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Listed real estate futures trading, market efficiency, and direct real estate linkages: International evidence

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ABSTRACT

Futures contracts focused on listed real estate firms have increased in popularity in recent years, with strong developed markets now established in Australia, Europe, Japan, and the United States. This study builds upon what is still relatively small literature to consider two key elements. Firstly, using the approach of Bessembinder & Seguin (1992), we examine whether futures trading leads to a stabilization of listed real estate. The results show that the inception of listed real estate futures contracts does have a stabilization effect by improving the market efficiency and reducing market noise in international real estate stocks. Secondly, we assess the impact of futures trading on price discovery using a Spline-GARCH model, panel analysis, and a Granger causality test. In particular, we examine the linkages with underlying private real estate. The empirical results reveal that reduced market noise of real estate stocks via the futures trading improves the price discovery process, leading to enhanced linkages between public and private real estate, as well as market fundamentals.

1. Introduction

Publicly listed real estate vehicles, such as Real Estate Investment Trusts (REITs), occupy a relatively unique space in the broad equity market in that they are stocks whose primary business involves the management of another asset. This does therefore allow a comparative analysis of the performance, and characteristics, of both the shares and the underlying asset. However, the fact that direct real estate is a private asset, rather than publicly traded, leads to additional concerning issues. Prime amongst these is the relative lack of liquidity in the underlying asset. Indeed, studies such as Dhar and Goeztmannm (2006) note that real estate fund managers view illiquidity as the most important risk factor that they face[1]. The illiquidity and private nature of real estate trading also lead to differences in the valuation mechanisms. REITs and property company shares are priced and traded as any stock, whereas real estate is primarily analyzed on the basis of appraisals due to the lack

Abbreviations: REITs, Real Estate Investment Trusts; Spline-GARCH, Spline-Generalized AutoRegressive Conditional Heteroskedasticity.

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[1] Additionally, the well observed heterogeneity of real estate asset returns when added to the indivisibility of the asset can lead to significant challenges in the creation of diversified real estate portfolios, and in particular the elimination of unsystematic risk, e.g. Byrne & Lee (2001); Callender et al. (2007) and Shuck & Brown (1997).

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of transactions. This can have advantages, such as the potential benefits of including a more liquid exchange traded asset in a real estate portfolio[2]. However, any examination of how public and private real estate interact and are related to each other needs to consider the underlying differences in the two assets, and that while connected and based upon the same underlying asset, display considerable differences.

Due in part to the unique features of REITs, they were one of the first stock market sectors to see specific futures contracts launched. A dedicated REIT futures market was established in Australia in 2002 in order to provide an alternative means of gaining exposure to A-REITs and to enhance the liquidity of the sector. Similar products were introduced in other major markets (e.g. US in 2007, Japan in 2008 and Europe in 2007) over the next few years. In Europe a slightly different approach was adopted, where contracts were launched on a continental level, rather than a national one (see Lee et al., 2014). It is of interest that in comparison to Australia and Europe, the US market took far longer to become established. While launched in 2007, it remains largely inactive until a surge in trading volume in 2014. After that slow start trading volume has grown significantly from US$1.3bn in 2014 to US$11.5bn in 2018 (Thomson Reuters, 2019). It is now the largest, and more active, index futures markets in public real estate. Table 1 shows a summary of each futures market, including the underlying indices.

The continued growth of the various markets, and the potential for future market development, has naturally attracted considerable attention in recent years from investors, policy makers and academics. As discussed earlier, real estate is among the very few asset classes in which the same underlying assets (e.g. real estate properties) are priced in both the asset market (e.g. direct property markets) and the stock market. However, private real estate is characterized by illiquidity, segmentation and a lack of transactions (Dhar and Goztmann, 2006; Ling and Naranjo, 2015). These also lead to differences in the valuation mechanisms for private and public real estate. Further, investors from these two types of markets do not always agree upon the value of the same assets, leading to divergence in property valuation (e.g. NAV dispersion). Numerous studies have demonstrated mixed results on the link between public real estate and private real estate as public real estate, which is listed on a stock exchange, is strongly influenced by the broader stock market noise (Oikarinen, Hoesli, and Serrano 2011; Yunus, Hansz, and Kennedy 2012).

As such, the market efficiency of public real estate in reflecting the underlying private real estate has been raised. An introduction of futures trading, a major financial innovation, on real estate is expected not only to provide another platform to allow speculation and hedging activities (Lee and Lee, 2012), but also offer extra market information that would enhance the market efficiency of its spot market via a reduction of market noise (Antoniou & Holmes, 1995; Bohl et al., 2011). The enhancement of information offers useful economic forecasting and now-casting tools. Importantly, Gormsen and Koijen (2020) has shown that dividend futures can shape the involvement of investors' expectations about economic growth in response to the COVID-19 outbreak. To sum up, the futures markets might be particularly important for real estate investors; thereby a dedicated study of real estate futures markets is crucial.

However, empirical research of real estate futures has been relatively lacking, in part due to its short history. In particular, virtually no empirical work has examined how futures trading could affect information in public real estate, particularly its linkage with the private market. This study aims to fill in this gap in the literature by complementing the existing work on listed real estate futures through an examination of a number of key elements concerning the introduction of listed futures. First, it is essential to understand the impact of index futures on the underlying real estate stocks. The impact on the volatility and market efficiency of the underlying spot market has been of particular interest to policy makers and investors. This study, therefore, aims to provide the first international empirical evidence concerning the linkage between futures trading and the volatility of the spot market. Secondly, the study is the first attempt to investigate the impact of futures trading on the relationship between private and public real estate. Specifically, it examines whether the reduced market noise of real estate stocks, due to futures trading, leads to increased connectivity between public and private real estate, as well as market fundamentals. To the best of our knowledge, no study has focused on this question. This issue is obviously of importance due to the significant growth of publicly listed real estate markets over recent years. The findings will also enable more informed investment decision-making regarding the role of such contracts from a policy maker perspective. The study, therefore, assesses the impact of real estate futures on information in public real estate, particularly its interlinkage with private real estate, in the US, Australia, Japan and Europe. Specifically, we consider the following questions:

(a) Does the inception of public real estate futures improve the market efficiency of the listed real estate sector? Is there a stabilization effect and reduced volatility?
(b) Is a stronger volatility association between public real estate and market fundamentals observed after the introduction of the futures contracts, i.e. is a stronger volatility linkage observed between private and public real estate?

By addressing these questions, the study aims to contribute to the literature in the following ways. First, we contribute to a relatively limited number of studies that have examined the stabilization effect of real estate futures. The impact of futures trading on the underlying spot market has been extensively debated in the mainstream finance literature. Specifically, two competing theoretical explanations, Kaldor (1939)'s theory of destabilization and the Cox (1976)'s information effect of futures trading, have been widely used to explain the contradictory empirical evidence of the impact of futures trading on the underlying spot market. Although Lee et al. (2014) found a stabilization effect from European real estate futures,

[2] See papers such as Ametefe et al. (2019); Farrelly & Moss (2014); Lee & Stevenson (2005) and Stevenson (2001).

Table 1
Summary of listed real estate futures markets.

Underlying Index	Inception Year	2018 Turnover (US$m)
FTSE EPRA/NAREIT Developed Europe Index	Oct 2007	2,886
FTSE EPRA/NAREIT Eurozone Index	Oct 2007	9
Dow Jones U.S. Real Estate Index	Feb 2007	11,815
Tokyo Stock Exchange REIT Index	June 2008	955
S&P/ASX 200 A-REIT Index Futures	Sep 2002	3,830

Sources: ASX (2019), FTSE (2019), TSE(2019), CBT (2019).

the number of international studies is extremely limited. Furthermore, as noted above, the European market is somewhat unusual in that it is not centred on a single domestic index, in contrast to the contracts in Australia, Japan and the US. As of yet, no study has tested for stabilization effects in the context of country specific contracts. In particular, no dedicated study has been undertaken on the largest and most actively traded contracts, namely those focused on the US REIT market. Furthermore, previous studies were constrained by the length of the time series available. Lee et al. (2014) only considered a time frame that covered 2004 through 2010, i.e. 3 years prior to and 3 years after the introduction of the futures market. An analysis of longer time series will allow a more robust analysis of the issues at hand. Our study not only extends to March 2019 but in addition, the pre-contract period is extended back to January 1990.

Second, we expand upon those studies that have examined the relationship between public and private real estate by considering, for the first time, the impact of listed real estate futures. While there is a rich literature that has now examined a variety of issues relating to real estate futures (e.g. Newell, 2010; Lee 2009; Lee & Lee, 2012; Lee et al., 2014; Lee et al., 2016; Clements et al., 2017; Zhou, 2016, 2017), there remains much to be explained. No study has fully considered how futures trading has an effect on the interlinkages between the public and private real estate markets. Importantly, a recent study of Ling et al. (2021) shows a "private predicts public" result in a cross-sectional due to slow information diffusion, suggesting that the lead-lag relationship is a more complex process than initially believed. This also highlights the importance of examining whether and how the futures trading would have an impact on the information diffusion process. Specifically, we examine whether real estate futures offer an alternative market for speculative and hedging strategies, and how this may affect the long-run volatility interlinkages among privately and publicly traded real estate. As highlighted by Lee et al. (2016) and Zhou (2016), index futures can be used as a speculative asset. As such, the launch of an index futures offers a new trading platform for investors to gain or reduce their exposure in the listed real estate market. Consequently, it could reduce market noise and allow the public market to better reflect fundamentals.

Third, this study is the first to explicitly examine the long-term volatility linkages between private and public real estate. Although extensive studies have examined the price discovery process, results have often been varied and been dependent upon the time period and markets examined. Furthermore, these studies have largely focused on the extent to which the prices and returns of these assets are interrelated, rather than the long-run volatility. This is despite the fact that the volatility series of an asset may contain important information that should be captured. The lack of empirical work in the context of public and private real estate may be attributed to the complexity in modelling volatilities as a combination of time series dynamics and market fundamental effects. A considerable challenge in the context of real estate is the different nature of the underlying data. The modelling of volatility in exchange traded assets is normally done so using high frequency data, indeed a number of REIT specific papers have highlighted how in that context high frequency data is important in shedding light on volatility dynamics (e.g. Cotter & Stevenson, 2006). However, private real estate and macroeconomic variables are limited to low-frequency data, often only quarterly.

This study circumnavigates this issue by apply a Spline-Generalized Autoregressive Conditional Heteroscedasticity (Spline-GARCH) model (Engle & Rangel, 2008) to extract the low-frequency volatility of real estate stocks. Specifically, the Spline-GARCH framework allows us to model high-frequency return volatility by specifying it to be the product of a slow-moving component, represented by a quadratic spline. Thereby, this offers a smooth and nonlinear long-run trend in the volatility time series (Engle & Rangel, 2008; Engle et al., 2013; Karali & Power, 2013). Importantly, the low-frequency volatility, i.e. the long-run volatility, can be associated with slowly varying deterministic conditions in the economy. This is supported with empirical evidence from the broad equity market (Engle & Rangel, 2008; Engle et al., 2013) as well as public real estate specifically (Lee et al., 2018).

The remainder of the paper is organized as follows. The following section provides a brief literature review on real estate index futures. The impact of index futures trading on the volatility of the underlying market is also considered. Section 3 details the data used and the methodological framework adopted. Section 4 reports and discusses the empirical findings, whilst the final section provides concluding comments.

2. Literature review

In comparison to the relatively large number of papers to have considered stock index futures the examination of contracts specifically covering the listed real estate sector is relatively sparce, in part due to the relative recent introduction of such contracts. This has also meant that research has largely focused on those markets that introduced futures contracts the earliest, e.g. Australia, purely due to the availability of longer time-series'. Of the literature that does exist a large proportion has examined the hedging effectiveness of listed real estate futures. These results have indicated that the contracts are an effective risk management tool in the context of protecting the value of listed real estate portfolios (Newell & Tan, 2004; Newell, 2010; Lee & Lee, 2012; Lee et al., 2014; Zhou, 2016). Lee et al. (2014) also found that that the introduction of a futures market in Europe improved the speed and quality of information flowing to the listed real estate sector. More specifically, they found evidence to suggest that futures improved market depth and have had an underlying stabilizing influence. The price discovery mechanism between listed real estate index futures and spot markets has also been examined by Shi & Xu (2013) and Zhou (2017). These studies suggest that the listed real estate market leads the corresponding futures contracts. Interestingly, Clements et al. (2017) also find that lumber futures contain information of relevance for Timber REITs in the U.S. Recently, Lee et al. (2016) expand upon these findings and observe that the role of REIT futures in the price formation process is related to investor structure. Importantly, they find that the Australian REIT futures market is attractive to speculators as a response to a surge in demand for risk-sharing offered by hedgers. In other words, index futures can be used as a speculative asset (Zhou, 2016). Thereby, a futures market can help facilitate investors' hedging and speculative strategies in that they offer opportunities and reduce their reliance on the spot market (Mckenzie et al., 2001). As such, the volatility of listed real estate is mitigated when the background level of futures activity is high. This finding is in line with results from the broader stock and futures markets (Bohl, et al., 2011). Given that listed real estate has been argued to embed stock market noise that is not related to underlying real estate market fundamentals (Hoesli & Oikarinen, 2012), the mitigated volatility of real estate securities could result in the listed real estate sector reflecting market fundamentals more effectively. As a result it is possible that a consequence is that listed real estate could behave more like the private market.

A large number of studies have examined the interlinkages among listed and direct real estate. These results have frequently observed that the interlinkage is time-varying and dependent on the time period examined. Early studies such as Li & Wang (1995), Liu et al. (1990) and Mei & Lee (1994) report a strong correlation between REITs and the general stock market. Ling & Naranjo (1999) find that REITs are integrated with stocks, but segmented from direct real estate. Glascock et al. (2000) also find that US REITs behave more like general stocks instead of direct real estate since 1992. However, Clayton & Mackinnon (2003) show contrasting evidence in which equity REITs become increasingly sensitive to the performance of underlying real estate. Similar evidence is provided in papers such as Li et al. (2009), Oikarinen et al. (2011) and Ling & Naranjo (2015). Lee et al. (2008) attribute the results to the involvement of sophisticated investors in the REITs market since the early nineties. It should be noted however, that there is also considerable evidence that the relationship between REITs and the overall equity market is extremely time-sensitive (e.g. Chong et al., 2009, Cotter & Stevenson, 2006). Oikarinen et al. (2011) investigated the dynamic relations between REITs and direct real estate, focusing on a long term cointegration. The results find that the two total return indices are cointegrated in the long term and there is a 'real estate factor' affecting their performance. Hoesli & Oikarinen (2012), using the US, UK and Australia data, also find that REITs are more closely related to direct real estate in the long term, results that are supported by findings in papers such as Serrano & Hoesli (2010) and Yunus et al. (2012). The primary area where there has been divergence in the findings relates to sector level data (e.g. Hoesli & Oikarinen, 2012, 2016; Hoesli, Oikarinen & Serrano, 2015).

The linkages in the volatility of the different asset markets has been relatively sparce, despite the important information that is incorporated into volatility data. Notable exceptions with respect to listed real estate and stocks generally include Cotter & Stevenson (2006), Yang et al. (2012) and Hoesli & Reka (2013). Cotter & Stevenson (2006) applied a multivariate GARCH model to investigate volatility in U.S. REITs, finding that despite an intuitive argument that value stocks may be more inter-related with REITs, the general stock market played a more dominant role with respect to volatility. This finding was in some respects supported by Hoesli & Reka (2013) who reported significant volatility spillovers between listed real estate markets and stock markets in the US, especially in a long term. However, Yang et al. (2012) did observe asymmetries in the conditional correlation between the two.

3. Data and methodological framework

3.1. Data

The data used in this study consists of daily series for international listed real estate markets in Australia, Europe, Japan and the U.S. The principal data sets used are the FTSE EPRA/NAREIT total return indices spanning the period January 1990 through March 2019. To assess the impact of futures trading the closing prices, volume and open interest of the corresponding index futures contracts are obtained from Thomson Reuters Eikon. The performance of the underlying private real estate market is proxied by the total return indices produced by MSCI/IPD, with the exception of the United States where NCREIF data is used. Given that all of these indices are appraisal based we account for valuation-smoothing using the standard Geltner (1993) procedure, with a one-year lag structure[3]. A variety of macroeconomic variables (GDP, interest rates, M2 money supply, exchange rates) are also examined in the study and this data is also procured from Thomson Reuters Eikon. Table 2 details of the series used in the study (see Table 3).

3.2. Methodological framework

There are two key stages in the methodological framework adopted in this paper. The first analyses the impact of the futures market on the volatility of listed real estate. The second extends that analysis to consider the linkages between the private and listed real estate markets. A standard way of answering the question whether the introduction of a futures market improves the information flow of a market is to consider volatility modelling. Following Lee et al. (2014), the Bessembinder & Seguin (1992) model is utilized. Specifically, an Autoregressive Integrated Moving Average (ARIMA) model is employed to decompose trading volume and open interest in the futures contracts into its expected and unexpected components. We then consider how these components affect the volatility of the spot market by including them in the variance equation of a GARCH model, which is specified as follows:

$$R_t = a_0 + a_1 R_{t-1} + \mu_t \tag{1}$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \alpha_3 ExpVol + \alpha_4 UnexpVol + \alpha_5 ExpOI + \alpha_6 UnexpOI + \alpha_7 Mon + \alpha_8 Tue + \alpha_9 Wed + \alpha_{10} Thu \tag{2}$$

where R_t represents the returns on the respective index, $ExpVol$ and $Un\exp Vol$ are the expected and unexpected components of volume respectively, $ExpOI$ and $Un\exp OI$ the expected and unexpected components of open interest, whileMon,Tue,Wed and Thu are daily dummies. Following Gulen & Mayhew (2000) and Lee et al. (2014), a negative link between expected volume and open interest and volatility is expected, indicating that futures markets improve liquidity and market depth; thereby the volatility of listed real estate can be reduced. It should be noted that expected volume and expected open interest are variables of interest in terms of the effectiveness of futures trading in enhancing the market efficiency of listed real estate.

A GARCH model is then used to examine whether the expected volume and open interest of real estate futures does reduce the volatility of spot market listed real estate. If futures trading offers an alternative means of exposure to listed real estate, for speculative and hedging purposes, a higher reduction of volatility of listed real estate would be expected as futures markets have been argued to be more attractive to speculators and hedgers (Lee et al., 2016; Zhou, 2016). This also supports the seminal work of Cox (1976) and the hypothesis concerning the information effect of futures trading, in which futures trading improves market efficiency. This finding is expected to offer an enhanced understanding of the impacts of real estate futures on real estate securities.

The second component of the empirical analysis considers whether the relationship between the listed and private real estate sectors alters after the introduction of a futures market. To assess this a Spline-GARCH model, as proposed by Engle & Rangel (2008), is employed to extract low-frequency volatility that is plausibly caused by macroeconomic variables. Engle & Rangel (2008) argue that the low-frequency volatility component describes permanent and/or slow-moving patterns of volatility (e.g. macroeconomic risk) more accurately. Their Spline-GARCH model can be represented as follows:

$$r_t - E_{t-1} r_t = \sqrt{h_t}\varepsilon_t = \sqrt{\tau_t} g_t \varepsilon_t \varepsilon_t \Big| \varphi_{t-1} \tilde{\mathrm{N}}(0,1) \tag{3}$$

$$g_t = (1-\alpha-\beta) + \alpha\left(\frac{(r_{t-1} - E_{t-2} r_{t-1})^2}{\tau_{t-1}}\right) + \beta g_{t-1} \tag{4}$$

$$\tau_t = c\exp\left(\omega_0 t + \sum_{i=1}^{k} \omega_i((t - t_{i-1})+)^2\right) \tag{5}$$

where ε_t denotes the innovation term at time t, $E_{t-1}(r_t)$ represents the expectation in which it is conditional on an information set (φ_t), g_t characterizes the high-frequency conditional volatility, α represents the ARCH term, β reveals the GARCH term and τ_t is the low-frequency component of the conditional volatility and can be estimated as a direct function of macroeconomic risk.

[3] The appraisal-based indices for private real estate are considerably more vulnerable to the smoothing issue. Unfortunately, MSCI did not provide a transaction-based index. We also attempted to obtain the US NCREIF TBI index. However, the NCREIF board has discontinued its TBI production due to the increasingly problematic as the number of properties in the NCREIF indices. Further, NCREIF has also indicated that the TBI cannot represent the larger commercial real estate universe as only small proportion of real estate being sold in each quarter. Thus, this is not intended to be a benchmark (NCREIF, 2021). Nevertheless, to address the smoothing issue of MSCI private real estate indices, Geltner (1993) desmoothing approach was employed to desmooth the appraisal-based indices. These steps have been widely used to remove the smoothing bias of appraisal-based indices such as Hoesli and Oikarinen (2014) [11] and Ling and Naranjo (2015). This limitation of data should be borne in mind when interpreting the results.

Table 2
Public and private real estate series.

Market	Public Real Estate	Private Real Estate
Australia	S&P/ASX 200 A-REIT Index*	MSCI/IPD Australia Index***
US	Dow Jones REIT Index*	MSCI/IPD US Index***
Japan	TSE REIT Index*	MSCI/IPD Japan Index**
Europe	FTSE/EPRA/NAREIT Developed Europe Index*	N/A
Eurozone	FTSE/EPRA/NAREIT Eurozone Index*	N/A
UK	FTSE/EPRA/NAREIT UK Index*	MSCI/IPD UK Index**
France	FTSE/EPRA/NAREIT France Index*	MSCI/IPD France Index****
Germany	FTSE/EPRA/NAREIT Germany Index*	MSCI/IPD Germany Index*****
Netherlands	FTSE/EPRA/NAREIT Netherlands Index*	MSCI/IPD Netherlands Index*****
Sweden	FTSE/EPRA/NAREIT Sweden Index*	MSCI/IPD Sweden Index*****

Note: * Daily / **Monthly / *** Quarterly / **** Semi-annually / ***** Annually, Quarterly interest rate, GDP, Money Supply, and Exchange rate for each country are also collected.

Table 3
Breakdown of FTSE/EPRA/NAREIT Developed Europe Index.

Country	Number of Companies	Net Market Cap (US$m)	Weight %
Germany	**13**	**66,446**	**27.62**
UK	**41**	**64,039**	**26.62**
Netherlands	**5**	**25,022**	**10.40**
Sweden	**15**	**23,052**	**9.58**
France	**6**	**21,098**	**8.77**
Switzerland	5	14,019	5.83
Belgium	11	11,222	4.67
Spain	3	7,535	3.13
Ireland	3	2,627	1.09
Austria	1	2,189	0.91
Finland	2	1,519	0.63
Norway	1	1,461	0.61
Italy	1	301	0.13
Total	**107**	**240,529**	**100.00**

Source: FTSE Russell as at 31 December 2018.

Following Liow & Yang (2005) and Lee et al. (2018), several macroeconomic risk proxies (interest rate volatility, GDP volatility, money supply volatility and foreign exchange volatility and direct real estate volatility) are used. These risk proxies are estimated with the absolute values of the residuals of an autoregressive AR (1) model. As macroeconomic variables are only sampled at a quarterly frequency, direct modelling with high-frequency (daily) data is not feasible. Therefore, for each securitized real estate market, we convert the daily low-frequency volatility series into an annual low-frequency volatility time series as proposed by Engle & Rangle (2008) and used in a real estate setting by Lee et al. (2018). The empirical framework, which models the low-frequency volatility as a function of macroeconomic and direct real estate volatility, can be represented as;

$$LowVol_{i,t} = c_0 + \gamma_1 IRVol_{i,t} + \gamma_2 GDPVol_{i,t} + \gamma_3 MSVol_{i,t} + \gamma_4 FXVol_{i,t} + +\gamma_5 DPVol_{i,t} + \mu_{i,t} \tag{6}$$

where $LowVol_{i,t}$ denotes the low-frequency volatility for listed real estate market i for period t, $IRVol_{i,t}$ represents interest rate volatility, $GDPVol_{i,t}$ is GDP volatility, $MSVol_{i,t}$ denotes the volatility of money supply, $FXVol_{i,t}$ is foreign exchange volatility and $DPVol_{i,t}$ represents direct real estate volatility. As discussed earlier, the linkages between listed real estate and macroeconomic risk proxies, including direct real estate are analyzed in two periods, pre and post the introduction of the respective futures market. If the market efficiency of listed real estate sector has improved, we would expect a strong link between listed and private real estate in the post-futures period, with no comparable evidence observed in the pre-futures period.

The composition of the European futures contract does create some complications as it is based on a pan-European index. We therefore include five European markets in our panel analysis, namely; France, Germany, the Netherlands, Sweden and the UK. Not only are these the largest publicly listed real estate markets in Europe, but they are also consistent with the constituents of MSCI/IPD Pan-European Index.

4. Empirical results and discussion

4.1. Impact of futures trading on volatility

The first section reports the results from a standard GARCH model which examines whether the introduction of listed real estate futures has improved information flow. Specifically, it examines the relationship between the volatility of the underlying index (i.e. listed real estate) and the level of futures-trading activity, as proxied by both expected trading volume and open interest. The results are reported in Table 4.

As noted previously, the variables of interest in this analysis are expected volume and expected open interest. With the exception of the Japanese J-REIT market, the coefficients for expected volume are, as hypothesized, negative and also statistically significant at the 1% level. This suggests that futures trading, irrespective of country-specified indices or continental indices, does enhance the rate of information flow and reduce the volatility of the underlying listed real estate market. This is reasonable given that that higher expected futures trading provides extra price expectation information. The findings can be explained by the information effect of futures trading (Cox, 1976), where trading increases the information incorporated in a spot price; leading to reduced volatility and the improvement of the price discovery process. In turn, a stabilization effect should also be documented. Comparable results are found by Bessembinder & Seguin (1992) and Watanabe (2001) in the broader stock index futures markets and by Lee et al. (2014) in the specific context of European listed real estate index futures.

It should be noted that expected volume is negatively related to Japanese listed real estate, suggesting that futures trading does reduce the volatility of the J-REIT market. However, it does not do so to a statistically significant extent. This means that the expected volume has little impact on spot price volatility. This can perhaps be attributed to the low trading volume observed in J-REIT futures in comparison to the markets in other individual countries such as Australia and the United States. To illustrate this, the total 2018 trading volume of J-REIT futures was US$919.4 m. This compares with figures of US$3.8bn for Australia and US$11.5bn in the case of the United States. The small size of the J-REIT futures market can also be illustrated in relative terms. The trading volume of J-REIT futures is negligible when compared to the market capitalization of the J-REIT sector, US$229.8bn. It is, therefore, not that surprising to find that J-REIT futures play a marginal role. In addition, the stabilization role of J-REIT futures, to certain extent, has also been offset by the Bank of Japan (BOJ) REITs and EFTs purchase program. The program allows the BOJ to purchase REITs during a bear market (Hattori & Yoshida, 2020; see section 4.4.3 for the extra details).

The results also highlight a negative relationship between expected open interest and the volatility of the spot market. This would imply that the futures market improves liquidity provision and depth in the underlying spot markets. As discussed by Bessembinder & Seguin (1992), market depth can be proxied by the expected open interest component as it measures the number of traders or the amount of capital dedicated to a futures market at the beginning of a trading session. Thus, the documented strong negative relationship suggests an improvement in market depth. The findings are consistent with the assertions futures markets should have a stabilizing effect (Gulen & Mayhew, 2000)[4] and that the creation of a futures contract is warranted as it results in an increase in the information flow into the spot market (Antoniou & Holmes, 1995; Darrat & Rahman, 1995).

With respect to unexpected volume, a positive relationship is noted with the volatility of listed real estate. This is intuitively appealing as exogenous volatility events lead to higher trading volume. According to Bessembinder & Seguin (1992), the unexpected component, unlike the expected component that reflects the predictable level of futures trading, can be interpreted as information shocks. Importantly, information shocks are expected to move prices and generate trading in both the spot and futures markets (Lee et al., 2014). Given that the unexpected component captures trading activity stimulated by unexpected price changes, it is therefore reasonable to document a positive relationship, after the futures contracts have been launched, between the unexpected level of futures trading and the volatility of the underlying index (Gulen & Mayhew, 2000). However, this variable is not significant in the US, Japan and the Developed Eurozone. This can perhaps be explained by the level of real estate futures trading in those markets. While the US is the most active REIT futures market it did take considerable time for it to become established, with trading volume only really accelerating from 2014 onwards. It is not very surprising to find little unexpected futures trading for the US market. The results also note a positive, and statistically significant, coefficient of unexpected open interest. This can be explained in a similar fashion, as the unexpected component of open interest can be viewed as representing information shocks. As information shocks would be expected to move prices it therefore follows that higher volatility would be expected. The magnitudes of the coefficients is relatively small, consistent with Bessembinder & Seguin (1992) and Gulen & Mayhew (2000), suggesting that the economic significance of futures trading is weak. Additionally, the variable only being a significant variable in the Australian market. This in itself is of interest given the A-REIT futures market as the oldest and arguably most established. The results are also consistent with the finding of Gulen & Mayhew (2000), in that they highlight the degree of variation in empirical findings across countries.

Overall, the results suggest that the listed real estate futures markets, irrespective of country-specific or continental-specific futures indices, improve liquidity and market depth; thereby the volatility of listed real estate prices can be reduced.

[4] They are also of the empirical results reported in Lee et al. (2014).

Table 4
Volatility and expected & unexpected futures trading activity.

	USA	Australia	Japan	Developed Europe	Eurozone
Panel A: Mean Equation					
Constant (α_0)	0.000 (0.987)	0.000 (0.726)	0.000 (1.106)	0.000 (0.983)	5.76×10^{-5} (0.147)
Lag Return (α_1)	0.028 (0.482)	0.032 (1.101)	0.005 (0.116)	0.081 (2.151)**	0.073 (2.855)***
Lag Return (α_2)	−0.048 (-0.933)	−0.042 (-1.543)	0.005 (0.132)	−0.059 (-1.670)*	
Lag Return (α_3)	0.004 (0.075)		0.005 (0.132)		
Panel B: Variance Equation					
Constant (α_0)	0.000 (5.754)***	0.000 (10.333)***	5.00×10^{-5} (4.386)***	6.86×10^{-5} (4.227)***	0.000 (5.821)***
ARCH (α_1)	0.133 (1.966)**	0.150 (8.272)***	0.133 (3.811)***	0.150 (4.628)***	0.133 (6.511)***
ARCH / GARCH (α_2)	0.044 (0.822)	0.600 (28.971)***	0.533 (2.510)***	0.600 (8.278)***	0.533 (3.675)***
GARCH (α_3)	0.533 (5.784)***		0.044 (0.283)		0.044 (0.390)
Expected Volume	-4.53×10^{-9} (-2.508)**	-5.31×10^{-8} (-1677.327)***	-8.52×10^{-9} (-0.836)	-9.62×10^{-9} (-4.291)***	$-1.3\,9 \times 10^{-7}$ (-3.628)***
Unexpected Volume	8.27×10^{-10} (0.398)	$1.7\,0 \times 10^{-8}$ (6.354)***	1.36×10^{-9} (0.020)	7.76×10^{-9} (2.333)**	6.67×10^{-8} (1.098)
Expected Open Interest	-8.13×10^{-10} (-17.949)***	-1.34×10^{-9} (-7.241)***	-8.10×10^{-9} (-118.905)***	-2.78×10^{-9} (-3.196)***	-1.43×10^{-8} (-111.227)***
Unexpected Open Interest	-1.05×10^{-9} (-0.376)	1.34×10^{-9} (2.143)**	1.31×10^{-9} (0.0192)	1.11×10^{-9} (0.358)	$-1.6\,4 \times 10^{-9}$ (0.750)
Monday	-1.20×10^{-6} (-0.046)	-3.68×10^{-6} (-0.174)	-2.63×10^{-5} (-1.861)	-1.03×10^{-5} (-0.753)	-8.85×10^{-5} (-1.938)**
Tuesday	-1.01×10^{-5} (-0.047)	-9.04×10^{-6} (-0.541)	-2.28×10^{-5} (-1.848)	-1.01×10^{-5} (-0.669)	−0.000 (-4.235)***
Wednesday	-9.13×10^{-7} (-0.045)	-9.22×10^{-6} (-0.397)	-1.76×10^{-5} (-1.131)	-7.45×10^{-6} (-0.512)	-7.84×10^{-5} (-2.332)**
Thursday	-1.13×10^{-6} (-0.047)	-8.06×10^{-6} (-0.419)	-3.01×10^{-5} (-1.943)**	-2.27×10^{-6} (-0.129)	-0.000 (-4.100)***

Notes: This table reports estimated coefficients from a GARCH model with expected and unexpected futures-trading activity. Figures in parentheses in Panels A and B are the Bollerslev-Wooldridge robust standard errors. **, *** denotes significance at the 5% and 1% level respectively.

This not only implies futures trading has profound implications in terms of the information flows of listed real estate, but it may also have an underlying stabilizing role.

4.2. Low frequency volatility analysis

The previous section demonstrated that REIT/listed real estate index futures markets can improve market depth and lead to a reduction of volatility in the underlying spot market. The second component of the empirical analysis extends this to consider whether the mitigated volatility may lead to the listed real estate sector reflect underlying market fundamentals more effectively; i.e. strengthening the connection between public and private real estate following the introduction of an index futures market. To gauge whether the introduction of listed real estate futures does enhance the linkages between listed real estate and direct real estate, a sub-period analysis is conducted. Following Lee at al. (2018), the low-frequency volatility of listed real estate was extracted utilizing a Spline-GARCH model. The low-frequency volatility linkages between listed real estate and macroeconomic risk was then analyzed in a panel framework, with the results reported in Table 5[5].

A number of interesting issues are raised when the results before and after the start of futures trading are compared. It can be seen from Table 5 that the coefficient of private real estate volatility is not statistically significant and is negative prior to the launch of futures contracts. This would suggest that there is a weak relationship between the low-frequency volatility of listed real estate and real estate volatility prior to the start of futures trading. However, a positive and statistically significant relationship is documented during the post-futures period. This would imply a strengthening of the relationship between private and public real estate, a finding that does make some intuitive sense. As previously noted, index futures offer investors a new trading platform to gain or reduce their exposure in real estate securities. Specifically, index futures can be used as a speculative asset and also for hedging purposes (Zhou, 2016). As such, it may reduce market noise and make the public real estate markets more efficient, as documented in the previous section. Importantly, listed real estate has been argued to embed noise unrelated to market fundamentals (Chiang et al., 2005; Hoesli & Oikarinen, 2012). The mitigated volatility, due to the introduction of index futures, may result in the listed sector reflecting the underlying private real estate more effectively. However, it should be noted that the magnitude of the real estate coefficient is relatively low compared with the other macroeconomic risk proxies (e.g. GDPVol and MSVol). This does illustrate

[5] One could make the case that the futures trading only have an impact on a listed real estate market if the futures markets being well established and actively traded. Hence, we examined the sub-period analysis by comparing the results before and after the maturity of futures trading. Nevertheless, a comparison of the results before and after the launch of futures was also conducted without considering the maturity of a futures market. Our results are robust and no significant different is found.

Table 5
Comparison between before and after futures trading.

Variable	Pre-Futures	Post-Futures
Constant	0.010 (1.478)	0.011(157.646)***
GDP Volatility	0.039(0.248)	−0.086(−32.011)***
Interest Rate Volatility	0.008(2.578)**	0.001(32.553)***
Money Supply Volatility	−0.012(-1.536)	0.009(12.654)***
Foreign Exchange Volatility	0.002(0.048)	−0.001(-16.501)***
Direct Real Estate Volatility	−0.017(1.625)	0.004(10.015)***

Notes: This table reports estimated coefficients from a fixed-effect regression. For IR volatility series, the model is estimated by an unbalanced panel analysis where the dependent variable is the low-frequency volatility obtained from a Spline-GARCH model. For other volatility series, the models are estimated in the same setup. Volatility series for IR, GDP, MS, FX and DP are obtained from the (absolute value of) residuals of AR(1) models. T-values are presented in parentheses. The White cross-section robust standard errors are utilized. **, *** denotes significance at the 5% and 1% level respectively.

that the economic significance of real estate volatility is relatively weak, despite its statistically significance. In addition, it also indicates that the other macroeconomic variables examined have a stronger economic impact on the low-frequency volatility of real estate stocks. Strong volatility linkages are documented between listed real estate and Interest Rates, GDP, Money Supply and Exchange Rates in the post-futures period, while no corresponding results are reported in the pre-futures period. This would therefore imply that listed real estate has stronger linkages with macroeconomic risk following the launch of the futures contracts. Given that these are key drivers of the underlying market, it can be speculated that there is still some evidence of an enhanced relationship with market fundamentals. The results also support the premise expressed by Engle & Rangel (2008), that low-frequency volatility is strongly linked with slowly varying deterministic economic conditions.

The results show that low-frequency volatility is positively, and statistically, associated with the majority of the macroeconomic volatilities in the post-futures period. Furthermore, these coefficients have the anticipated signs. Positive and statistically significant coefficients are reported in the case of Interest Rates and Money Supply. Given that real estate cap rates/ yields and publicly traded real estate is strongly linked to direct real estate (Bredin et al, 2007; Stevenson et al., 2007), it is reasonable to document a strong link between listed real estate volatility and interest rate volatility, as well as money supply volatility. The GDP results do however warrant further discussion. While the coefficient found is statistically significant, the sign is negative, implying that heightened GDP risk reduces the low-frequency volatility of public real estate. This could, at least in part, be due to sensitivity with respect to the exact sample analyzed. Many listed real estate futures (i.e. US, Japan and Europe) were launched during the onset of Global Financial Crisis (GFC). The GFC had a severe adverse impact on both public and private real estate as well as the global economy (Lee et al., 2016). In response to the worsening economic climate a number of stimulus packages were launched, such as quantitative easing; loose monetary policies; reduction of interest rates etc (Akimov et al., 2015). Despite these policies economic growth was slow to respond in a number of markets examined in the current paper. The unique circumstances prevalent during the post-futures period may be a major factor behind the reported negative relationship. This may also be the reason behind the negative coefficient observed with respect to Exchange Rates. This finding is contrary to that reported by Engle & Rangel (2008) in the mainstream equity market. At first glance it would be easy to come to the conclusion that the different characteristics so frequently noted between stocks generally with REITs and other listed real estate may be the reason[6]. However, the results are in line with the finding of Lee et al. (2018) in the listed real estate market.

To conclude, stronger volatility linkages between listed real estate and macroeconomic proxies are evident in the post-futures period. Furthermore, a strong link between the low-frequency volatility of real estate stocks and private real estate volatility is also evident in the post-futures period, with no comparable evidence found in the pre-futures period. While these findings can be interpreted as supporting the hypothesis that futures trading leads to stronger linkages between the public and private real estate markets, as well as macroeconomic variables, they need to be formally investigated further.

4.3. Causal analysis

The previous section showed that a well-established real estate futures market does lead to a stronger link between the low-frequency volatility of listed real estate and futures. This section expands upon that analysis to consider the causal relationship present. The results are presented in Table 6 and show no strong causal relationship between listed real estate low-frequency volatility and direct real estate volatility in the pre-futures period. However, strong evidence is found in the subsequent post-futures period. Specifically, there is evidence to support the view that direct real estate leads listed real estate in the post-futures period. Similar results are found by Tuluca et al. (2000) for the US market and Hoesli et al. (2015) for the

[6] See Cotter & Stevenson (2008), Bredin et al. (2011) and Anderson & Beracha (2012).

Table 6
Pairwise granger causality tests between listed and direct real estate volatility.

Variable	Pre-Futures	Post-Futures
Direct RE Volatility → Listed RE Volatility	7.381 (0.061)	7.125 (0.028) **
Listed RE Volatility → Direct RE Volatility	3.255 (0.354)	0.126 (0.939)

Notes: This table reports the pairwise Granger causality test results. The low-frequency volatility is obtained from a Spline-GARCH model. Volatility series for direct/private real estate is obtained from the (absolute value of) residuals of AR(1) models. **, *** denotes significance at the 5% and 1% level respectively.

industrial sector[7]. The results may be attributed to the effectiveness of futures in reducing market noise in listed real estate. As discussed previously, futures trading offers a new trading avenue, thereby reducing the reliance of investors on REITs and public real estate stocks for speculative trading, hence the argument that the introduction of futures can reduce market noise. In turn, this may allow public real estate to better reflect market fundamentals. Specifically, the cash flow of real estate stocks, particularly REITs are mainly generated from the underlying direct assets; thereby the performances of listed real estate and direct real estate are expected to be based on similar direct assets (Hoesli & Oikarrinen, 2014; Lee et al., 2018)[8]. The results can also be viewed as being consistent with the papers such as Clayton & Mackinon (2003), Lee et al. (2008) and Ling & Naranjo (2015) with respect to the how Equity REITs reflect underlying real estate fundamentals. Further, Hoesli & Oikarrinen (2014) noted that volatility in the private and public sectors do not differ from each other at statistically significant levels, implying that listed real estate is strongly connected with underlying real estate assets (Lee et al., 2018). As such, it is reasonable to suppose a strong linkage between public and private real estate volatility in the post-futures period.

Further, a recent study of Ling et al. (2022) also shows how private real estate returns can predict public real estate returns in the cross-section due to slow information diffusion from local property markets to the public stock market, contrasting with the "public predicts private" evidence at the index level. The volatility linkages documented in Table 6 is consistent with the "private predicts public" narrative as the introduction of futures trading enhances information diffusion from private property markets to the public stock market. This also offers some indirect evidence to support the assertion of Hoesli & Oikarinen (2014) in that the risk profiles of privately and publicly traded real estate that are based on similar direct assets are alike, as well as the recent empirical finding of Ling et al. (2022) in which private real estate leads public real estate.

The results thus far discussed have established an entirely one-way causal relationship from direct real estate to listed real estate in the post-futures period. To further assess whether this is related to the launch of index futures the final section of the empirical analysis consists of the examination of the casual relationship between listed real estate futures and listed real estate volatility. The low-frequency volatility of listed real estate futures is extracted using with the Spline-GARCH method detailed previously, with causality tests then run. It would be expected that the futures contracts would have some a discernible impact on the low-frequency volatility of public real estate, but not vice versa. The results presented in Table 7 do support this hypothesis. They are intuitively appealing and in line with findings from the broader stock and futures markets (e.g. Pizzi et al., 1998; Ryoo & Smith, 2004; Bohl, et al., 2011). The creation of a futures contract makes the listed real estate market relatively more efficient, as volatility shocks are more quickly assimilated into the underlying market. As such, it is reasonable to find evidence of futures markets lead its underlying markets of listed real estate. However, results here are contrary to the finding of Lee et al. (2016) based on the A-REITs market they considered. The divergence of the results can be attributed to the fact that the low-frequency volatility, a long-run volatility component, is used in this analysis. As discussed by Engle & Rangel (2008), the low-frequency volatility component is a more appropriate risk measure to describe market fundamentals instead of an aggregated volatility component. This also highlights the important to decompose aggregate volatility shocks of real estate stocks into their high- and low-frequency components in a volatility analysis. The findings assist real estate investors to understand and analyze real estate and real estate futures more accurately and improve the risk management of institutional investors through an enhanced understanding of the long-term volatility of listed real estate. Collectively, the results suggest a one-way relationship between private and public real estate and a one-way relationship from real estate futures to the private market in the post-futures period. These support the viewpoint that futures markets can aid in reducing market noise and as result there is a strong relationship between the public and private markets.

[7] This indirectly supports the previous findings of Tuluca et al. (2000) and Hoesli et al. (2015) in that "a universal lead-lag relationship goes from the public to the private real estate market is not as evident as has generally been thought." (Hoesli et al. 2015; page 106). This also suggests that the lead-lag relationship is a more complex process than initially believed.

[8] This study is unique as it models the low-frequency volatility of listed real estate. The low-frequency volatility, unlike aggregate volatility and high-frequency volatility (e.g. transitory component), describes market fundamentals effectively (Engle & Rangle, 2008). Given the transitory component and market noise have been removed from our analysis, the cash flow of listed real estate, particularly REITs would be heavily tied with the underlying properties; thereby it is not surprising to document the performance of direct property leads the low-frequency volatility of listed real estate. For instance, the movement of direct property value should affect the net asset and book value of a REIT. Then the share price will respond to it accordingly. Recognising the lead-lag relationship is a complex process, it is critical to check the robustness of the study by considering different sub-sectors as Hoesli et al. (2015) found the importance of sub-sector analysis in understanding the lead-lag relationship between both markets. However, a dedicated study of this is beyond the scope of this study, although it warrants further research.

Table 7
Pairwise granger causality tests between spot and futures volatility.

Variable	Pre-Futures	Post-Futures
Futures Volatility → Spot Volatility	7.381 (0.061)	7.125 (0.028) **
Spot Volatility → Futures Volatility	3.255 (0.354)	0.126 (0.939)

Notes: This table reports the pairwise Granger causality test results. The low-frequency volatility is obtained from a Spline-GARCH model. **, *** denotes significance at the 5% and 1% level respectively.

4.4. Robustness checks

4.4.1. The impact of index futures only after there have become more fully established

The final section of the empirical analysis runs robustness tests that consider the impact of index futures only after there have become more fully established. All of the markets that have introduced futures based on public real estate indices have seen that it has taken some time for the market to see a reasonable degree of trading. There is therefore a very strong intuitive argument that during the initial phases the results may differ, i.e., the futures markets need to be sufficiently large and actively traded to have a meaningful impact. The well-established period for each futures market is summarized in Table 8 and are of important for the volatility linkages analysis with a threshold of USD 115 (€ 100) million[9]. To ensure the robustness of our baseline results, we re-run the panel analyses with the well-established futures period[10].

By comparing the robustness check results with the baseline results in Table 5, it can be seen that the low-frequency volatility of listed real estate is broadly similar to the findings for the entire sample period. The results indicate that a positive and statistically significant causal relationship between listed real estate low-frequency volatility and direct real estate volatility in the post-futures period, whilst no similar evidence is observed in the pre-futures period. In addition, strong linkages are documented between listed real estate and Interest Rates, GDP, Money Supply, CPI or Exchange rate in the post-futures period. No similar evidence is found for the pre-futures period. The results confirm the premise that listed real estate markets have stronger links with both direct real estate and macroeconomic risk following the launch of index futures. This supports our assertion of futures trading offering a new trading avenue that reduces the reliance on listed real estate markets for speculative trading. Therefore, speculative activities and market noise may be seen to be reduced after futures contracts are introduced. Importantly, the mitigated volatility of real estate securities due to noise trading could make the listed real estate sector reflect market fundamentals more effectively. In other words, it is reasonable to document an enhanced low-frequency volatility linkage between public and private real estate after the introduction of listed real estate futures markets.

4.4.2. The impact of leverage

One could make a case that the MSCI/IPD and NCREIF indices are unlevered indices, whilst listed real estate indices are levered. To estimate property market volatility more precisely, this is crucial to deleverage public real estate series (Giacomni Ling and Naranjo, 2015). A robustness check, therefore, is conducted to remove the leverage effect by deleveraging the levered public real estate series. Following Barkham and Geltner (1995) and Stevenson (2001) a weighted average cost of capital (WACC) approach is applied. The model can be displayed as follows:

$$R_{pt} = \frac{R_{et} - [1 - (P/E)_t]R_{dt}}{(P/E)_t} \tag{7}$$

where R_{pt} is the unlevered listed real estate return at time t, R_{et} is the return to equity, R_{dt} is the return on debt and $(P/E)_t$ is the ratio of real estate assets to shareholders equity. Thereafter, the low-frequency volatility of unlevered listed real estate is extracted with the Spline-GARCH model detailed previously in the methodology section (see Equations 3–5), with causality tests then run over the pre-futures and post-futures periods individually.

The causal relationship between unlevered public real estate and private real estate is documented in Table 9. Results here suggest that no causal volatility relationship between both markets prior to the introduction of futures markets. However, a strong linkage between both markets has been identified in the post-futures period. This reinforces our baseline results in which the onset of futures reduces market noise by providing a means of reducing the reliance of investors on public real estate for speculation. This also allows private real estate to better reflect market fundamentals. The finding here also offers some indirect support to the finding of Ling et al. (2022). They show that a "private predicts public" result in a cross-sectional due to slow information diffusion. Given the introduction of futures trading enhances information diffusion from private property markets to the public stock market, this is reasonable to find the empirical evidence of "private predicts public". In other words, our baseline results are robust to the use of unlevered listed real estate indices that capture the leverage effect Table 10.

[9] The Appendix highlights the growth in trading volume for each futures market. The FTSE/EPRA NEREIT Eurozone index contract was excluded from the analysis as it was not actively traded.

[10] The results are not displayed for brevity, but the results are available upon on request.

Table 8
The well established period for futures trading.

Underlying Index	Year
FTSE EPRA/NAREIT Developed Europe Index	2014
FTSE EPRA/NAREIT Eurozone Index	–
Dow Jones U.S. Real Estate Index	2014
Tokyo Stock Exchange REIT Index	2015
S&P/ASX 200 A-REIT Index Futures	2005

Table 9
Pairwise granger causality tests between unlevered listed and direct real estate volatility.

Variable	Pre-Futures	Post-Futures
Direct RE Volatility → Unlevered Listed RE Volatility	0.004 (0.998)	22.467 (0.002) ***
Unlevered Listed RE Volatility → Direct RE Volatility	0.047 (0.977)	2.895 (0.576)

Notes: This table reports the pairwise Granger causality test results. The low-frequency volatility is obtained from a Spline-GARCH model. Volatility series for direct/private real estate is obtained from the (absolute value of) residuals of AR(1) models. **, *** denotes significance at the 5% and 1% level respectively.

Table 10
Pairwise granger causality tests between listed and direct real estate volatility: individual countries.

Panel A: US	Pre-Futures	Post-Futures
Direct RE Volatility → Unlevered Listed RE Volatility	0.382 (0.826)	5.991 (0.014) **
Unlevered Listed RE Volatility → Direct RE Volatility	0.964 (0.618)	2.389 (0.122)
Panel B: Australia	**Pre-Futures**	**Post-Futures**
Direct RE Volatility → Unlevered Listed RE Volatility	0.699 (0.403)	13.263 (0.010) ***
Unlevered Listed RE Volatility → Direct RE Volatility	1.683 (0.195)	7.359 (0.118)
Panel C: Japan	**Pre-Futures**	**Post-Futures**
Direct RE Volatility → Unlevered Listed RE Volatility	0.370 (0.831)	3.033 (0.082)
Unlevered Listed RE Volatility → Direct RE Volatility	0.145 (0.930)	2.836 (0.092)
Panel D: UK	**Pre-Futures**	**Post-Futures**
Direct RE Volatility → Unlevered Listed RE Volatility	0.056 (0.972)	17.609 (0.000) ***
Unlevered Listed RE Volatility → Direct RE Volatility	2.139 (0.343)	0.577 (0.749)

Notes: This table reports the pairwise Granger causality test results. The low-frequency volatility is obtained from a Spline-GARCH model. Volatility series for direct/private real estate is obtained from the (absolute value of) residuals of AR(1) models. **, *** denotes significance at the 5% and 1% level respectively.

4.4.3. The impact of Bank of Japan (BOJ) J-REITs and EFTs purchases

The Quantitative and Qualitative Monetary Easing (QQE) was formally introduced on 4th April 2013. This allows the Bank of Japan (BOJ) to purchase J-REITs and EFTs (Hattori and Yoshida, 2020). This naturally raises a question of whether this would offset the effect of futures trading on spot market volatility. To gauge the impact of BOJ's equity purchases program, we introduced a time dummy variable in the variance equation of a GARCH model in the Bessembinder and Seguin (1992) framework, which is specified as follows:

$$R_t = a_0 + a_1 R_{t-1} + \mu_t \tag{8}$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 h_{t-1} + \alpha_3 ExpVol + \alpha_4 UnexpVol + \alpha_5 ExpOI + \alpha_6 UnexpOI + \alpha_7 Mon + \alpha_8 Tue + \alpha_9 Wed + \alpha_{10} Thu + \alpha_{11} BOJ \tag{9}$$

where BOJ is a time dummy in which zero for the period before 4th April 2013 with the approval of J-REIT purchases, whilst unity for the period after 4th April 2013. The results show that expected volume and expected open interest are statistically insignificant once the BOJ dummy is introduced. However, the BOJ dummy variable is negative and statistically significant, indicating that the BOJ J-REIT purchases program does have a discernible impact on the J-REIT spot market volatility. As discussed by Hattori and Yoshida (2020), the BOJ tends to purchase REIT shares in a bear market with the aim of stabilizing the J-REITs market. A significant and inverse volatility relationship between the BOJ program and REITs, therefore, is intuitive appealing. Importantly, this also implies that the effect of J-REIT futures trading on spot market volatility, to certain extent, is offset by the BOJ J-REIT purchases program[11].

4.4.4. The pan European futures and the sensitivity of the methodological framework adopted

Our next robustness test is concerned with the sensitivity of the methodological framework adopted. To examine this, we use, as an alternative, a seemingly unrelated framework as suggested by Engle & Rangel (2008), a random-effect regression and a simple pooled regression. The results suggest that the baseline results are robust. No significant variation is documented, reflecting that strong volatility linkages between listed real estate and direct real estate and other macroeconomic risk proxies. This suggests that our preceding results are robust to alternative methodological framework. The final issue to be considered in the current paper concerns the pan European nature of the indices used. To enhance the specificity of the evidence, we examine whether the baseline results are robust to the use of national indices such as the US, Australia and Japan futures markets by removing the European markets from our panel analysis. The robustness results, in general, are consistent with the baseline results. More specifically, stronger volatility linkages between listed and direct real estate are evident in the post-futures period, reflecting that our baseline results are robust, although an investigation of individual futures specific contracts is undertaken. As previously discussed, the reduction of market noise in the public real estate market via the launch of real estate futures allows public real estate to better reflect the fundamental of private real estate. As such, the one-way causal volatility relationship from private to public real estate is documented in the post-futures period. This also supports the finding of Hoesli and Oikarinen (2014) in which listed real estate is based on similar direct assets are alike, as well as the recent empirical finding of Ling et al. (2022) in which private real estate leads public real estate.

4.4.5. The contribution of each futures market to the enhanced linkages between public and private real estate

To enhance the reliability of generalizability of our analysis, this is also crucial to estimate country-specific models as discussed by Hoesli and Okarinen (2012). As such, we have rerun the analyses in a time series setting. The one-to-one relationship of individual country allows us to assess the contribution of each futures market. The results are reported in Table 10[12].

The result showed that the onset of futures contract on public real estate in the US and Australia did improve market efficiency and lead to an enhanced linkages between public and private real estate in the US and Australia. Comparable evidence is also documented in the UK via the launch of Pan-European futures. However, no similar result is found in Japan. The Japanese results are not very unsurprising with respect to the Bessembinder and Seguin (1992) framework in previous section found that J-REIT futures play a lesser role compared with other futures. The lesser role of J-REIT futures can be arguably attributed to the Bank of Japan (BOJ) equity purchases program for ETFs and J-REITs. Importantly, the effect of futures trading on spot market volatility, to a certain extent, is offset by this program.

5. Conclusion and implications

Given the increasing popularity of listed real estate futures in the US and internationally in line with the growth of its markets size, a specific study of the impact of US and international listed real estate futures is a compelling topic for research. This study examines the impact of futures trading on the volatility linkages between listed real estate and direct real estate. The total returns of real estate stocks in Australia, Japan, the US and Europe over January 1990 to March 2019 were assessed via a number of empirical approaches.

Several key findings have been identified. First, the inception of listed real estate futures, in general, does improve the market efficiency of listed real estate market. It appears that the launch of listed real estate futures has improved market efficiency and the quality of information flowing to the listed market. Specifically, the results suggest that futures improve liquidity and market depth; thereby the volatility of REITs, and other listed vehicles, can be reduced. Second, the launch of futures leads to an enhanced volatility linkage between the public market and macroeconomic risk. A stronger volatility linkage between public real estate and market fundamentals has been observed after the introduction of listed real estate futures markets. This can be attributed to the fact that listed real estate futures markets reduce market noise in the underlying market by allowing investors to hedge and speculate in the futures market, thereby reducing their reliance on spot (listed real estate) market. Consequently, this allows the sector to better reflect market fundamentals. Lastly, the onset of real estate futures leads to a stronger volatility linkage between public and private real estate. We documented an enhanced low-frequency volatility linkage between public and private real estate after the introduction of futures contracts. This suggests that public real estate may reflect fundamentals more effectively following the launch of the futures market.

The findings have several implications for policy makers and investors. Firstly, the finding that futures markets can improve liquidity provision and depth in an underlying spot market suggests that policy makers should encourage the development of listed real estate futures. Specifically, the futures markets would enhance information flow and increase market efficiency. It would also help facilitate investors' hedging strategies by reducing their reliance on the spot market. Specifically, it offers an effective platform for real estate investors to hedge the price movement of the underlying asset (i.e. public

[11] We sincerely thank the referee to raise this point.

[12] We only considered the US, Australia, Japanese as well as the UK markets as these markets offer quarterly datasets that allow us to gauge the linkages in a time-series setting. This should be noted that the MSCI/IPD France, Germany, Sweden private real estate series are only available either in a bi-annual or annual format. This data limitation of the study should be borne in mind when interpreting the results.

real estate). As such, a stabilizing effect is also provided by the launch of a futures market. Secondly, the reduction in the observed volatility of public real estate does raise the question as to whether the public real estate markets may act as a more effective proxy for the private market. The finding of an enhanced relationship between the public and private markets would encourage institutional investors to invest in REITs and other property stocks.

CRediT authorship contribution statement

Chyi Lin Lee: Conceptualization, Methodology, Writing – original draft, Supervision. **Simon Stevenson:** Conceptualization, Methodology, Writing – review & editing. **Hyunbum Cho:** Resources, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Annual and accumulated futures trading volume

Figs. A1–A5.

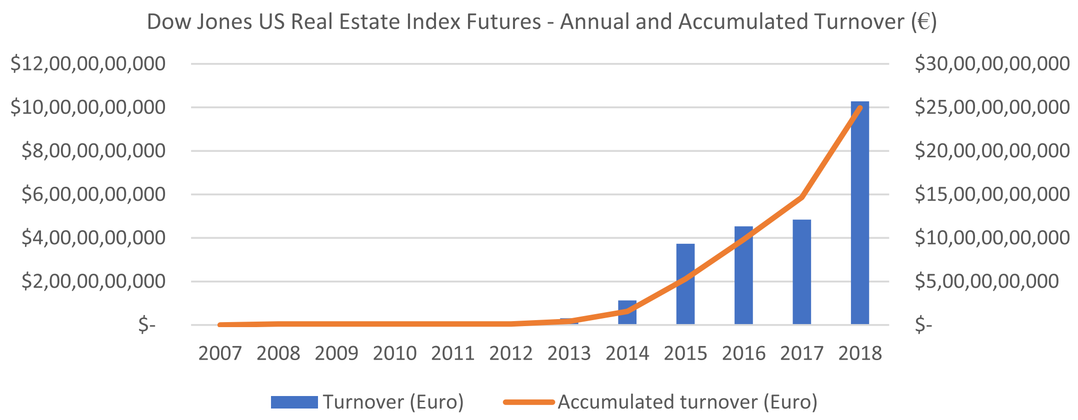

Fig. A1. United States.

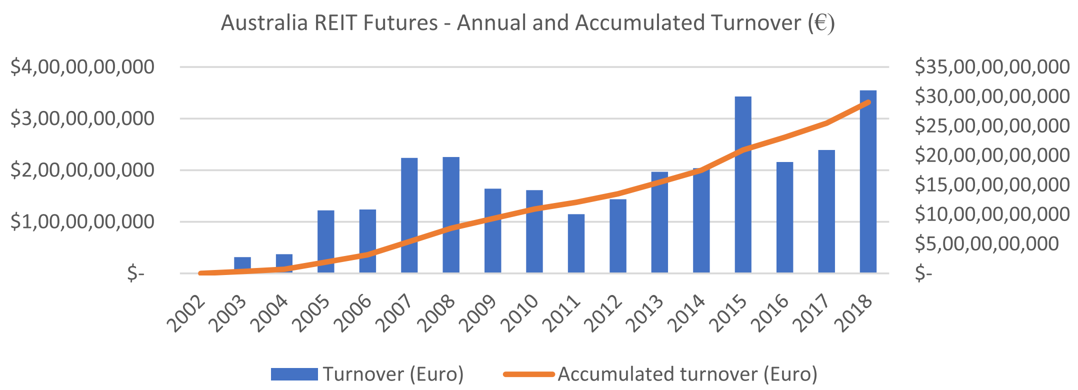

Fig. A2. Australia.

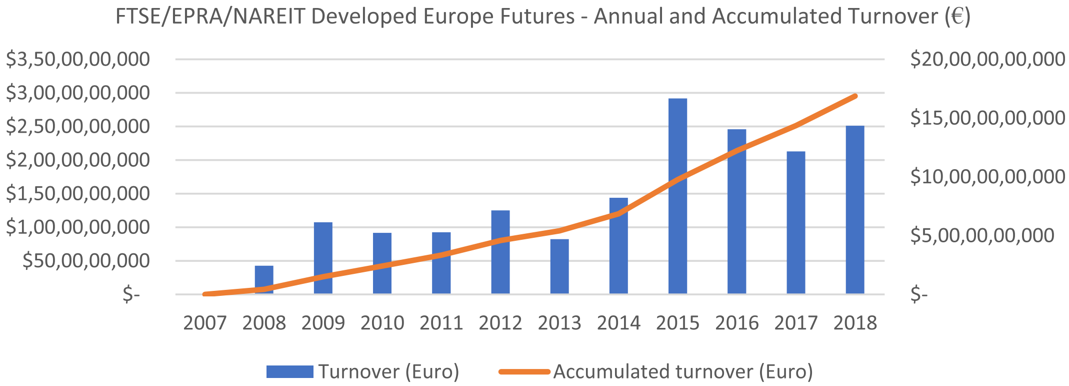

Fig. A3. Developed Europe.

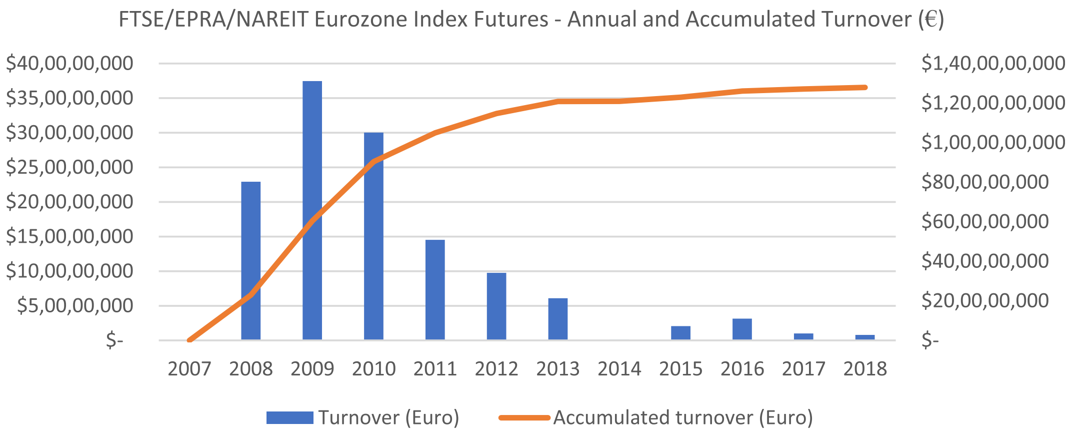

Fig. A4. Eurozone.

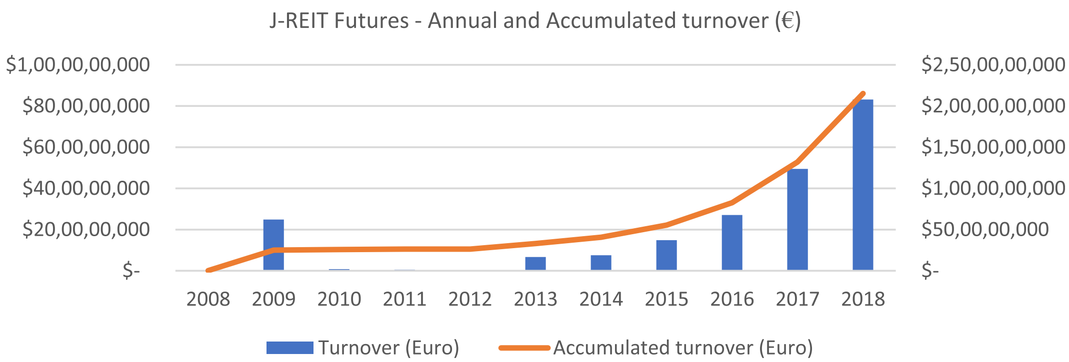

Fig. A5. Japan. Sources: ASX (2019), FTSE (2019), TSE (2019), CBT (2019). Note: As of 31 December 2018, the exchange rate between Euro and US is €1: USD 1.1492.

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