negative common factor loading is possible if price series are not cointegrated.

3.3 Transaction Windows

In this study, we argue that NAVs should be more important in contributing to price discovery around property transaction dates because the underlying properties should reflect the new information on property transactions (i.e., buy or sell properties). We now illustrate the process of constructing the transaction windows around property transaction dates. To the best of our knowledge, there is no related study that we can follow in constructing transactions windows. We postulate new information should be incorporated into NAVs quickly when there is a significant property transaction for a specific firm since analysts should immediately update their estimates in light of the new information. We therefore define our transaction window as the short time period before and after the transaction date. To ensure robustness, we include three different transaction windows in our study which are "lead-lag of 25 days", "lead-lag of 30 days", and "transaction-date-lag of 5 days & lead-lag of 25 days". Our main analysis is conducted on the "lead-lag of 25 days" transaction windows, which we define the sample observations as [t-25, t+25] daily observations for each transaction date at the firm-level. Take for example, a property transaction that took place on April 25th 2013 for Starwood Hotels & Resorts Worldwide. To construct the transaction window of "lead-lag of 25 days", we include the firm-level observations from March 20th 2013 to May 30th 2013 for this company; weekends and holidays excluded. We construct the transaction window of "lead-lag of 30 days" in the same manner. In our third specification of transaction windows, we use "transaction-date-lag of 5 days & lead-lag of 25 days". Based on each transaction date t, we set $t\text{-}5$ as each new transaction date, denoted as t_5, and include [t_5-25, t_5+25] observations. For example, to construct the transaction window of "transaction-date-lag of 5 days & lead-lag of 25 days" for the above-mentioned property transaction, we first lag the transaction date back to 5 days[3] which should be April 18th 2013. Then, based on this revised date, we include the observations of [t_5-25, t_5+25]. Therefore, the transaction window spans from March 13th 2013 to May 23rd 2013, weekends and holidays excluded. We include this alternative transaction window to account for the possibility of any early news leak before the transaction date.

4. Data

Our sample period spans from January 1st 2001 to December 31st 2013. Our dataset includes firm-level U.S. REIT prices (total return indices)[4] and NAV

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[3] The term "5 days" refers to 5 trading days in a public market which is equivalent to 7 calendar days or 1 week in a private market.

[4] The total return index from the SNL is the cumulative total return that is indexed between the start and end dates of a firm. To obtain the change in price, we calculate the total return change between the values of the total return indices. For details on index value construction, see the SNL online manual: https://www.snl.com/help/HelpFile/Index_Values.htm?rhsearch=total%20return.

estimates, both in daily frequency, obtained from SNL Financial. The REIT price calculation assumes that dividends paid by a company are reinvested. The NAV estimates from SNL Financial are appraisal-based, which may result in estimation bias.[5] The sample periods covered in the dataset are different across different firms based on the availability of SNL Financial data.[6] We form paired daily observations of REIT prices and NAV estimates for each firm and include observations within the transaction windows in our empirical analysis.[7] There are a total of 3,782 transactions on 69 distinct firms over the sample period, with 91,278 paired observations within the transaction windows of "lead-lag of 25 days" for the total sample. These sample firms can be classified into four property types: diversified, office, hotel, and industrial.[8] Table 1 provides descriptive statistics of the 3,782 property transactions. Office REITs have the largest number of property transactions (1,316), followed by Diversified REITs (1,116), then Hotel REITs (717) and lastly, Industrial REITs (633). The mean (median) price of property traded is 28.1 (7.9) million USD. The mean (median) size of property traded is 214.3 (104.0) thousand square feet. These descriptive statistics suggest that both transaction price and property size are positively skewed. Office REITs have the largest standard deviation in transaction prices while Diversified REITs have the largest standard deviation in property size. Overall, our sample displays a moderate variation in property transaction characteristics across property types. Table 2 shows the summary statistics for the paired observations of the differenced price, $\Delta price_t = price_t - price_{t-1}$and the differenced NAVs, $\Delta NAV_t = NAV_t - NAV_{t-1}$.[9] As suggested by Table 2, U.S. REIT prices are more volatile than NAV estimates at the daily level. The standard deviation of $\Delta price$ is 10.546 much greater than that of ΔNAV, 0.553. ΔNAV exhibits larger values of kurtosis (1126.87) than $\Delta price$ (138.13), thus implying that ΔNAV is of less normality than $\Delta total\ return$. We observe a similar pattern across different property types.

[5] Prior studies (Lai and Wang 1998; Corgel and deRoos 1999; Childs et al. 2002) show that despite the existence of appraisal bias, there is no agreement on its magnitude and the method of correction. However, we believe that appraisal bias should be less of a concern in our study, as we are focusing on the transaction windows when property acquisition and disposal occur with sales prices information available for all analysts.

[6] For example, the availability of the observations of Cedar Realty Trust Inc. begins on November 2003 and ends on December 2013, while the data of Cousins Properties Incorporated starts on May 2001 and ends on December 2013. Moreover, we only include daily observations around the time periods where property transactions occur for the firms.

[7] In an unreported analysis, we exclude observations which we have multiple property transactions in a transaction window. Our empirical results remain robust.

[8] We do not include other property types in our analysis because there are very few firms for the other property types for us to conduct the empirical analysis.

[9] In following Hasbrouck (1995), we only apply real indices of prices and NAV estimates.

Table 1 Descriptive Statistics of Property Transactions

Property type	Diversified		Office		Hotel		Industrial		All	
	Prop Size	*Prop Price*	*Prop Size*	*Prop Price*	*Prop Size*	*Prop Price*	*Prop Size*	*Prop Price*	*Prop Size*	*Prop Price*
Number of Property Transactions	1,116		1,316		717		633		3,782	
Mean	295.6	21.3	200.3	45.8	236.6	57.8	194.5	7.9	214.3	28.1
Median	52.0	4.3	110.0	15.0	213.6	28.0	119.8	5.1	104.0	7.9
Standard Deviation	2422.0	58.7	311.0	100.3	158.6	83.5	212.4	11.5	1028.1	69.8

Notes: This table presents the summary statistics of property transactions for the total sample and across different property types. The property size is in thousands of square feet and the property price is in millions.

Table 2 Descriptive Statistics of Differenced Series of "Lead-Lag of 25 days"

Property type	Diversified		Office		Hotel		Industrial		All	
	$\Delta Price$	ΔNAV	$\Delta Price$	ΔNAV	$\Delta Price$	ΔNAV	$\Delta Price$	ΔNAV	$\Delta Price$	ΔNAV
Number of Firms	23	23	18	18	20	20	8	8	69	69
Sample Size	26,162	26,162	32,727	32,727	21,179	21,179	11,210	11,210	91,278	91,278
Mean	0.158	0.004	0.132	0.005	0.085	0.001	0.183	0.003	0.135	0.004
Median	0.160	0.000	0.190	0.000	0.000	0.000	0.120	0.000	0.120	0.000
Standard Deviation	11.741	0.633	11.382	0.520	7.162	0.596	10.427	0.314	10.546	0.553
Skewness	-0.914	4.209	-3.530	-11.658	-0.590	-4.833	1.175	-18.500	-1.854	-3.469
Kurtosis	113.31	1219.80	146.29	1067.98	68.46	689.88	114.32	1124.69	138.13	1126.87

Notes: This table presents the summary statistics of the differenced price and NAV series for the total sample and across different property types. The number of observations per firm is not the same for each property category because each REIT has a different time period for available observations.

5. Empirical Results

5.1 Unit Root Test

Before conducting the Johansen cointegration test, we utilize the ADF test to check for the non-stationary property of each price and NAV series. We test whether these two time series are stationary. We conduct the ADF unit root test on the price and NAV series with dynamic lags across each firm predetermined by the HQ information criteria. In Table 3, we report the average p-values of the τ statistics of all firms and firms within each property type for the "lead-lag of 25 days" transaction windows. The time series exhibit a non-stationary property because the p-values of the τ statistics of the price and NAV series are 0.68 and 0.60, respectively, which are greater than 0.05. We therefore do not reject the null hypothesis that there is a unit root.

Table 3 ADF Unit Root Test of Transaction Windows of "Lead-Lag of 25 days"

	Diversified		**Office**		**Hotel**		**Industrial**		**All**	
	Price	NAV	Price	NAV	Price	NAV	Price	NAV	Price	NAV
Firms	23	23	18	18	20	20	8	8	69	69
Prob < τ	0.68	0.60	0.71	0.63	0.65	0.59	0.69	0.62	0.68	0.60

Notes: This table reports the ADF unit root test results for each price and NAV series with dynamic lags across each firm predetermined by the HQ information criteria.

5.2 Long-Term Cointegration Relation

To investigate whether transaction windows matter in price discovery, we first study the long-term relation between the prices and NAV estimates by using the sample of the transaction windows of "lead-lag of 25 days". When long-term cointegration relation exists, we can then construct the VECM and apply the price discovery approach in Gonzalo and Granger (1995) to derive the GG ratios. Table 4 presents the empirical results that show the cointegration relationship between the prices and NAV estimates. The results confirm the cointegration relationships between the prices and NAV estimates. According to the trace test statistics, there is only one cointegration relationship between the prices and NAV estimates. To explain, we reject the null hypothesis ($\mathrm{H_0{:}\,r} = 0$) that there is no cointegration relationship between the prices and NAV estimates because the trace test statistics is 25.855 greater than the critical value of 12.21. We then test for the null hypothesis ($\mathrm{H_0{:}\,r} = 1$) that there is one cointegrating relationship between these two variables and do not reject $\mathrm{H_0{:}\,r} = 1$ because the trace test statistics is 0.549 smaller than the critical value of 4.14. We then test the cointegration relationships between the prices and NAV estimates by property type. According to the trace test statistics, a cointegration relationship of order one exists between the price and NAV estimates for each of the four property types. Only firms that are cointegrated are included in the samples.

Table 4 Average Cointegration Test Statistics of Transaction Windows of "Lead-Lag of 25 days"

All		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	25.855	0.526
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.118 price	0.055	-0.011
Diversified		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	21.729	0.549
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.125 price	0.008	-0.009
Office		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	39.232	0.231
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.091 price	0.065	-0.008
Hotel		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	20.546	0.569
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.130 price	0.019	-0.015
Industrial		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	20.368	0.895
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.127 price	0.012	-0.006

Notes: This table presents the average estimates of the error correction coefficients, trace test statistics, and cointegration relation coefficients of non-stationary prices and NAV of all firms and within each property type. The lag length is selected based on the HQ information criteria and may be different across different firms.

5.3 Common Factor Loadings

Given that the time series of prices and NAV estimates of the transaction windows of "lead-lag of 25 days" exhibit cointegration relations, we investigate the common factor loadings, namely the GG ratios, of the public and private real estate markets. Table 5 presents the GG ratios of the sample with "lead-lag of 25 days" transaction windows. Of the total sample, the GG_{reits} and GG_{NAV} ratios are 14% and 86%, respectively. Previous studies (e.g., Yunus et al. 2012; Hoesli and Oikarinen 2012) find that the public real estate market leads the private real estate market. Our findings indicate that when the transaction windows are taken into consideration, the GG_{NAV} ratio significantly exceeds the GG_{reits} ratio. We then study the GG ratios by property type. Across the four property types, we find that GG_{NAV} ratios are consistently significantly greater than the GG_{reits} ratios. Our empirical results imply that the direct real estate market plays an important role in price discovery around transaction dates. The results support our notion that the private real estate market is likely to incorporate new information with regard to property transactions into the NAV estimates which then get incorporated into REIT prices, therefore pulling up the common factor loadings of NAVs.

Table 5 GG Ratios of Price Discovery of Transaction Windows of "Lead-Lag of 25 days"

Property type	Lead-lag of 25 days	
	Price	NAV
All	14%	86%
Diversified	18%	82%
Office	11%	89%
Hotel	19%	81%
Industrial	6%	94%

Notes: In this table, we report the average GG ratios of all firms and within each property type.

5.4 Additional Analysis

One interesting question is whether our findings are driven by certain firm attributes that could explain the causality of returns between the public and private real estate markets. We postulate that larger and glamour firms are faster in price discovery from private markets as they are usually followed by more analysts. As such, we expect that for larger and glamour firms, private market prices contribute even more to the price discovery process during property transaction times. Hence, we investigate the common factor loadings of the public and private real estate markets for large vs. small firms and glamour vs. value firms. We use different measures of firm size (i.e., market capitalization, total assets, book value of equity) and market-to-book ratio to divide the sample observations into two subsamples. Table 6 presents the GG ratios for the subsamples and we find that consistent with our main results, $\mathrm{GG_{NAV}}$ ratios are consistently larger than the $\mathrm{GG_{reits}}$ ratios for both large and small firms across all definitions of firm size and for both glamour and value firms. In particular, the $\mathrm{GG_{NAV}}$ ratios for large and glamour firms are higher than the $\mathrm{GG_{NAV}}$ ratios for small and value firms, thus indicating that price discovery is more apparent for firms that are well-followed by the capital market.

We then investigate how our study could be affected by market events. Over the sample period, the most significant market event is perhaps the financial crisis with serious impact on the real estate market. We study the GG ratios for firms with high and low numbers of transactions both before and after the crisis. We also divide our sample firms into those with more property transactions and less property transactions after the crisis. In Table 7, we show that $\mathrm{GG_{NAV}}$ ratios are consistently significantly greater than $\mathrm{GG_{reits}}$ ratios with no significant differences from before to after the financial crisis, thus implying that the financial crisis does not alter our findings that property transactions induce significant transfers from the private to the public real estate markets. We also find that price discoveries are more evident for firms with high numbers of property transactions and those that are conducting more property transactions after the crisis.

Table 6 GG Ratios of Price Discovery of the Transaction Windows of "Lead-Lag of 25 days" for Large vs. Small Firms and Glamour vs. Value Firms

Property type	Large/ Glamour Firms		Small/ Value Firms	
	Price	NAV	Price	NAV
Market Capitalization	6%	94%	23%	77%
Total Assets	12%	88%	17%	83%
Book Value of Equity	8%	92%	21%	79%
Market-to-Book Ratio	11%	89%	18%	82%

Notes: In this table, we report the average GG ratios of subsamples divided by the median values of market capitalization, total assets, book value of equity and market-to-book ratio.

Table 7 GG Ratios of Price Discovery of the Transaction Windows of "Lead-Lag of 25 days" Before and After the Financial Crisis

Property type	High Transactions		Low Transactions	
	Price	NAV	Price	NAV
Before Crisis	10%	90%	19%	81%
After Crisis	7%	93%	22%	78%
After vs. Before Crisis	11%	89%	18%	82%

Notes: In this table, we report the average GG ratios of subsamples divided by the median number of transactions and before vs. after the financial crisis, as well as by the median change in number of transactions from before to after the crisis.

5.5 Sensitivity Analysis

In order to further support our notion that the private real estate market matters in price discovery around property transaction dates, we check the robustness of other transaction windows of "lead-lag of 30 days" and "transaction-date-lag of 5 days & lead-lag of 25 days". Tables 8 and 9 present the basic descriptive statistics of these two transaction windows. We have conducted an ADF unit root test on the samples of these two transaction windows.[11] Most of the time series exhibit a non-stationary property.

[11]The results are untabulated but available upon request.

Table 8 Descriptive Statistics of "Lead-Lag of 30 days"

Property type	Diversified	Office	Hotel	Industrial	All
Number of Firms	23	18	20	8	69
Sample Size	28,199	35,207	23,321	11,935	98,662
Number of Transactions	1,116	1,316	717	633	3,782

Table 9 Descriptive Statistics of "Transaction-Date-Lag of 5 days & Lead-Lag of 25 days"

Property type	Diversified	Office	Hotel	Industrial	All
Number of Firms	23	18	20	8	69
Sample Size	26,170	32,717	21,202	11,188	91,277
Number of Transactions	1,116	1,316	717	633	3,782

We further examine the cointegration relationships of the "lead-lag of 30 days" and "transaction-date-lag of 5 days & lead-lag of 25 days" between the public and private real estate markets. Tables 10 and 11 show that cointegration relationships exist between the public and private real estate markets. To explain, we reject the null hypothesis ($H_0: r = 0$) for Table 10 in that there is no cointegration relationship between the prices and NAV estimates because the trace test statistics is 24.620 greater than the critical value of 12.21. We then test for the null hypothesis ($H_0: r = 1$) in that there is one cointegrating relationship between these two variables and do not reject $H_0: r = 1$ because the trace test statistics is 0.520 smaller than the critical value of 4.14. For Table 11, we reject the null hypothesis ($H_0: r = 0$) in that there is no cointegration relationship between the prices and NAV estimates because the trace test statistics is 26.828 greater than the critical value of 12.21. We then test for the null hypothesis ($H_0: r = 1$) in that there is one cointegrating relationship between these two variables and do not reject $H_0: r = 1$ because the trace test statistics is 0.525 smaller than the critical value of 4.14. When investigating these two transaction windows by property type, we also find that the public and private real estate markets are cointegrated and each property type includes only one cointegration relation.

We report the GG ratios for the transaction windows of both the "lead-lag of 30 days" and "transaction-date-lag of 5 days & lead-lag of 25 days" in Table 12. Overall, the results are similar to our main results of "lead-lag of 25 days"; that is, when the transaction windows are taken into account, the GG_{NAV} ratios are significantly greater than the GG_{reits} ratios. We further explore the GG ratios by property type and continue to obtain robust results similar to the transaction windows of "lead-lag of 25 days".

Table 10 Average Cointegration Test Statistics of Transaction Windows of "Lead-Lag of 30 days"

All		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	24.620	0.520
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.119 price	0.063	-0.010
Diversified		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	21.882	0.535
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.125 price	0.009	-0.009
Office		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	33.248	0.130
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.091 price	0.060	-0.008
Hotel		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	20.501	0.568
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.130 price	0.029	-0.013
Industrial		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	23.648	0.922
Long-run relation	Adjustment speed of Price	Adjustment speed of NAV
NAV = 0.127 price	0.217	-0.009

Notes: This table presents the average estimates of the error correction coefficients, trace test statistics, and cointegration relation coefficients of non-stationary prices and NAV of all firms and within each property type. The lag length is selected based on the HQ information criteria and may be different across different firms.

Table 11 Average Cointegration Test Statistics of Transaction Windows of "Transaction-Date-Lag of 5 days & Lead-Lag of 25 days"

All		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	26.620	0.520
Long-run relation	Adjustment speed of Price	Adjustment speed of Price
NAV = 0.120 price	0.063	-0.010
Diversified		
Hypothesis	r = 0 (critical value = 12.21)	r = 1 (critical value = 4.14)
Trace test statistics	22.869	0.593
Long-run relation	Adjustment speed of Price	Adjustment speed of Price
NAV = 0.125 price	0.002	-0.009

(Continued…)

(Table 11 Continued)

Office		
Hypothesis Trace test statistics Long-run relation *NAV = 0.096 price*	r = 0 (critical value = 12.21) 42.821 Adjustment speed of Price 0.063	r = 1 (critical value = 4.14) 0.148 Adjustment speed of Price -0.009
Hotel		
Hypothesis Trace test statistics Long-run relation *NAV = 0.130 price*	r = 0 (critical value = 12.21) 20.813 Adjustment speed of Price 0.037	r = 1 (critical value = 4.14) 0.559 Adjustment speed of Price -0.017
Industrial		
Hypothesis Trace test statistics Long-run relation *NAV = 0.127 price*	r = 0 (critical value = 12.21) 20.807 Adjustment speed of Price 0.188	r = 1 (critical value = 4.14) 0.931 Adjustment speed of Price -0.010

Notes: This table presents the average estimates of error correction coefficients, trace test statistics, and cointegration relation coefficients of non-stationary prices and NAV of all firms and within each property type. The lag length is selected based on the HQ information criteria and may be different across different firms.

Table 12 GG Ratios of the Transaction Windows of "Lead-Lag of 30 days" and "Transaction-Date-Lag of 5 days & Lead-Lag of 25 days"

Panel A

Property type	**Lead-lag of 30 days**	
	Price	NAV
All	18%	82%
Diversified	7%	93%
Office	25%	75%
Hotel	23%	77%
Industrial	18%	82%

Panel B

Property type	**Transaction-date-lag-of 5 days & Lead-lag of 25 days**	
	Price	NAV
All	20%	80%
Diversified	20%	80%
Office	11%	89%
Hotel	22%	78%
Industrial	28%	72%

6. Concluding Remarks

In this study, we examine the lead-lag relationship between the public and private real estate markets within the transaction windows when significant property transactions occur. Despite the prominent role of the public market in the price discovery process of real estate prices, we show that the private real estate market nonetheless provides crucial information to market participants. Our findings show that around periods when real estate firms make important property acquisition and disposal decisions, information is quickly incorporated into NAV estimates before being reflected in security prices. Although it is intuitive that material events such as property transactions should be quickly incorporated into real estate prices, surprisingly, such information would show up first in the NAV estimates. This seems to imply that investors would wait for the analysts to revise the NAV estimates based on the new property transaction information before they make their investment decisions on the related real estate security. Overall, our study reinforces the importance of private market signals in the price formation process of the real estate market, and show that the private real estate market can lead the public market.

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