Varying Interest Rate Sensitivity of Different Real Estate Sectors

Global Listed Real Estate Evidence

EPRA
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EXECUTIVE SUMMARY

Although the world emerged strongly from the debilitating COVID-19 pandemic, it presents a unique high inflationary situation, which results in an immediate and significant shift in global monetary policies. Key global central banks' monetary policies have turned increasingly hawkish and have aggressively increased fund rates, both in speed and magnitude. Importantly, the Federal Reserve's dot plot signaled a higher-for-longer interest rate environment in 2024 due to inflation continuously above the target range (Federal Reserve, 2023). This report is the first to examine interest rate risk management and institutional investment opportunities of global listed real estate (LRE) sub-sectors in light of the recent global rate hike cycle. The first research theme is to address the quantitative interest rate sensitivity of LRE sub-sectors by using various interest rate proxies, particularly for 10y-2y spread - a leading indicator of projecting economic recession risk (FRBSF, 2022). The second research theme is to assess institutionalized portfolio construction strategies in global LRE across sectors and markets in different phases of interest rate cycles by using mean-downside variance portfolio analysis.

Using monthly indices of LRE sub-sectors, stocks, 3-month treasury bill (3mth T-bill) rates, 10-year government bond yields (10y GBY) and 10y-2y spread as proxies for interest rate maturities across the Developed Europe, Eurozone, USA, UK and Globe from Dec 2000 to Dec 2022. This research investigates the sectoral effect and specialization value in the context of interest rate sensitivity in both interest rate expansion and contraction phases and the impacts of interest rates on institutionalized portfolio construction of global LRE sub-sectors. The expansion and contraction phases of the monetary policy cycle were empirically approximated by the Harding and Pagan's (2002) Bry-Boschan dating algorithm.

The findings of the research are extremely insightful and valuable for global commercial real estate (CRE) investors as private real estate and public real estate converge in the long run (Hoesli et al., 2015) and are affected by the same fundamental drivers (LaSalle, 2023). First, the practical use of the results in the first theme is expected to inform global buy-side (real estate institutional investors) and sell-side CRE asset managers (real estate investment managers) of distressed asset investment strategies in pitching non-performing assets (NPA) across sectors and markets in the stock pitching and due diligence processes in global private equity and credit markets, where the sub-sectors were rigorously validated as vulnerable to 3mth T-bill rates, 10y GBY and 10y-2y spread proxies. Second, the results provide global conventional and alternative CRE lenders deploying debt investment strategies across sectors and markets in global private credit markets, with the quantitative interest rate sensitivity of LRE sub-sectors to identify where loans are at a greater risk and ensure margins are sufficient to compensate for the recent global investment risks: the scale of fund rate increases and the depth of yield curve inversion across global capital markets. In particular, inverted yield curves have a long history of preceding economic recession (FRBSF, 2022).

The investment implications of the second theme acknowledge global buy-side asset managers of well-informed tactical asset allocation (TAA) strategies in portfolio construction of LRE sub-sectors across the Globe, Developed Europe, Eurozone, USA and UK in rate hike cycles. First, portfolio allocation weightings to LRE sub-sectors were empirically and tactically adjusted based on varying phases of interest cycles, and downside risk considerations so as to take advantage of short-term investment opportunities whilst aligning asset allocations to long-term investment objectives. Second, the findings provide buy-side and sell-side asset managers with empirical evidence on quantitative market and sector selections of global LRE in rate hike and rate cut cycles. The investment implications of the empirical results in the two themes are summarized as follows:

Distressed asset investment strategies

- Self-storage, residential, diversified and retail were empirically estimated as cyclical real assets to interest rate cycles. Specifically, self-storage and residential were the most sensitive sectors to 3mth T-bill rates and 10y GBY changes across the Developed Europe, Eurozone, USA and UK. Meanwhile, diversified and retail were susceptible to 3mth T-bill rates across four markets, and industrial was vulnerable to 10y GBY. These imply that self-storage, residential, diversified and retail may benefit the most and could potentially be quiet outperformers when interest rate proxies fall caused by the turning point of the rate cut cycle.

- Office, diversified and residential were significantly and positively sensitive to 10y-2y spread swings across the Developed Europe, Eurozone, USA and UK. This implies that office, diversified and residential

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F +32 (0) 2739 1020   **W** www.epra.com
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responded negatively to rising possibilities of economic recession risk, in which the inverted yield curve occurs. As of Jun 2023, the 10y-2y yield curve inversion (-1.06% as of Jun 2023) was the longest and deepest in the last four decades, following the most aggressive rate hike from the historically lowest level (FRED, 2023). Alternatively, office, diversified and residential may enjoy benefits from economic resurgence across the four markets.

- Industrial/office and lodging were empirically tested as defensive real assets to economic recessions and interest rate cycles in the USA. In particular, industrial/office showed strong interest rate risk aversion and hedging benefits to 10y-2y spread changes in the USA. Lodging was immune to swings in interest rate proxies in the USA and Globe.

- Healthcare's defensive characteristic to interest rates behaved divergently across the three markets. In the USA, healthcare featured strong interest rate risk aversion and hedging benefits to 10y GBY and 10y-2y spread. However, healthcare was vulnerable to 3mth T-bill rates in the Developed Europe and UK, as well as 10y GBY in Developed Europe. This is despite the findings that healthcare has traditionally been seen as a defensive real asset in highly volatile markets (Newell and Marzuki, 2018).

- Strong interest rate risk aversion and hedging benefits characteristics of industrial/office and healthcare may be attributed to their fundamental drivers, bolstered less by economic growth but more on the growth of demographics, technology and healthcare (Nuveen, 2023b).

The impacts of US monetary policy

- The impacts of US monetary policy on global LRE sub-sectors were assessed in respect to the speed of recent US fund rate hikes since Mar 2022, which is the fastest in the last 35 years, increasing 500 bps in 14 months (Federal Reserve, 2023). The findings are broadly consistent with the baseline results, in which global industrial/office and healthcare were found to be defensive real assets to interest rate cycles, with strong interest rate risk aversion and hedging benefits, while global lodging was immune to all interest rate proxies in the USA, unlike the mainstream global LRE sub-sectors.

Debt investment strategies

- Loan-to-value ratio (LTV) was significantly negative with the mainstream sub-sectors, namely diversified, office and retail in Developed Europe. This may be attributed to a high level of LTV in diversified (35.7%) and retail (45.2%) as of Dec 2022. CRE sector's greater reliance on higher levels of shorter-term debts may be significantly affected and result in the collapse and recapitalization of CRE firms when the systematic risk of CRE changes and rises (Reddy and Wong, 2018).

- LTV was significantly positive in industrial, self-storage and residential. These indicate that industrial, self-storage and residential delivered higher total returns boosted by higher leverages. This may be attributed to the low level of LTV in industrial (28.4%) and self-storage (21.5%) as of Dec 2022. Lower leverages provide flexibility in adding more debt facilities to increase returns (Brounen et al., 2016).

TAA strategies in portfolio construction in rate hike and rate cut cycles

- In the rate hike cycle, the addition of industrial enhanced portfolio returns of an existing composition of stocks and bonds (the baseline portfolio) across the Globe, USA, UK, Eurozone and Developed Europe. This was followed by residential, self-storage and healthcare. Specifically, the inclusion of residential increased portfolio returns of the baseline portfolios across most of the markets, except for the UK. In addition, the presence of self-storage increased portfolio returns of the baseline portfolios across the UK and Developed Europe. Further, the inclusion of healthcare increased portfolio returns of the baseline portfolio across the Globe, UK and Developed Europe.

- Industrial was the strongest and most resilient sector in the rate hike cycle, with a high allocation in mixed-asset portfolios across the Globe (average portfolio weighting: 66%), USA (54%), UK (52%), Eurozone (52%) and Developed Europe (52%). In the following rate cut cycle, industrial portfolio weightings fell slightly to 51%, 51% and 44% in the Globe, Developed Europe and USA respectively and was unchanged in the UK. However, industrial portfolio weighting declined to 0% in Developed Europe.

- Residential was empirically the second most resilient sector in the rate hike cycle. The average portfolio weighting to residential was 57%, 52%, 52% and 37% in the Globe, Eurozone and Developed Europe and US respectively, but was limited to 8% in the UK. In the subsequent rate cut cycle, a portfolio weighting to residential reduced to 0% in the Globe, USA and Developed Europe, respectively. Nevertheless, the

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F +32 (0) 2739 1020

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portfolio weighting to residential increased to 28% in the UK. These are despite the fact that residential was measured as a cyclical real asset to different phases of interest rate cycles.

- Healthcare was significantly weighted in the rate hike cycle, with 51%, 46% and 42% in the Globe, UK and developed Europe portfolios, respectively. However, the portfolio allocation to healthcare was only 10% in the USA. Healthcare was empirically tested as a defensive real asset in the rate hike cycle, with strong interest rate risk aversion and hedging benefits to 10y GBY and 10y-2y spread in the USA but was sensitive to 3mth T-bill rates in the Developed Europe and UK.

- Self-storage was weighted across Europe (51%), UK (48%) and Globe (16%) in the rate hike cycle. The average portfolio weighting to self-storage was limited to 10% in the USA. The decline in portfolio weightings to self-storage can be observed across the Globe (dipped by -46%), USA (-45%) and Developed Europe (-5%) from the previous rate cut cycle. The trend is generally consistent with the results that self-storage was assessed as a cyclical real asset to 3mth T-bill rates and 10y GBY across the Developed Europe, Eurozone, USA and UK.

- Office was unweighted in mixed-asset portfolios across the USA and UK in the rate hike cycle but was included in the portfolio mix across the Eurozone (53%), Developed Europe (52%) and Globe (20%). These are consistent with the results that office in the UK was unexpectedly sensitive to 3mth T-bill rates and 10y GBY changes.

- Retail was generally unweighted in mixed-asset portfolio across all markets, consistent with the results that retail was measured as a cyclical real asset to interest rate cycles, particularly to 3mth T-bills. In contrast, retail was weighted across the Globe and Eurozone in rate cut cycles.

- Market and sector selection were empirically assessed as important investment criteria, thus capitalizing on the outperforming sector can result in higher overall risk-adjusted returns and minimizing downside risk. The attractiveness of LRE across sectors and markets can vary significantly based on market dynamics and investor sentiment. In particular, alternative LRE sub-sectors in TAA strategies led to higher achievable mixed-asset portfolio returns. These findings provide global buy-side and sell-side asset managers with TAA strategies in portfolio weightings to LRE across sectors and markets in varying phases of interest rate cycles and highlight the need for global real estate investors to understand the impacts of monetary policy changes on market- and sector-specific characteristics.

Active-passive investment strategies

- The strategic importance of sectoral specialization versus naïve diversification in portfolios has been highlighted, where more tailored sector-specific LRE investment strategies can offer value-add and potentially outperform the portfolio of diversified LRE. Across the markets, the downside risk optimized portfolios contain a higher concentration of sector-specific LRE versus diversified LRE (13%), compared with sector-specific LRE: office (25%), self-storage (31%), healthcare (38%), residential (41%) and industrial (55%), respectively. This suggests institutional investors should actively make their own sectoral portfolio diversification decisions by investing in different property types of LRE, rather than passively relying on a diversified portfolio with multiple real estate sectors.

The investment implications of this research are extremely valuable and insightful for a wide range of LRE investors, buy-side and sell-side asset managers, including real estate fund managers (e.g.: AXA IM, APG AM, PGGM, Goldman Sachs AM, Morgan Stanley IM, Macquarie AM), insurance companies (e.g.: AIG, Prudential Financial), pension funds (e.g.: CPPIB, CalSTRS, Nuveen AM), sovereign wealth funds (e.g.: GIC, ADIA) and income-oriented investors (e.g.: UHNW). The investment implications of the quantitative interest rate sensitivity of global LRE sub-sectors are insightful for global institutional CRE lenders implementing debt investment strategies. These global institutional CRE lenders in global private credit markets include conventional CRE lenders, commercial and investment banks, insurance companies, commercial mortgage-backed securities (CMBS) and alternative lenders (e.g.: CRE debt funds (DWS AM, AEW Capital AM, Savills IM), pension funds (Nuveen AM, AustralianSuper)) in light of a higher-for-longer interest rate environment being expected in 2024 due to inflation continuously above the target range (Federal Reserve, 2023), and an approximately total value of US$1.6 trillion in outstanding CRE debt matures in the next three years (KKR, 2024).

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Real Estate Association

Square de Meeus, 23
1000 Brussels, Belgium

T +32 (0) 2739 1010
F +32 (0) 2739 1020

W www.epra.com
E info@epra.com

Content table

AUTHORS

Dr Yu-Cheng (Robbie) Lin, MRICS
Sessional Lecturer, Western Sydney University
and University of New South Wales

Dr Jufri Marzuki
Lecturer in Property, Western Sydney
University

CONTACT

Yu-cheng.lin@westernsydney.edu.au

J.Marzuki@westernsydney.edu.au

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Square de Meeus, 23
1000 Brussels, Belgium

T +32 (0) 2739 1010
F +32 (0) 2739 1020

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Introduction

Rising interest rates are of significant concern to various CRE stakeholders as global capital markets have been saturated with government debts since the onset of the COVID-19 pandemic. Aggressive spending as part of stimulus programs implemented by governments globally was aimed at preventing an economic meltdown. Key central banks around the world (e.g.: the Federal Reserve, European Central Bank (ECB) and Bank of England (BOE)) have cut fund rates to a near-zero level in 2020 and implemented Quantitative Easing (QE) measures by expanding balance sheets at a historically high level (FRBSF, 2022). Notably, the US Federal Reserve has enlarged its balance sheet from US$4 trillion in 2020 to more than US$9 trillion in 2022 (Federal Reserve, 2023). These liquidity injections were seen as necessary to overcome the adverse effects of economic shutdowns and lockdown rules (Krugman, 2020).

The high level of government bonds raised concerns amongst economists, in that a persistently elevated supply of government bonds could lift the equilibrium interest rate (Del Negro et al., 2017; Caballero and Fahri, 2018), particularly in a post-COVID context (Krugman, 2020). The inflationary environment since the end of 2021 has resulted in that central banks' monetary policy turning increasingly hawkish and aggressively heightening fund rates, including the Federal Reserve (an increase of 525 basis points as of Sep 2023), ECB (450 bps) and BOE (500 bps) (BOE, 2023; ECB, 2023; Federal Reserve, 2023). Furthermore, the Federal Reserve has planned to reduce its US$9 trillion balance sheet in Jun 2022, with US$ 47.5 billion in the first three months and US$ 95.0 billion in the following three months (Federal Reserve, 2023). Therefore, global central banks' fund rates are expected to be "normalized" or "neutral" in the near future.

The first theme of this research aims to empirically assess the interest rate sensitivity of LRE sub-sectors in light of recent rate hike cycles implemented by key global central banks. This is owing to the acknowledgement of the sectoral effect and specialization value in global LRE markets (Hoesli and Oikarinen, 2012; Lin et al., 2019a). The second theme of this research is to understand the impacts of rate hikes on constructing LRE portfolio compositions by assessing differential portfolio allocations to each real estate sector between rate hike and non-rate hike cycles. Overall, this research will be the first to demonstrate distinctions in interest rate risk management for global LRE across sectors and markets in respect to recent global rate hike cycles and to examine differential allocations to each real estate sector between rate hike and non-rate hike cycles. This research will be the first study to assess the impacts of LTV on interest rate risk management strategies of LRE at a sector level, using various interest rate proxies, given the varying nature of debt levels across different LRE companies (Reddy and Wong, 2018). Since Oct 2010, the growth of debt ratio for US specialty REITs was 18.1%, followed by office (14.7%), diversified (11.2%), retail (-6.1%), residential (-30.4%) and industrial REITs (-18.6%) (NAREIT, 2022). In Developed Europe, retail was 5.2%, followed by diversified (-16.1%), healthcare (-32.3%), residential (-33.1%), office (-35.8%), industrial (-41.8%) and self-storage (-42.8%) (EPRA, 2022).

In this research, the LRE sub-sectors are taken to be diversified, office, retail, industrial, industrial/office, self-storage, residential, lodging and healthcare sectors, categorized by the Industry Classification Benchmark (ICB) system provided by FTSE. The purpose of this research is to assess the magnitude and direction of the interest rate sensitivity level and volatility of each LRE sub-sector, as well as the impacts of rate hike cycles on portfolio allocation weightings to each real estate sector. The following specific research questions will be assessed:

- What are the impacts of key global central banks' monetary policies on LRE sub-sectors at global, regional and market levels?

- What are the level and volatility of interest rate sensitivity of LRE sub-sectors at global, regional and market levels?

- Do debt levels affect the interest rate sensitivity of LRE sub-sectors?

- What are differential portfolio allocation weightings to each real estate sector in rate hike cycles compared with stocks and bonds?

By answering these research questions, this research will offer significant contributions in the following areas:

- A fuller understanding of the investment implications of key global central bank policies on LRE sub-sectors at global, regional and market levels.

- A rigorous understanding of the impact of short- and long-term interest rate and term spread changes on LRE sub-sectors at global, regional and market levels.

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T +32 (0) 2739 1010
F +32 (0) 2739 1020

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- An in-depth understanding of the impacts of LTV ratios on LRE sub-sector sensitivity to interest rate swings.
- A comprehensive understanding of the implications of rate hike cycles on constructing LRE portfolio compositions at global, regional and market levels.
- A validation of the notion of the sectoral effect and specialization value in LRE markets at global, regional and market levels.

By addressing the research questions will enhance institutional lenders' and investors' understanding of interest rate risk management strategies in LRE across sectors and regions, particularly with the growth of refinancing capitals and distressed real estate in the post-COVID context (Lin et al., 2021). The findings of this research are particularly important to LRE investors, buy-side and sell-side asset managers, such as real estate fund managers (e.g.: AXA IM, APG AM, PGGM, Goldman Sachs AM, Morgan Stanley IM, Macquarie AM), insurance companies (e.g.: AIG, Prudential Financial), pension funds (e.g.: CPPIB, CalSTRS, Nuveen AM), sovereign wealth funds (e.g.: GIC, ADIA) and income-oriented investors (e.g.: UHNW). The practical use of these findings is expected to provide well-informed distressed asset investment strategies in pitching NPA across sectors and regions in the stock pitching and due diligence processes, where the sectors were rigorously validated as vulnerable to changes in the level and volatility of 3mth T-bill rates, 10y GBY and 10y-2y spread proxies.

Second, the results provide up-to-date and strategic insights on interest rate risk management strategies of LRE across sectors and markets, and the impacts of LTV on the interest rate sensitivity of LRE sectors and markets, with using various interest rate proxies. These are extremely useful to institutional lenders of global CRE markets, including commercial and investment banks, insurance companies, commercial mortgage-backed securities (CMBS) and alternative lenders (e.g.: CRE debt funds, pension funds) (LaSalle, 2023). As of Sep 2023, a total value of $5.8 trillion in outstanding mortgage debt was recorded, including banks (50% of outstanding mortgage debt as of Sep 2023), agencies (21%), insurance (12%), CMBS (12%) and other (5%) (KKR, 2024). However, a high volume of traditional lenders was on the sidelines due to challenging credit markets in a higher-for-longer interest rate environment in the last 18 months (DWS, 2023; Nuveen, 2023b; KKR, 2024).

Therefore, alternative CRE lenders have aimed to fill the debt funding gap (DFG) and implement a non-bank debt investment strategy (Nuveen, 2023a). This is due to that longer and higher fund rates implemented by key global central banks have caused constraints in global credit markets and fundraising for global CRE markets (PERE, 2023). Conventional CRE lenders, namely commercial and investment banks, therefore mainly focused on refinancing existing loans coming up to maturity and have shrunk from global lending markets (AEW, 2022; DWS, 2023). Global institutional lenders of global CRE markets will be urged to identify where loans are at greater risk and ensure margins are sufficient to compensate for the risks, particularly for interest rate risk and economic recession risk (DWS, 2023, PERE, 2023), which can be effectively detected by the 10y-2y spread (FRBSF, 2022). As of Jun 2023, the 10y-2y spread reached -1.06%, the four-decade lowest level after Aug 1981 (FRED, 2023).

Third, the results inform global buy-side asset managers of TAA strategies in portfolio construction of LRE sub-sectors across the Developed Europe, Eurozone, USA, UK and Globe in rate hike and rate cut cycles, using mean-downside variance portfolio analysis in light of turbulent investment contexts. The results validate portfolio return enhancement capabilities of LRE sub-sectors in institutional investors' multi-asset portfolios across these markets.

Fourth, the findings are expected to inform buy-side and sell-side asset managers of empirical evidence on quantitative market and sector selections of LRE across the markets in rate hike and rate cut cycles.

Literature Review

Linkages between LRE and interest rates

Since the first rate hike by the Federal Reserve in Mar 2022, hawkish monetary policy has been implemented by key global central banks. Asset values of global CRE consequently dipped by 6.2% over the year to Jun 2023 (MSCI, 2023). Fundamentally, rising interest rates increase the cost of debt financing in real estate firm management, create upward pressure on yields and a decrease in real estate capital values, substantially impact term structure of real estate leases, reduce occupational demand and lead to oversupply in the real estate submarkets (Crosby et al., 2003; Agarwal et al., 2011, Brounen et al., 2016).

Scholars have assessed the impact of interest rates on LRE (REITs and REOCs) in the USA (Mueller and Pauley, 1995; Devaney, 2001; Bredin et al., 2007, 2011, Chang et al., 2011), Europe (Lizieri and Satchell, 1997; Stevenson

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1000 Brussels, Belgium

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F +32 (0) 2739 1020

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et al., 2007; Lee et al., 2014; Akimov et al., 2020), Asia-Pacific (Liow and Huang, 2006) and globally (Akimov et al., 2015; Dirk et al., 2016). First, one consensus amongst these studies is that time-varying interest rate sensitivity results have been frequently observed, as denoted by He et al. (2003) and Akimov et al. (2015). For example, Mueller and Pauley (1995) found a different conclusion when they examined the reaction of REIT prices to interest-rate movements over several cycles. They discovered that REIT price changes showed a low correlation with swings in interest rates from 1972 to 1995. Bredin et al. (2007) reported similar evidence by examining the effects of unanticipated turbulence in monetary policy in the USA on US equity REITs from 1996 to 2005. However, Chang et al. (2011) documented that equity US-REIT returns were responsive to either long-term interest rates or the interest rate spread from 1975 to 2008.

Second, the varying degrees of interest rate sensitivity of REITs across different markets were raised by Lee et al. (2014), Akimov et al. (2015) and Brounen et al. (2016). These may be cross-country variations in countries' degrees of financial integration, as noted by Bardhan et al. (2008), Akimov et al. (2020) and Lin et al. (2021). Third, the significance of the interest rate proxy used on the results of the sensitivity was raised by He et al. (2003). They discovered that mortgage REITs were sensitive to all proxies, whilst equity REITs were affected only by changes in yields of long-term US government bonds and high-yield corporate bonds.

Lastly, the literature domain, existing and previous literature, has mainly focused on the interest rate sensitivity of LRE before the Global Financial Crisis (GFC). However, no up-to-date evidence is available to gauge this issue with the coverage of both post-GFC and post-COVID contexts in respect to the significant impacts of both the GFC and pandemic on global LRE. This is despite that time-varying interest rate sensitivity results were frequently detected owing to systemic events (He et al., 2003). In particular, the speed of recent US fund rate hikes since Mar 2022 is the fastest in the last 35 years by increasing 500 bps in 14 months (Federal Reserve, 2023). Hence, it is essential to provide updated empirical evidence on the interest rate sensitivity of LRE across various markets in the post-GFC and post-COVID contexts, with the use of different interest rate proxies.

Lack of sector-level analysis

The sectoral effect has been acknowledged by a number of studies due to the fact that various real estate sectors feature distinct risk-return characteristics (Miles and McCue, 1982; Crosby et al., 2003; Hamelink and Hoesli, 2004; Yavas and Yildirim, 2011; Hoesli and Oikarinen, 2012; Geltner et al., 2014; Lin et al., 2019a; Newell and Marzuki, 2023). Recent hawkish monetary policy implemented by key global central banks has consistently heightened real estate cap yields, and therefore different types of global CRE markets significantly devalued in various magnitudes (MSCI, 2023). Over the year to Jun 2023, asset values of global office, retail, industrial, residential and lodging markets declined by 11.4%, 3.5%, 4.7%, 3.5% and 5.7%, respectively (MSCI, 2023). Hence, it is vital to scrutinize the interest rate sensitivity of LRE at a sector level.

Although numerous studies have issued the impact of interest rate changes on composite LRE, no comparable study has been devoted to this issue across various sectors and markets. The only exception is the empirical analysis conducted by Lin et al. (2021). The study analyzed the sensitivity of REIT sub-sectors across the USA, Japan, Australia and Singapore from 2006 to 2018. These REIT sub-sectors included diversified office, retail, industrial, residential and specialty sectors (the composite of self-storage, lodging, healthcare and data centers). The results showed that REIT sub-sectors across various four markets had different propensity to be impacted by interest rate movements. Nonetheless, the study has yet to assess global and regional LRE and the impacts of LTV on the interest rate sensitivity of LRE at a sector level, with the addition of alternative real estate sub-sectors, such as self-storage, lodging, healthcare and data centers. In the light of recent longer and higher tightening monetary policy assigned by key global central banks has significantly impacted global CRE markets in the post-COVID context regionally and globally, updated empirical evidence on the interest rate sensitivity of LRE sub-sectors at global and regional levels is crucial to be provided.

Portfolio construction of LRE sub-sector in various rate hike cycles

While time-varying studies on allocations of CRE (both public and private) in investment portfolios are abundant, there is limited research on allocations to LRE across interest rate cycles. Thus, one of the innovations of this research is its empirical analysis of allocations in LRE sub-sectors across various interest rate cycles. The most comparable study to date is by Mueller and Mueller (2023), wherein a 45-year study period to 2022 was divided into six economic cycles, with periods of peak and trough. The overall results showed that the composite NAREIT LRE index maintained an average allocation of 1% during the down cycle and a 0% allocation during the up cycle in mean-variance Sharpe ratio optimized portfolios. However, higher allocations to LRE were observed in the

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1000 Brussels, Belgium

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F +32 (0) 2739 1020

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E info@epra.com

return-optimized portfolios, recording 14% and 2% allocations in down and up cycles, respectively. The low allocation to LRE was caused by the lack of consideration for the sectoral effect (Hoesli and Oikarinen, 2012; Lin et al., 2019a), as well as the standard risk-aversion assumption used in the optimization model in the volatile investment context. Hence, the need for further research on LRE allocation accounting for the sectoral effect and using a robust portfolio optimization model that reflects a realistic investment approach by investors.

Overall, this study extends the literature in several ways. First, building on the work of Lin (2021) and Lin et al. (2021), this is the first paper to offer strategic insights into the varying interest rate sensitivity of LRE sub-sectors at global and regional levels, whereas previous studies primarily focused on composite LRE. This is despite the acknowledgement of the sectoral effect (Geltner et al., 2014) and specialization value (Lin et al., 2019a). Second, key global central banks' fund rates have been tightened from the historically low and stable interest rate level since the GFC and further rate hikes by key global central banks are expected to continue in 2023 and 2024. This paper provides the first rigorously empirical analysis of the interest rate of LRE sub-sectors in both post-GFC and post-COVID contexts. However, most of the real estate literature has focused on this issue before the GFC, with no comparable study focusing on this issue on systemic events between post-GFC and pre-COVID contexts. Third, this paper is the first to validate the interest rate sensitivity of LRE sub-sectors, with the use of alternative real estate sub-sectors, including self-storage, lodging, healthcare and data centers. Fourth, this is the first analysis to investigate the impacts of debt levels on the interest rate sensitivity of LRE at a sector level, given that levels of debt can be significantly affected by interest rates (French, 2019) and vary among different real estate sectors (Reddy and Wong, 2018). Lastly, the portfolio allocation weightings to LRE sub-sectors will be estimated for the first time by using mean-downside variance portfolio analysis in respect to highly turbulent investment contexts. The interest rate sensitivity and mean-downside variance portfolio analyses of LRE sub-sectors across the Developed Europe, USA, UK and globally will be assessed in the following sections.

Methodology

Statistical Analysis

QUANTITATIVE INTEREST RATE SENSITIVITY ANALYSIS

This research employed several rigorous methodologies. First, it utilized a Generalized Autoregressive Conditional Heteroskedasticity in Mean (GARCH-M) model to assess the interest rate sensitivity of LRE sub-sectors at global, regional and market levels. In light of that the interest rate is a significant variable in the portfolio and capital theories for both global practitioners and scholars, Merton (1980) suggested that the interpretation of the effects of changes in interest rates can offer a clear picture of shifts in the investment opportunity set. Although a GARCH-M model is not directly linked to the portfolio and capital theories, Engle et al. (1987) proposed a theoretical linkage between volatility and mean return. Neuberger (1994) also reported that the risk premia should be influenced by the impact of volatility clustering on returns. Given that the GARCH-M specification allows a time-varying risk premium and tolerates the effect of volatility clustering, it can be seen as consistent with asset pricing models such as the Capital Asset Pricing Model (CAPM) and Arbitrage Pricing Theory (APT), as noted by Cotter and Stevenson (2007), Stevenson et al. (2007), Lee et al. (2014) and Akimov et al., (2020). The GARCH-M model used in this research builds upon previous literature such as Devaney (2001), Liow and Huang (2006), Stevenson et al. (2007), Lee et al. (2014), Akimov et al. (2020) and Lin et al. (2021).

Previous studies (e.g. Devaney, 2001; Liow and Huang, 2006) have noted the advantages of the GARCH-M model, which enables simultaneous modelling of the level and volatility of the return series. However, the standard GARCH model assumes a constant variance of the error term. This assumption of homoskedasticity may pose significant issues when analyzing financial time series, as it does not account for volatility clustering in the data. On the opposite, the GARCH-M framework models the mean of total returns as a function of the conditional variance. It accommodates time-varying risk premia and considers the impact of volatility clustering. By doing this, it acknowledges the impact of an asset's volatility on the risk premia that investors seek. A basic GARCH-M model is displayed as follows:

$$ER_t = \gamma x_t + \delta h_t + \varepsilon_t \tag{1}$$

$$h_t = \alpha_0 + \sum \alpha_i \varepsilon_{t-i}^2 + \sum \beta_j h_{t-j}^2 \tag{2}$$

$$\varepsilon_t | I_{t-1} \sim N(0, H_t) \tag{3}$$

where Equation (1) models the conditional mean and Equation (2) models the conditional variance. The mean equation models total returns of LRE sub-sectors (ER_t) in relation to the vector of exogenous variables (x_t) and its own conditional variance (h_t). The variance equation models the conditional variance on both lagged square errors (ε^2) and a moving average of lagged conditional variances (h_t^2).

The GARCH-M specification framework used in this study differs from that of Elyasiani and Mansur (1988), Devaney (2001) and Liow and Huang (2006), in which the interest rate volatility was not directly incorporated into the variance equation. This study follows the approaches of Stevenson *et al.* (2007), Lee *et al.* (2014), Akimov *et al.* (2020) and Lin et al. (2021) by including interest rate volatility in the variance equation. Unlike Devaney (2001) and Stevenson *et al.* (2007), this study does not include financial dummy variables since the aim is to examine the differential interest rate sensitivity of all LRE sub-sectors. This specification is similar to Lee *et al.* (2014) and Akimov et al. (2020), who estimate the interest rate sensitivity of real estate securities across seven markets in Europe. The AIC and HQIC statistics also indicate that the standard GARCH-M (1,1) model is a better model than other lag models. The final specifications used are displayed as follows:

Model 1: 3-month Treasury Bill Rates

$$ER_{ij,t} = \theta_o + \theta_j . ER_{ij,t-1} + \rho_j . \Delta R_{j,t}^M + \mu_j . \Delta 3mIR_{j,t-1} + \delta_j . h_{j,t} + \varepsilon_{j,t} \tag{1a}$$

$$h_{j,t} = \alpha_0 + \alpha_j . \varepsilon_{j,t-1}^2 + \beta_j . h_{j,t-1} + v_{1j} . cvR_{j,t-1}^M + v_{2j} . cv3mIR_{j,t-1} \tag{2a}$$

$$\varepsilon_{j,t} | \Omega_{j,t-1} \sim N(0, h_{j,t}) \tag{3a}$$

Model 2: 10-year Government Bond Yields

$$ER_{ij,t} = \theta_o + \theta_j . ER_{ij,t-1} + \rho_j . \Delta R_{j,t}^M + \mu_j . \Delta 10yIR_{j,t-1} + \delta_j . h_{j,t} + \varepsilon_{j,t} \tag{1b}$$

$$h_{j,t} = \alpha_0 + \alpha_j . \varepsilon_{j,t-1}^2 + \beta_j . h_{j,t-1} + v_{1j} . cvR_{j,t-1}^M + v_{2j} . cv10yIR_{j,t-1} \tag{2b}$$

$$\varepsilon_{j,t} | \Omega_{j,t-1} \sim N(0, h_{j,t}) \tag{3b}$$

As noted by FRBSF (2022), 10y-2y spread is a leading indicator of 10y-3m spread, to predict and measure economic recession risk. Therefore, the 10y-2y spread is included in this research as the significant interest rate proxy. The 10y-2y spread has yet to be employed in the analyses of Stevenson et al. (2007), Lee et al. (2014), Akimov et al. (2020) and Lin et al. (2021) in response to the acknowledge of the significance of the interest rate proxy used on the interest rate sensitivity analysis, as denoted by He et al. (2003).

Model 3: 10y-2y Spread

$$ER_{ij,t} = \theta_o + \theta_j . ER_{ij,t-1} + \rho_j . \Delta R_{j,t}^M + \mu_j . \Delta spreadIR_{j,t-1} + \delta_j . h_{j,t} + \varepsilon_{j,t} \tag{1c}$$

$$h_{j,t} = \alpha_0 + \alpha_j . \varepsilon_{j,t-1}^2 + \beta_j . h_{j,t-1} + v_{1j} . cvR_{j,t-1}^M + v_{2j} . cvspreadIR_{j,t-1} \tag{2c}$$

$$\varepsilon_{j,t} | \Omega_{j,t-1} \sim N(0, h_{j,t}) \tag{3c}$$

In the mean equations (1a, 1b and 1c), ER_i represents total returns of the *i* th LRE sub-sector in the *j* th market (*I* = 1, 2, 3, 4, 5, 6; diversified, office, retail, industrial, industrial/office, self-storage, residential, lodging and healthcare sectors, respectively; *j* = 1, 2, 3, 4; Developed Europe, the USA, Eurozone, the United Kingdom and Developed Global, respectively). R_j^M is total returns of the respective market equity index. $3mIR_j$, $10yIR_j$ and $spreadIR_j$ are the 3mth T-bill rates and 10y GBY and 10y-2y spread proxies, respectively. $h_{j,t}$ is a conditional covariance matrix of the respective market. In the variance equations (5a and 5b), $cvR_{j,t}^M$ is the conditional variance of the respective market equity index. $cv3mIR_{i,t}$, $cv10yIR_{j,t}$ and $cvspreadIR_{j,t}$ are the conditional variances of the 3mth T-bill rates, 10y GBY and 10y-2y spread proxies, respectively. Importantly, US interest rate proxies were utilized in the Developed Global analysis.

DOWNSIDE RISK PORTFOLIO ALLOCATION ANALYSIS

Lastly, to assess portfolio allocation weightings to each LRE sub-sector during various interest rate cycles, downside risk portfolio analysis was used in this research project. Downside risk captures downside deviation rather than standard deviation which comprises both downside and upside volatilities and is therefore a superior risk measure in most investment situations, particularly the volatile investment contexts: rate hike cycles, as acknowledged by numerous studies (Sortino and Van Der Meer, 1991; Lin et al., 2019a). The annualized average returns, downside risks and Sortino ratios (risk-adjusted performance) for both LRE sub-sectors and other asset

European Public
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Square de Meeus, 23
1000 Brussels, Belgium

T +32 (0) 2739 1010
F +32 (0) 2739 1020

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E info@epra.com

classes were calculated individually for each LRE market across the interest rate cycle sub-periods. The analysis was then expanded to assess the role of LRE in an investment portfolio management context. This involved constructing mixed-asset portfolios, using mean-downside variance portfolio technique derived from the index-level monthly returns over various timeframes. The purpose of this analysis was to examine the added value role of LRE in a multi-asset portfolio composed of mainstream asset classes in different interest rate movement cycles. Importantly, the downside risk optimization methodology follows established research to assess portfolio allocations to LRE in mixed-asset portfolios (e.g. Sing and Ong, 2000; Tien and Sze, 2003; Finzkenzeller et al., 2010). The average allocation to LRE across the portfolio risk-return spectrum was calculated and presented in asset allocation diagrams. It is noteworthy that the post-COVID-19 pandemic optimal portfolio scenario was not considered as the timeframe is currently too short to effectively assess the dynamics of this investment context due to the limited number of monthly total returns. Hence, the stability of the portfolio construction parameters and the accuracy of their results based on the post-pandemic sub-period data could not be guaranteed.

Description of Data

Monthly indices (in local currency) were obtained and assessed LRE sub-sectors, as well as stocks, from Dec 2000 to Dec 2022. Proxies for interest rate maturities included the fund rates, 3mth T-bill rates, 2Y, 10y GBY and 10y-2y spread. The Financial Times Stock Exchange-European Public Real Estate Association-National Association of Real Estate Investment Trusts (FTSE-EPRA-NAREIT) assesses the total return performance of LRE sub-sectors. The stock market index was retrieved from either the MSCI or FTSE database. Since this research does not have the luxury of a comparable historical data series for LRE sub-sectors due to the limited number of companies and market capitalization, the timeframe of the index is only available from Jan 2006. Nevertheless, the timeframe from 2006 to 2022 was sufficient to achieve the objectives of this research and allows for a consistent empirical assessment of LRE sub-sectors across various markets. It is also noteworthy that, due to the same limitation, there was inconsistent coverage of LRE sub-sectors across markets. For example, the healthcare, self-storage, and lodging sub-sectors were not available in the Eurozone market, while the lodging sub-sector was only available in the USA and globally.

Appendix 1 reports descriptive statistics for total returns of LRE sub-sectors across the four markets from Jan 2006 to Dec 2022. As in other LRE literature, all LRE sub-sector distributions display skewness and leptokurtosis. In other words, distributions of total returns for all LRE sub-sectors have thicker tails than a normal distribution. The Jarque-Bera statistics rejected a normal distribution for all LRE sub-sectors across these five markets. All series were examined by the Augmented Dickey-Fuller (ADF) test. The ADF test results show that all variables disproved the null hypothesis with a 1% significance level when the time series for all variables were stated in the first differences. In general, all series are appropriate for further analysis of time-varying return and volatility transmissions. The volatility clustering characteristics of LRE sub-sector total return series were also confirmed by the LM tests, supporting the use of GARCH-related frameworks.

Empirical Results I: Interest Rate Effects

Baseline GARCH-M Model

This research aims to assess the magnitude and direction of the sensitivity to interest rate level and volatility of each LRE sub-sector across the Developed Europe, Eurozone, USA, UK and Globe from Jan 2006 to Dec 2022. The impact of interest rate level and volatility on LRE sub-sector total returns can be estimated by the parameter (μ_j) and (v_{2j}), respectively. The results of the interest rate effect (μ_j) and (v_{2j}) for 3mth T-bill rates (Tables 1, 4, 7 and Appendix 2 - Panel 1), 10y GBY (Tables 2, 5, 8 and Appendix 2 - Panel 2) and 10y-2y spread series (Tables 3, 6, 9 and Appendix 3) are depicted, respectively.

MODEL 1: 3-MONTH TREASURY BILL RATES

The interest rate effect is different in sign and magnitude among LRE across sectors and markets. In terms of the sensitivity to 3mth T-bill rates changes, μ_j is significantly negative for diversified, self-storage and residential in the Developed Europe, Eurozone (excluding self-storage) and UK. Meanwhile, μ_j is significantly negative for office and healthcare in the UK, as well as industrial in Developed Europe. However, LRE sub-sectors were immune to 3mth T-bill rates swings in the USA.

The impact of 3mth T-bill rates volatility on LRE sub-sector total returns can be estimated by the parameter v_{2j}. v_{2j} is significantly negative for retail and self-storage in the Developed Europe, Eurozone (excluding self-storage),

USA and UK. Besides, v_{2j} is significantly negative for industrial and residential in the Developed Europe and Eurozone, as well as diversified in the USA, office in the UK and healthcare in Developed Europe.

MODEL 2: 10-YEAR GOVERNMENT BOND YIELDS

In terms of sensitivity to 10y GBY changes, μ_j is significantly negative for industrial and self-storage in the Developed Europe, Eurozone (excluding self-storage) and UK, as well as office in the UK, and residential in the Developed Europe and Eurozone. At the same time, μ_j is significantly negative for diversified and retail in the USA. However, μ_j is significantly positive for healthcare in the USA.

In terms of the impact of 10y GBY volatility measured by the parameter v_{2j}. v_{2j} is significantly negative for self-storage in the Developed Europe and USA, as well as residential in the USA and UK. Also, v_{2j} is significantly negative for industrial in the USA, as well as retail in Developed Europe and Eurozone. The significantly positive sign of v_{2j} was found in office in the UK.

MODEL 3: 10Y-2Y SPREAD

In terms of the sensitivity to changes in 10y-2y spread, μ_j is significantly positive for office across the Developed Europe, Eurozone, USA and UK. Simultaneously, μ_j is significantly positive for diversified and residential in the Developed Europe, Eurozone and UK, as well as self-storage and industrial in the USA and retail in the Developed Europe. The results indicate that total returns of these sectors across the four markets responded negatively to rising possibilities of economic recession risk when 10y-2y spread inversion occurred.

In terms of the impact of 10y GBY volatility approached by the parameter v_{2j}. v_{2j} is significantly negative for diversified across the Developed Europe, Eurozone, USA and UK. Besides, v_{2j} is significantly negative for retail in the Eurozone, USA and UK, as well as industrial and self-storage in the UK and residential in the Eurozone and USA. However, v_{2j} is significantly positive for healthcare and industrial/office in the USA.

The overall picture from these findings is that self-storage and residential were the most sensitive sectors to the level and volatility of both 3mth T-bill rates and 10y GBY fluctuations across four markets. In addition, diversified and retail were susceptible to 3mth T-bill rates across four markets. Meanwhile, industrial was vulnerable to 10y GBY movements. Unexpectedly, office in the UK was sensitive to both 3mth T-bill rates and 10y GBY changes. Particularly, office across four markets were susceptible to turbulence in 10y-2yr spread, as well as diversified and residential across these four markets.

On the opposite, industrial/office, lodging and healthcare in the USA were generally immune to fluctuations in the level and volatility of short- and long-term interest rates and 10y-2y spread. Particularly, healthcare in the USA was significantly positive with long-term interest rate fluctuations. However, healthcare in the UK was sensitive to 3mth T-bill rates changes and healthcare in Developed Europe was susceptible to 10y GBY movements. The lack of significance or positive significance of the interest rate level and volatility effects on LRE sub-sectors may imply that the sectors were characterized by stronger interest rate risk aversion and greater interest rate hedging benefits than the other sub-sectors over the sample period, particularly for industrial/office, lodging and healthcare in the USA. This is despite that time series of industrial/office and lodging were only available in the USA and healthcare was only available in the USA and UK.

SUMMARY

In sum, the results of the research are broadly consistent with Lin (2021) and Lin et al. (2021), where diversified, retail and residential were more sensitive to interest rate changes than the other LRE sub-sectors across the USA, Japan, Australia and Singapore. Specifically, retail was susceptible to 3mth T-bill rates, while industrial and residential were vulnerable to 10y GBY. These might be explained by the prevalent lease structures of percentage rent in retail (Crosby et al., 2003) and industrial leased on a long-term based (Miles and McCue, 1982). However, the following results of the research are distinctions from the previous studies (e.g. Lin, 2021; Lin et al., 2021), particularly in assessing the impacts of 10y-2y spread on LRE sub-sectors as the 10y-2y spread has been seen as a leading indicator of recession risk predictions as noted by FRBSF (2022).

First, office was significantly and positively sensitive to 10y-2y spread across these four markets. This implies that office total returns responded negatively to rising possibilities of economic recession risk. Besides, office in the UK was vulnerable to both 3mth T-bill rates and 10y GBY. The differences from the results of Lin et al. (2021) may be attributed to that the analysis timeframe between Jul 2006 and Dec 2018 employed by Lin et al. (2021) is variant from this research by including the timeframes of COVID and post-COVID contexts. In addition, as denoted by Hoesli and Malle (2022), the prices of office across European markets were significantly affected by the pandemic due to structural and cyclical changes, such as hybrid working strategies during and post-COVID environment and rapid global rate hike cycle since Mar 2022. In the office space market, hybrid working strategies have significantly heightened office vacancy rate since the onset of the pandemic. As of Jun 2023, office vacancy rate was recorded at 20% in North Americas, 8% in Europe, 15% in the Asia Pacific and 16% in the Globe (JLL, 2023). In the capital markets, the Federal Reserve hiked fund rates at a historically fast pace by 500 bps in the last 14 months as of Jun 2023 (FRED, 2023). As of Jun 2023, the 10y-2y spread reached -1.06%, the four-decade lowest level after Aug 1981 (FRED, 2023). Asset values of office markets as of the year to Jun 2023 therefore dipped by 9.4% in Europe, 17.6% in the USA, 12.9% in the UK and 11.4% in the Globe (MSCI, 2023).

Second, diversified was significantly and positively sensitive to 10y-2y spread changes across the Developed Europe, Eurozone and UK. These indicate that diversified total returns were affected negatively by rising possibilities of economic recession risk. Particularly, diversified was susceptible to the volatility of 10y-2y spread movements across four markets. The results of diversified across the Developed Europe, Eurozone and UK are consistent with Lin et al. (2021) by assessing the sector across the USA, Japan, Australia and Singapore with the use of 10y-3m spread. This may be attributed to a diversified REIT portfolio comprising multiple real estate sectors. As noted by Danielsen and Harrison (2007), a REIT diversified by real estate type can increase borrowing costs and decrease the capitalization value of REITs. The findings support the existence of REIT specialization value across Developed Europe, the Eurozone, USA and UK from the interest rate sensitivity perspective.

Third, residential was significantly and positively vulnerable to 10y-2y spread changes across the Developed Europe, Eurozone and UK and was sensitive to the volatility of 10y-2y spread swings in the Eurozone, USA and UK. These provide empirical evidence that residential total returns responded negatively to rising possibilities of economic recession risk. The result is in line with the findings of McDonald and Stokes (2013), in which housing prices were negatively related to the monetary policy of the Federal Reserve.

Fourth, retail was also susceptible to the volatility of 10y-2y spread fluctuations in the Eurozone, USA and UK. The results of retail and residential align with Lin et al. (2021), where retail was sensitive to 3mth T-bill rates, and residential was sensitive to both 3mth T-bill rates and 10y GBY. These may be attributed to the prevalent short-term lease structures of residential properties and percentage rent in retail properties, as noted by Miles and McCue (1982) and Crosby et al. (2003).

Lastly, alternative real estate sub-sectors were examined in this research for the first time, including industrial/office and lodging in the USA, as well as self-storage and healthcare in the Developed Europe, USA and UK. Self-storage was one of the most sensitive to changes in both 3mth T-bill rates and 10y GBY but was only susceptible to 10y-2y spread movements in the USA. Healthcare behaved divergently across three markets. In the USA, healthcare featured empirically strong interest rate risk aversion and hedging benefits to both 10y GBY and 10-2y spread. However, healthcare was vulnerable to 3mth T-bill rates in the Developed Europe and UK, as well as 10y GBY in Developed Europe. Meanwhile, industrial/office was equipped with empirically strong interest rate risk aversion and hedging benefits to 10y-2y spread swings in the USA, while lodging was empirically immune to all interest rate proxies in the USA.

**European Public
Real Estate Association**

Square de Meeus, 23
1000 Brussels, Belgium

T +32 (0) 2739 1010
F +32 (0) 2739 1020

W www.epra.com
E info@epra.com

Table 1. Developed Europe GARCH-M 3mth T-bill rates results: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial
Developed Europe	*Mean equation*				
	Const	0.027(3.524)***	-0.030(-1.571)	-0.004(-0.648)	0.021(3.518)***
	GARCH term	-8.558(-1.821)*	-0.006(-2.227)**	3.834(4.980)***	2.833(1.876)*
	Market	0.690(14.838)***	0.631(18.320)***	0.748(13.693)***	0.618(12.590)***
	IR(μ_j)	-0.208(-1.926)*	-0.147(-1.057)	-0.128(-0.643)	-0.531(-3.200)***
	Variance equation				
	Const	0.000(0.495)	0.000(6.397)***	0.001(0.453)	0.000(0.428)
	Arch	0.003(2.280)**	0.061(5.765)***	0.234(5.576)***	0.246(3.027)***
	GARCH	0.953(2.304)**	0.919(14.359)***	0.749(2.567)**	0.697(1.945)*
	Market Vol	-3.305(-3.120)***	-2.087(-1.977)**	-1.676(-0.853)	-6.279(-3.380)***
	IR Vol(v_{2j})	-113.385(-0.282)	298.989(0.977)	-492.446(-1.764)*	-1,272.236(-3.069)***
		Self-Storage	**Residential**	**Healthcare**	
	Mean equation				
	Const	0.022(2.142)**	0.006(0.731)	0.007(1.050)	
	GARCH term	0.175(0.062)	-0.593(-0.235)	-1.473(-0.498)	
	Market	0.604(8.426)***	0.543(8.875)***	0.228(3.444)***	
	IR(μ_j)	-0.741(-2.476)**	-0.793(-3.496)***	0.034(0.085)	
	Variance equation				
	Const	0.001(1.439)	0.000(2.988)***	0.000(1.668)*	
	Arch	0.367(2.177)**	0.346(3.164)***	0.055(1.757)*	
	GARCH	0.624(3.430)***	0.641(6.372)***	0.931(4.262)***	
	Market Vol	-2.939(-1.664)*	1.867(0.775)	0.996(0.539)	
	IR Vol(v_{2j})	-394.318(-0.848)	-673.149(-0.425)	-1,180.320(-1.850)*	

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

Sources: Authors' compilation/analysis

European Public
Real Estate Association

Square de Meeus, 23
1000 Brussels, Belgium

T +32 (0) 2739 1010
F +32 (0) 2739 1020

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E info@epra.com

Table 2. Developed Europe GARCH-M 10y GBY results: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial
	Mean equation				
	Const	0.017(1.196)	-0.028(-1.377)	-0.022(-1.360)	0.025(0.515)
	GARCH term	-8.190(-1.804)*	-0.006(-2.310)**	4.817(4.721)***	0.644(0.151)
	Market	0.694(16.020)***	0.630(19.243)***	0.726(11.093)***	0.799(6.648)***
	IR(μ_j)	-0.074(-0.417)	-0.071(-0.363)	-0.011(-0.045)	-1.865(-1.921)*
	Variance equation				
	Const	0.000(15.137)***	0.000(6.208)***	0.001(2.549)**	0.000(0.633)
	Arch	0.002(2.296)**	0.058(5.510)***	0.365(3.103)***	0.268(2.142)**
	GARCH	0.948(5.189)***	0.934(10.174)***	0.562(2.081)**	0.697(2.099)**
	Market Vol	-3.796(-3.669)***	-1.500(-1.741)	-4.689(-2.460)**	-4.006(-0.551)
	IR Vol(v_{2j})	2,640.211(0.850)	-446.743(-0.124)	-5,691.871(-1.825)*	1,185.589(0.066)
Developed Europe		**Self-Storage**	**Residential**	**Healthcare**	
	Mean equation				
	Const	0.001(0.065)	0.002(0.116)	0.036(2.120)**	
	GARCH term	0.849(0.338)	-0.936(-0.556)	-4.065(-1.546)	
	Market	0.618(9.699)***	0.538(8.923)***	0.226(3.298)***	
	IR(μ_j)	-0.713(-2.262)**	-0.300(-2.047)**	0.551(1.302)	
	Variance equation				
	Const	0.000(1.583)	0.000(0.194)***	0.000(1.734)*	
	Arch	0.230(2.412)**	0.179(2.773)***	0.071(1.846)*	
	GARCH	0.753(3.621)***	0.779(3.689)***	0.914(3.048)***	
	Market Vol	-4.621(-2.907)*	1.920(0.737)	0.937(0.472)	
	IR Vol(v_{2j})	-7,927.291(-1.693)*	2,086.031(0.468)	-8,412.521(-1.670)*	

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

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Square de Meeus, 23
1000 Brussels, Belgium

T +32 (0) 2739 1010
F +32 (0) 2739 1020

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Table 3. Developed Europe GARCH-M 10Y-2Y Spread results: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial
Developed Europe	*Mean equation*				
	Const	$0.018(2.430)^{**}$	$-0.529(-3.002)^{***}$	$-0.005(-0.658)$	$0.013(1.753)^{*}$
	GARCH term	$-7.041(-1.539)$	$-0.079(-2.944)^{***}$	$4.963(5.155)^{***}$	$0.032(0.032)$
	Market	$0.704(15.090)^{***}$	$0.649(18.317)^{***}$	$0.758(12.799)^{***}$	$0.711(16.616)^{***}$
	IR(μ_j)	$0.387(1.818)^{*}$	$0.649(2.098)^{**}$	$0.324(1.691)^{*}$	$0.114(0.343)$
	Variance equation				
	Const	$0.000(14.281)^{***}$	$0.000(2.818)^{***}$	$0.000(3.626)^{***}$	$0.000(0.462)$
	Arch	$0.003(2.038)^{**}$	$0.017(2.214)^{**}$	$0.257(4.272)^{***}$	$0.401(1.713)^{*}$
	GARCH	$0.967(6.316)^{***}$	$0.964(4.336)^{***}$	$0.724(5.969)^{***}$	$0.569(2.258)^{**}$
	Market Vol	$-4.184(-3.762)^{***}$	$-1.978(-1.404)$	$-4.686(-2.073)^{**}$	$-4.133(-2.393)^{**}$
	IR Vol(v_{2j})	$-7.781(-2.154)^{*}$	$18.194(1.317)$	$16.216(1.024)$	$10.127(1.202)$
		Self-Storage	**Residential**	**Healthcare**	
	Mean equation				
	Const	$0.018(1.325)$	$-0.006(-0.717)$	$0.006(0.768)$	
	GARCH term	$-0.905(-0.387)$	$-0.406(-0.263)$	$-1.967(-1.059)$	
	Market	$0.633(8.046)^{***}$	$0.547(8.277)^{***}$	$0.241(3.679)^{***}$	
	IR(μ_j)	$0.366(0.652)$	$0.632(1.802)^{*}$	$0.172(0.411)$	
	Variance equation				
	Const	$0.000(1.397)$	$0.000(1.663)^{*}$	$0.000(1.787)^{*}$	
	Arch	$0.169(1.911)^{*}$	$0.263(3.053)^{***}$	$0.069(1.891)^{*}$	
	GARCH	$0.767(2.044)^{**}$	$0.665(3.650)^{***}$	$0.914(2.952)^{***}$	
	Market Vol	$-4.083(-2.319)^{**}$	$0.385(0.183)$	$0.197(0.096)$	
	IR Vol(v_{2j})	$9.577(0.450)$	$22.582(1.030)$	$10.004(0.896)$	

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

Sources: Authors' compilation/analysis

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1000 Brussels, Belgium

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Table 4. US GARCH-M 3mth T-bill rates results: Jan 2006 - Dec 2022

	Diversified	Office	Retail	Industrial	Industrial/Office
Mean equation					
Const	-0.001(-0.243)	-0.005(-0.801)	0.004(0.698)	-0.005(-0.937)	-0.001(-0.770)
GARCH term	2.020(0.866)	7.120(2.416)**	0.980(0.676)	-0.242(-0.377)	0.787(0.288)
Market	1.051(16.970)***	1.036(19.788)***	1.078(19.297)***	1.247(19.019)***	1.127(16.417)***
IR(μ_j)	0.117(0.539)	-0.214(-0.943)	-0.007(-0.029)	0.121(0.604)	-0.065(-0.242)
Variance equation					
Const	0.000(1.545)	0.000(1.729)*	0.001(1.991)**	0.001(3.272)***	0.000(1.291)
Arch	0.115(2.285)**	0.089(2.018)**	0.206(3.253)***	0.602(5.525)***	0.072(2.134)**
GARCH	0.839(4.805)***	0.840(3.223)***	0.700(1.881)*	0.367(5.298)***	0.864(1.791)*
Market Vol	-1.469(-0.791)	-4.805(-2.905)***	-1.567(-0.581)	3.383(1.182)	2.279(0.980)
IR Vol(v_{2j})	-473.781(-1.658)*	-196.497(-0.555)	-122.255(-2.287)**	-44.707(-0.286)	-334.000(-0.774)
USA	**Self-Storage**	**Residential**	**Lodging**	**Healthcare**	
Mean equation					
Const	-0.018(-0.783)	-0.015(-0.892)	-0.021(-3.413)***	-0.002(-0.117)	
GARCH term	-0.238(-0.766)	12.714(1.444)	2.306(1.307)	1.319(0.271)	
Market	0.584(11.900)***	0.858(12.719)***	1.454(18.245)***	0.840(10.993)***	
IR(μ_j)	-0.208(-0.806)	-0.019(-0.085)	0.105(0.437)	0.169(0.651)	
Variance equation					
Const	0.002(0.973)	0.000(1.975)**	0.000(2.650)***	0.001(1.221)	
Arch	0.256(1.841)*	0.005(1.712)*	0.269(3.837)***	0.143(2.193)**	
GARCH	0.670(1.708)*	0.989(25.598)***	0.688(9.084)***	0.785(4.052)***	
Market Vol	-1.256(-2.676)***	-4.447(-2.006)**	5.108(2.570)***	-0.675(-0.282)	
IR Vol(v_{2j})	-623.082(-2.454)**	-202.741(-0.526)	-271.264(-0.924)	104.039(0.284)	

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

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Table 5. US GARCH-M 10y GBY results: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial	Industrial/Office
	Mean equation					
	Const	-0.005(-0.391)	-0.001(-0.049)	0.003(0.269)	0.016(1.075)	-0.007(-0.388)
	GARCH term	1.859(0.755)	6.875(1.754)*	0.350(0.184)	-0.279(-0.338)	-0.058(-0.021)
	Market	1.089(17.723)***	1.066(18.858)***	1.115(19.969)***	1.227(19.198)***	1.144(16.874)***
	IR(μ_j)	-0.398(-1.733)*	0.329(1.190)	-0.217(-1.652)*	-0.107(-0.374)	0.203(0.593)
	Variance equation					
	Const	0.000(1.584)	0.000(1.783)*	0.001(1.866)*	0.001(2.146)**	0.000(1.202)
	Arch	0.116(2.098)**	0.077(2.055)**	0.360(3.015)***	0.460(3.355)***	0.053(2.215)**
	GARCH	0.841(4.445)***	0.845(3.490)***	0.572(1.812)*	0.526(2.803)***	0.891(2.260)**
	Market Vol	-2.493(-1.886)**	-4.421(-3.200)***	-0.747(-0.252)	4.044(1.287)	2.935(1.189)
	IR Vol(v_{2j})	-1,074.386(-0.390)	-3,359.858(-1.383)	-1,276.161(-0.438)	-4,377.521(-1.943)*	-1,346.524(-0.401)
USA		Self-Storage	Residential	Lodging	Healthcare	
	Mean equation					
	Const	-0.433(-0.915)	0.002(0.101)	-0.032(-2.858)***	-0.002(-0.120)	
	GARCH term	-0.079(-0.987)	12.420(1.452)	2.152(1.131)	-0.435(-0.144)	
	Market	0.627(7.678)***	0.865(12.644)***	1.472(18.697)***	0.819(11.182)***	
	IR(μ_j)	0.315(0.796)	0.181(0.589)	0.335(1.057)	0.549(1.752)*	
	Variance equation					
	Const	0.001(0.215)	0.000(0.118)	0.000(2.271)**	0.000(1.941)*	
	Arch	0.082(1.914)*	0.007(2.118)**	0.264(3.551)***	0.000(2.321)**	
	GARCH	0.871(2.287)**	0.985(2.132)**	0.699(8.770)***	0.986(16.018)***	
	Market Vol	-1.666(-1.791)*	-2.628(-1.161)	3.980(1.759)*	1.317(0.721)	
	IR Vol(v_{2j})	-8,361.938(-3.884)***	-5,569.563(-2.629)***	988.413(0.406)	-2,231.484(-0.603)	

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

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Table 6. US GARCH-M 10Y-2Y Spread results: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial	Industrial/Office
	Mean equation					
	Const	-0.005(-0.689)	-0.015(-2.109)**	-0.007(-0.841)	-0.002(-0.268)	-0.011(-1.289)
	GARCH term	1.729(0.709)	6.558(2.205)**	-1.694(-0.786)	0.006(0.009)	-1.380(-0.482)
	Market	1.111(16.157)***	1.063(17.805)***	1.192(20.496)***	1.256(18.820)***	1.189(17.289)***
	IR(μ_j)	-0.001(-0.003)	0.624(1.695)*	0.193(0.463)	0.165(1.655)*	-0.271(-0.572)
	Variance equation					
	Const	0.000(1.479)	0.000(1.958)*	0.000(2.300)**	0.001(2.143)**	0.001(2.365)**
	Arch	0.116(1.947)*	0.106(2.196)**	0.175(2.060)**	0.135(4.584)***	0.289(2.479)**
	GARCH	0.834(3.725)***	0.804(3.493)***	0.758(1.724)*	0.779(1.662)*	0.684(1.699)*
	Market Vol	-4.883(-2.658)***	-5.704(-4.212)***	-4.544(-1.606)	4.192(1.331)	2.176(0.849)
	IR Vol(v_{2j})	-2,799.082(-1.721)*	621.398(0.372)	-5,241.942(-2.898)***	-484.520(-0.446)	3,484.227(2.252)**
USA		**Self-Storage**	**Residential**	**Lodging**	**Healthcare**	
	Mean equation					
	Const	-4.524(-0.180)	-0.013(-0.911)	-0.022(-3.206)***	0.002(0.208)	
	GARCH term	-0.783(-0.180)	10.489(1.201)	2.099(1.089)	-1.669(-0.575)	
	Market	0.641(7.253)***	0.837(12.751)***	1.491(17.242)***	0.825(10.813)***	
	IR(μ_j)	0.916(1.716)*	0.409(0.886)	-0.051(-0.099)	-0.141(-0.336)	
	Variance equation					
	Const	0.000(0.656)	0.000(0.930)	0.000(2.385)**	0.000(1.925)*	
	Arch	0.000(1.775)*	0.014(1.962)**	0.260(3.275)***	0.000(2.072)**	
	GARCH	0.916(7.086)**	0.974(7.138)**	0.696(8.315)***	0.987(12.247)***	
	Market Vol	-2.201(-1.016)	-4.148(-1.498)	2.901(1.235)	-1.287(-0.636)	
	IR Vol(v_{2j})	-620.904(-0.278)	-914.163(-2.473)**	1,739.057(1.093)	2,876.001(1.692)*	

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

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Table 7. UK GARCH-M 3mth T-bill rates results: Jan 2006 - Dec 2022

	Diversified	**Office**	**Retail**	**Industrial**
Mean equation				
Const	0.009(1.423)	0.015(1.913)*	0.001(0.102)	0.039(0.462)
GARCH term	-1.655(-0.506)	-1.028(-0.368)	-0.837(-0.599)	0.005(0.362)
Market	0.946(14.406)***	0.908(10.736)***	1.122(11.622)***	0.597(4.071)***
IR(μ_j)	-0.518(-2.798)***	-0.731(-2.842)***	0.187(0.759)	-2.350(-1.446)
Variance equation				
Const	0.000(1.397)	0.000(1.729)*	0.000(0.990)	0.001(1.171)
Arch	0.139(2.283)**	0.229(1.852)*	0.083(1.774)*	0.328(2.153)**
GARCH	0.843(4.921)***	0.699(4.440)***	0.917(11.517)***	0.636(1.827)*
Market Vol	4.282(1.656)*	5.598(1.658)*	-1.203(-0.549)	60.497(0.052)
IR Vol(v_{2j})	-272.180(-0.941)	-586.207(-1.817)*	-662.061(-1.954)*	592.763(0.408)
UK	**Self-Storage**	**Residential**	**Healthcare**	
Mean equation				
Const	0.017(2.341)**	0.005(0.965)	0.010(2.029)**	
GARCH term	0.050(0.027)	0.415(0.421)	0.255(0.078)	
Market	0.745(6.850)***	0.970(11.690)***	0.253(4.398)***	
IR(μ_j)	-0.779(-2.690)***	-0.499(-1.686)*	-0.603(-1.648)*	
Variance equation				
Const	0.000(0.752)	0.000(0.976)	0.000(1.641)*	
Arch	0.386(1.854)*	0.154(2.891)***	0.117(2.147)**	
GARCH	0.569(1.278)	0.845(18.302)***	0.861(16.525)***	
Market Vol	10.820(5.331)***	6.501(2.626)***	6.025(1.766)*	
IR Vol(v_{2j})	-723.300(-4.685)***	-321.105(-0.764)	-400.652(-1.254)	

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

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Table 8. UK GARCH-M 10y GBY results: Jan 2006 - Dec 2022

	Diversified	Office	Retail	Industrial
Mean equation				
Const	-0.105(-2.418)**	-0.585(0.147)	-0.001(-0.035)	0.030(1.321)
GARCH term	-0.016(-2.802)***	0.885(0.148)	-1.266(-0.989)	0.230(0.201)
Market	0.924(14.241)***	0.925(11.160)***	1.128(11.644)***	0.804(12.175)***
IR(μ_j)	-0.183(-0.671)	-0.688(-2.097)**	0.354(1.052)	-0.718(-2.882)***
Variance equation				
Const	0.000(1.256)	0.001(1.442)	0.000(0.650)	0.000(1.924)**
Arch	0.339(2.801)***	0.203(2.151)**	0.066(2.761)***	0.241(3.050)***
GARCH	0.646(7.105)***	0.748(4.112)***	0.928(2.078)**	0.742(11.015)***
Market Vol	1.800(0.839)	2.085(0.684)	-1.722(-0.838)	1.330(0.782)
IR Vol(v_{2j})	1,749.616(0.593)	6,278.810(2.596)***	-939.434(-0.159)	-1,468.069(-0.321)

UK	Self-Storage	Residential	Healthcare
Mean equation			
Const	0.025(1.330)	0.023(1.782)*	0.006(0.548)
GARCH term	-0.111(-0.054)	1.492(2.417)**	-1.714(-0.574)
Market	0.730(6.819)***	1.028(11.517)***	0.257(4.477)***
IR(μ_j)	-1.120(-3.476)***	-0.351(-1.182)	-0.253(-0.681)
Variance equation			
Const	0.000(1.577)	0.000(0.781)	0.000(1.488)
Arch	0.234(2.716)***	0.064(6.674)***	0.118(1.750)*
GARCH	0.707(7.002)**	0.936(3.275)**	0.864(13.999)***
Market Vol	10.513(5.494)***	5.202(2.421)**	4.222(1.465)
IR Vol(v_{2j})	1,002.109(0.278)	-3,623.826(-1.690)*	1,458.924(0.647)

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

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Table 9. UK GARCH-M 10Y-2Y Spread results: Jan 2006 - Dec 2022

	Diversified	**Office**	**Retail**	**Industrial**
Mean equation				
Const	-0.067(-1.486)	-0.022(-0.448)	0.007(0.761)	0.019(2.901)***
GARCH term	-0.010(-1.423)	-0.004(-0.454)	-0.275(-0.201)	-0.028(-0.025)
Market	0.946(14.639)***	0.965(10.181)***	1.071(11.053)***	0.866(11.061)***
IR(μ_j)	0.692(1.735)*	0.838(1.684)*	0.198(0.350)	-0.293(-0.605)
Variance equation				
Const	0.000(1.124)	0.000(1.874)*	0.000(0.667)	0.000(1.945)*
Arch	0.278(1.890)*	0.281(1.954)*	0.201(2.210)**	0.296(2.595)***
GARCH	0.673(5.313)***	0.671(2.758)***	0.744(9.206)*	0.690(2.414)**
Market Vol	2.685(1.361)	2.001(0.899)	0.385(0.147)	-1.965(-1.645)*
IR Vol(v_{2j})	-1,433.000(2.262)**	-1,583.331(-0.982)	-2,978.502(-1.660)*	-1,907.664(-1.864)**

UK	**Self-Storage**	**Residential**	**Healthcare**
Mean equation			
Const	0.018(2.315)**	-0.006(-0.893)	0.005(0.755)
GARCH term	0.036(0.019)	0.436(0.433)	-1.771(-0.759)
Market	0.743(6.571)***	0.962(9.609)***	0.254(4.162)***
IR(μ_j)	0.459(0.832)	0.954(1.685)*	0.206(0.406)
Variance equation			
Const	0.000(1.395)	0.000(0.840)	0.000(1.606)
Arch	0.465(1.794)*	0.070(3.341)***	0.124(2.403)**
GARCH	0.520(2.970)**	0.922(10.499)***	0.852(16.211)***
Market Vol	6.921(4.860)***	5.544(2.775)***	3.194(1.120)
IR Vol(v_{2j})	-4,729.034(-5.050)***	454.928(0.212)	542.065(0.448)

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

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1000 Brussels, Belgium

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Impacts of US Monetary Policy

International real estate investors typically implement a mandate to construct global CRE/LRE portfolios from a practical point of view (LaSalle, 2023). Global finance and the correspondent rates in other economies were empirically influenced by the spillovers of US monetary policy actions, particularly in the circumstance of tightening fund rates at an unprecedentedly rapid pace (Caldara et al., 2022). Therefore, the impacts of US monetary policy on global LRE sub-sectors were gauged by using various US interest rate proxies. The results are exhibited in Appendices 4, 5 and 6, respectively.

Global office and residential were the most sensitive to changes in the level and volatility of both 3mth T-bill rates and 10y GBY in the USA. In addition, global diversified and industrial were susceptible to movements in the volatility of both 3mth T-bill rates and 10y GBY in the USA. Global self-storage was vulnerable to the level of 3mth T-bill rates in the USA and the volatility of 10y GBY in the USA. Global retail was only sensitive to fluctuations in the level of 3mth T-bill rates in the USA.

In terms of the sensitivity to 10y-2y spread in the USA, global industrial/office and healthcare had empirically strong interest rate risk aversion and hedging benefits, while global lodging was immune to all interest rate proxies in the USA, unlike the mainstream LRE sub-sectors. Importantly, these findings are generally consistent with the baseline results. This might be explained by that the sample markets (the Developed Europe, Eurozone, USA and UK) utilized in this study accounted for 52.3% of the global LRE markets by market capitalization as of Dec 2022 (EPRA, 2022). However, total returns of global office and self-storage were affected negatively by rising possibilities of economic recession risk. The result of global office was also observed across the Developed Europe, Eurozone, USA and UK. In addition, the result of global self-storage was consistent with the USA but was not found in the Developed Europe and UK. This implies US self-storage was more sensitive to potential economic recession risk than that in the Developed Europe and UK.

These results are significantly important to buy-side asset managers mandating global LRE portfolio construction and exposing both geographical and sector diversification benefits by offering empirical evidence on the magnitude and direction of global LRE sub-sectors sensitivity to US monetary policy. In particular, the Federal Reserve tightened fund rates by 500 bps in the last 14 months as of Jun 2023 (FRED, 2023). The prevalent rising interest rate may result in upward pressure on yields and a drag on CRE capital values (French, 2019). Over the year to Jun 2023, cap rates of US public and private real estate sectors increased by 134 bps and 61 bps, respectively (NAREIT, 2023). The trend results in devaluations in CRE markets with a decline of 9.1% in Europe, 6.8% in the USA and 12.8% in the Globe (MSCI, 2023).

Loan-To-Value Case Study - Developed Europe

CRE is funded with a combination of debt and equity. CRE firms often utilize high degrees of leverage with the expectation of driving the returns of investors. However, the use of leverage could alter companies' cost-of-capital and potentially lead CRE firms to display heightened sensitivity to interest rate changes, resulting in the future availability of external debt facilities (Bredin et al., 2007). In light of longer and higher tightening monetary policy by key global central banks, conventional lenders, such as commercial and investment banks, have been cautious of fundraising for global CRE markets (DWS, 2023). In Europe, fundraising for CRE debt investment strategies fell from $10.9 billion in 2021 to $5.8 billion in 2023 (PERE, 2023). In the next three years, DFG in Europe was projected to be $23.7 billion (AEW, 2022). Alternative CRE lenders have targeted to fill DFG by measuring the LTV ratio of CRE firms that protect the lender from the event of default and create equity cushion to reduce the downside risk (Lasalle, 2023; Nuveen, 2023a). Hence, the use of LTVs was included in the baseline GARCH-M model. This is despite that sector-level LTV variable is only available in Developed Europe.

Appendices 7, 8 and 9 show that the timeframe examined in the LTV case study was between Oct 2010 and Dec 2023 since LTV proxies of LRE sub-sectors are available since Oct 2010. In terms of the sensitivity to changes in interest rate proxies in Developed Europe, the results are broadly consistent with the baseline findings, where retail, self-storage and residential were more sensitive to swings in 3mth T-bill rates and 10y GBY than the other LRE sub-sectors in Developed Europe. In terms of the sensitivity to turbulence in 10y-2y spread as a leading indicator of recession risk predictions (FRBSF, 2022), diversified, office, retail and residential were empirically vulnerable to movements in 10y-2y spread.

In terms of the impacts of LTV on LRE sub-sectors in Developed Europe, LTV was significantly negative with the mainstream sub-sectors, namely diversified, office and retail. This may be attributed to a high level of LTV in diversified (35.7%) and retail (45.2%) as of Dec 2022. At times, the trend was also witnessed in diversified (57.5%)

and retail (46.2%) in the USA (NAREIT, 2022). In consideration of CRE sector's greater reliance on debt, higher levels and shorter-term may be significantly affected and result in collapsing and recapitalizing CRE firms when the systematic risk of CRE changes and rises (Brounen et al., 2016; Reddy and Wong, 2018). Despite the fact that LTV of office was 29.8%, which was relatively lower than the other sectors, the sector total returns were negatively influenced by LTV.

Unexpectedly, LTV was significantly and positively signed in industrial, self-storage and residential. These indicate that industrial, self-storage and residential delivered higher total returns boosted by higher leverages. This may be attributed to a low level of LTV in industrial (28.4%) and self-storage (21.5%) as of Dec 2022. At times, the trend was also observed in industrial (32.0%) and self-storage (26.2%) in the USA (NAREIT, 2022). Lower leverages may provide availabilities of adding more debt facilities to heighten the returns, in line with the findings of Brounen et al. (2016), where LRE returns were relative to the level of debt levered by LRE firms. It is noteworthy that residential total returns signed positively with the second-highest leverage of 40.0% among all LRE sub-sectors as of Dec 2022. These results echo the findings of Mueller and Pauley (1995), where the firm total returns can be heightened by leverage either positively or negatively.

Empirical Results II: Allocation Analysis

Monetary Policy Rate Cycles

Table 2 presents interest rate cycles across the USA, Eurozone and UK, using fund rates by the Federal Reserve, ECB and BOE, respectively. Interest rate expansion cycles are designated as PT (peak-to-trough), and rate hike cycles are defined as TP (trough-to-peak). The USA and UK were statistically close to rate hike cycles (TP), in that the average cycle length over the expansion period was approximately 57.3 months for the USA and 46 months for the UK. The Eurozone cycle was longer than the peers, with 70 months. On the other hand, the UK and Eurozone were statistically close to rate cut cycles (PT), with approximately 21.6 and 14.5 months, respectively. The USA was longer than the peers by 41 months.

Turning points of interest rate cycles in the USA were Dec 2000 - Apr 2004 (interest rate expansion), May 2004-Jul 2007 (rate hike cycle), Aug 2007 - Oct 2015 (interest rate expansion), Nov 2015 - May 2019 (rate hike cycle), Jun 2019 - Feb 2022 (interest rate expansion) and Mar 2022 - Dec 2022 (rate hike cycle). It is noteworthy that the starting points of interest rate expansion cycles in the USA aligned with structure changes in the global economy, such as the Dot-com bubble (Mar 2001 - Nov 2001), Global Financial Crisis (GFC) (Jul 2007 - Aug 2009), US debt ceiling suspension concern (Jul 2019 - Oct 2019) and COVID recession (Feb 2020 - Apr 2020).

The UK and Eurozone interest rate cycle turning points overlapped with the USA. More importantly, the UK and Eurozone entered interest rate turning points after the USA. The results may be attributed to structural changes in the US economy affecting the turning points of UK and Eurozone interest rate cycles and therefore the monetary policy of the ECB and BOE.

In short, this research employs turning points of interest rate cycles in the USA statistically detected by the Harding and Paga's (2002) Bry-Boschan program as expansion and contraction phases of interest rate cycles.

Table 10. Interest rate cycles: the USA, Eurozone and UK

	USA	Eurozone	UK
Mean duration (months)			
PT	41.000	14.500	21.667
TP	57.333	71.000	46.250
Mean Amplitude (%)			
PT	1.980	0.528	0.550
TP	-2.406	-0.838	-1.436
Cumulation (%)			
PT	57.804	4.845	11.566
TP	-126.475	-49.720	-81.345
Excess (%)			
PT	41.143	24.205	50.027
TP	56.321	60.454	65.365

Sources: Authors' compilation/analysis

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Risk-Adjusted Performance

The risk-adjusted performance statistics for various markets in different interest rate cycles are provided in Appendices 10 to 14. The results offer compelling insights into linkages between LRE and interest rate changes.

USA

By comparing the two periods, rate cut cycles seemed to be particularly favorable for industrial, healthcare and self-storage. Rate hike cycles highlighted the strength of industrial and residential. Throughout the various interest rate cycles, industrial stood out prominently in terms of performance, posting consistently strong average annual returns and a resilient downside risk profile. Similarly, self-storage, a sector that is considered as an alternative sector of real estate investments, consistently showed strong performance metrics, highlighting its potential as a stable and profitable investment. Meanwhile, diversified and retail experienced more varied performance statistics, with certain periods of relatively low average return performance adversely impacted by high downside risks. Retail, in particular, exhibited the worst risk-adjusted performance amongst the sector-specific LRE.

DEVELOPED EUROPE

During interest rate cut cycles, most LRE sectors demonstrated positive growth. For the Aug 2007 - Oct 2015 interest rate cut cycle, while diversified, office, and self-storage recorded high performance, industrial declined. However, the Jun 2019 - Feb 2022 interest rate cut cycle recorded a significant surge in industrial's average return performance, during which period retail recorded significant underperformance. During interest rate hike phases, the performance showed more disparity across LRE sectors. For the Nov 2015 - May 2019 hike cycle, industrial and residential stood out with strong total return performance, while retail experienced significant underperformance. Despite the significant underperformance in the Aug 2007 - Oct 2015 interest rate cut cycle, the industrial sector had a relatively high Sortino Ratio during the Jun 2019 - Feb 2022 cut cycle.

UK

During the interest rate cut periods of Dec 2000 - Apr 2004, May 2004 - Jul 2007, and Jun 2019 - Feb 2022, composite LRE showed strong positive performance. Diversified and office showed mixed results, while retail had a substantial decline in Jun 2019 - Feb 2022 and Nov 2015 - May 2019. Industrial maintained stability, apart from a drop in Aug 2007 - Oct 2015. Healthcare and self-storage demonstrated relatively consistent performance, particularly excelling in the interest rate hike cycle of Nov 2015 - May 2019. This period was a challenging time, but industrial, healthcare, residential and self-storage stood out for their strong performance, highlighting their potential as resilient LRE investment sectors during times of economic tightening.

EUROZONE

During the interest rate cut cycles of Dec 2000 - Apr 2004, Aug 2007 - Oct 2015, and Jun 2019 - Feb 2022, Composite LRE showed strong performance, particularly in the first period, with an annual average annual return of 12.93%. However, it faced a significant underperformance in the last period. Diversified had its highest performance during the interest rate hike cycle in Nov 2015 - May 2019. Office and retail had varied performance; for example, retail showed strong average return performance during interest rate hike cycles but was offset by significant volatility, as reflected by its high downside risk, particularly in Jun 2019 - Feb 2022. Industrial maintained a relatively strong average return performance and managed to keep its downside risk comparatively lower. Residential's investment performance peaked in Nov 2015 - May 2019, but it recorded the highest risk in Aug 2007 - Oct 2015. Amongst the LRE sub-sectors, it can be seen that industrial and residential had comparatively higher risk-adjusted performance.

GLOBAL

Residential showed consistent and strong performance, registering strong positive Sortino ratio over the various cycles. The performance statistics also highlight more volatile LRE sub-sectors, such as retail and lodging experiencing greater fluctuations, with retail showing a negative average annual return and high downside risk in the most recent cut cycle (Jun 2019 - Feb 2022). In contrast, industrial and self-storage tend to outperform other LRE sub-sectors in the same period, with both of these LRE sub-sectors showing high average return performance and a relatively high Sortino ratio. Overall, some traditional LRE sectors, such as diversified, office and retail have comparatively low risk-adjusted performance.

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Downside Risk Portfolio Optimization in Different Interest Rate Cycles

Figure 1 presents the downside risk-averse portfolio optimization results for LRE across sectors and markets in interest rate cut cycles. The overall results indicate the importance that portfolios should be tactically adjusted to take advantage of the dynamics of market conditions, opportunities and downside risk considerations.

During the cycle from Dec 2000 to Apr 2004, there was a pronounced presence across different markets, which suggests that during this period, composite LRE was a favored sector to achieve optimum downside-risk aversion investment strategies as it takes up a major proportion of the optimized portfolios. Composite LRE occupied 71% of the portfolio, 55% in the Eurozone and Developed Europe, 54% in the USA and 52% in the UK. In the next cycle of Aug 2007 - Oct 2015, composite LRE's presence remained strong in the Eurozone (58%), Developed Europe (59%), and Global (52%) portfolios, indicating its ability to contribute to the optimum portfolio risk-return mix. However, except in the UK, the period of the most recent cycle of Jun 2019 - Feb 2022 demonstrates a significantly less presence of composite LRE in optimum portfolios, hinting at a potential shift in the ability of broad LRE to deliver portfolio diversification benefits.

The portfolio analysis results of diversified LRE provide an interesting overview of the feasibility of using a "naive diversification" strategy in rate cut cycles from an LRE investment perspective. Overall, there are limited added-value benefits for investors to invest in the diversified sector as the overall allocation leans heavily towards bonds and stocks across most of the markets, and no variation is observed in the two rate cut cycle timeframes; Aug 2007 - Oct 2015 and Jun 2019 - Feb 2022. Diversified LRE was only prominently featured in the portfolio of Developed Europe (59%), which is an outlier given the non-existent allocations for other markets during the same period. The results not only suggest the limited role of diversified LRE during these interest rate cycles, but hinting at the ineffectiveness of a naive diversification strategy through investment in diversified LRE.

It is also interesting to see that the analysis also highlights the investment dynamics of sector-specific LRE. For example, self-storage is the most prominent sector-specific LRE in this portfolio analysis. Its allocation constitutes a significant portion of the optimized asset mix, receiving allocation as high as 62% in the global portfolio during Aug 2007 - Oct 2015, and 52% in the UK portfolio during Jun 2019 - Feb 2022. Self-storage LRE is the dominant sector-specific LRE in the rate cut cycle portfolios, suggesting a favorable outlook for the self-storage sector during these timeframes. Both office and retail share contrasting allocation patterns between Aug 2007 - Oct 2015 and Jun 2019 - Feb 2022. The portfolio mix indicates generous allocations in both office and retail in various markets in Aug 2007 - Oct 2015, taking up major proportions of the downside-risk optimized portfolios, especially in the mid to high risk-return portfolio strategies. However, the results indicate a more conservative to non-existent allocation in both of these sectors in the latest rate cut cycle over Jun 2019 - Feb 2022. For example, office LRE in the UK had a 56% allocation during Aug 2007 - Oct 2015, which contrasts significantly with the 0% allocation in Jun 2019 - Feb 2022. Similarly, retail LRE in the Eurozone showed a sharp decline from 58% in Aug 2007 - Oct 2015 to 0% in Jun 2019 - Feb 2022. This sharply contrasts with the portfolio mix involving industrial as it is more prominently allocated in portfolios in the later stages of the cycle.

As for healthcare, it has a stronger stature in all markets in the optimized portfolios in the period of Aug 2007 - Oct 2015, with less substantial weightage observed for Jun 2019 - Feb 2022, with portfolio exposure limited to the UK and Developed Europe. Lastly, varying degrees of portfolio representation can be seen for residential LRE, noting the bullish presence of the USA (48%) and Global (64%) portfolios initially, before being excluded altogether in the subsequent period. The Jun 2019 - Feb 2022 portfolio analysis indicates a considerable allocation in the residential sector only in the UK portfolio (29%).

Figure 2 provides a comprehensive view of the unconstrained downside risk-averse portfolio optimization results for LRE across different markets during interest rate hike cycles. It is worth noting that only composite LRE's analysis covers the two interest rate hike cycles: May 2004 - Jul 2007 and Nov 2014 - May 2019, whilst the sub-sector LRE's analysis covers the interest rate hike cycle over Nov 2014 - May 2019 due to data limitations.

There is a balanced portfolio blend of composite LRE, stocks and bonds in the period Dec 2000 - April 2004, with the perspective of more significant allocation in composite LRE in more optimistic downside risk portfolios. The global portfolio saw the highest representation in composite LRE at 47%, while the US portfolio had the second highest composite LRE allocation at 45% share. Other markets also recorded a sizable allocation in this broad

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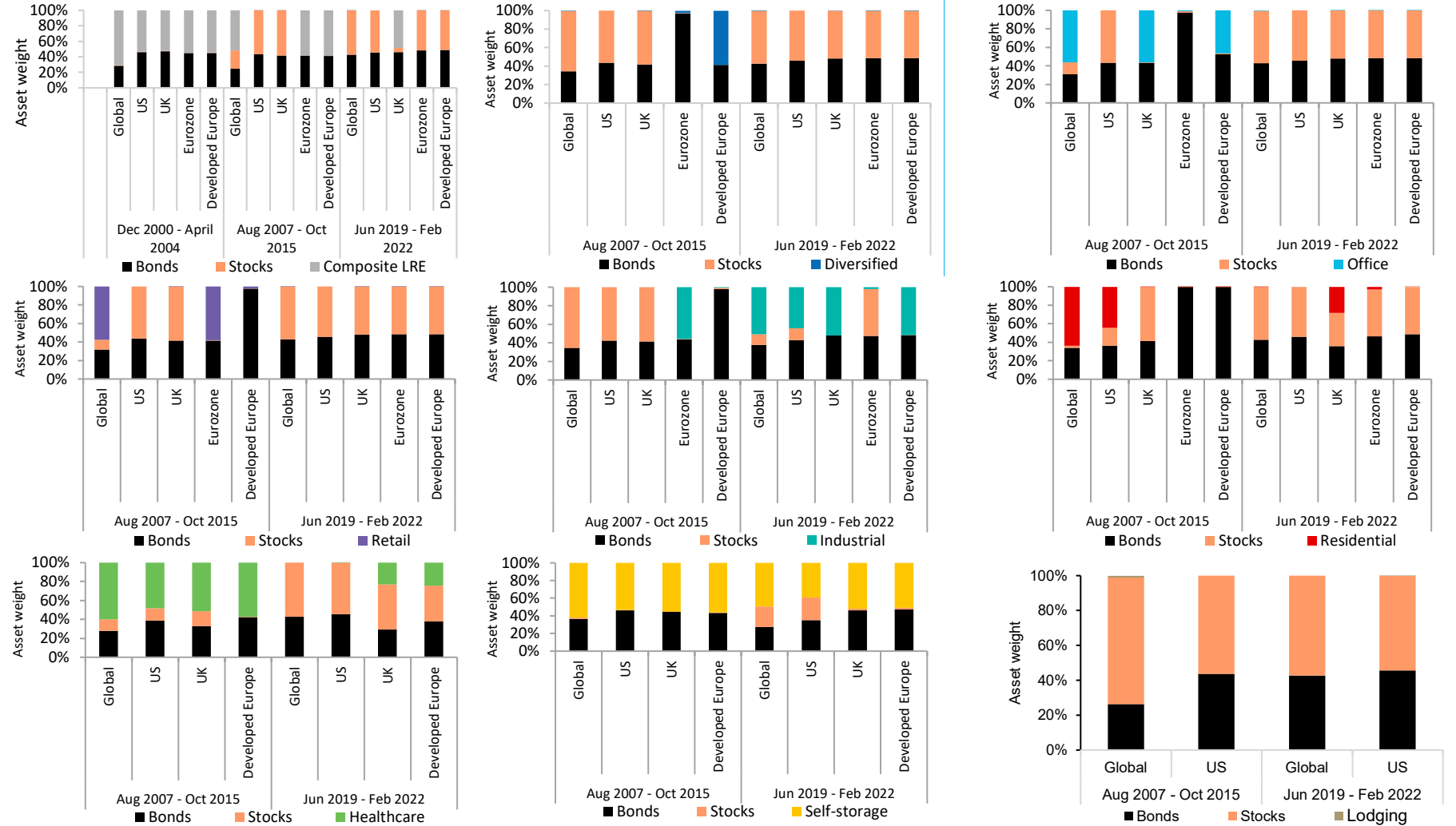**W** www.epra.com
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LRE (e.g.: the UK at 37%, the Eurozone at 38% and Developed Europe matched the Eurozone with a 38% allocation). However, the subsequent interest rate hike period of Nov 2014 - May 2019 shows a more noticeable inclination towards stocks in most of the markets, resulting in lesser weightings to composite LRE. Only the global market (24%) had an allocation in composite LRE. Further, the poor performance of diversified LRE during this period has made it challenging for the sector to be optimally included in the portfolio. The results from Panel B show a generally low representation for diversified LRE during the Nov 2015 - May 2019 cycle, with a significant allocation that can only be seen in the Eurozone portfolio (54%). This implies that investors would be better off diversifying their investments across various sector-specific LRE.

Several sector-specific LREs have received substantial allocations in the optimum asset allocation strategy during the interest rate hike period. For example, the results suggest a strong asset distribution preference towards industrial in the downside risk-optimized portfolios across the markets, reflecting the sector as a performant and less volatile segment of the LRE market. Specifically, the global portfolio's allocation to industrial LRE was at a high of 66%, and a comparably significant 54% allocation in the USA and 52% in the remaining three markets. The results are in line with the findings of Lin et al. (2020), where the USA was the investment hotspot of industrial markets across the Pacific Rim region. There is also a consistent presence of residential in the asset mix, showing significant allocations in this sector in the global portfolio at 57%, as well as the Eurozone and Developed Europe portfolios, each at 52% allocation. The findings are consistent with the works of Lin et al. (2019b) and Lin (2021), in which the USA and Japan were the investment hotspots of residential markets across the Pacific Rim region.

A similar allocation pattern is evident in healthcare, with healthcare LRE-heavy allocations observed in the UK (46%), Developed Europe (42%) and more prominently in the global market (51%). Despite this high allocation in healthcare, the results do not suggest a full replacement effect in the asset allocation fabric, as stocks are still included in the asset mix, suggesting the co-existence potential of this sector with the overall stock market due to their diversification efficiency. Office LRE held a dominant position in the Eurozone and developed Europe portfolios with its above 50% weight. Both the UK and Developed Europe showed substantial allocation preferences in for self-storage LRE, weighting the sector at 48% and 51%, respectively.

Overall, both the risk-adjusted performance statistics and the optimal asset allocation patterns of LRE highlight the dynamics of LRE markets and the importance of strategic investment choices concerning LRE in investment portfolios in response to interest rate cycles. Market selection is especially important during changing interest rate cycles due to how different markets react to structural changes. Unique allocation preferences in the downside-risk optimized portfolios show the importance of choosing markets that can offer potential gains during various interest rate cycles. Meanwhile, LRE sectoral specialization gives the ability to take advantage of sector-specific LRE that is primed to outperform during the evolving interest rate phase.

Figure 1. Asset allocation analysis of LRE sub-sectors during various interest rate cut cycles

Sources: Authors' compilation/analysis

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Figure 2. Asset allocation analysis of LRE sub-sectors during various interest rate hike cycles

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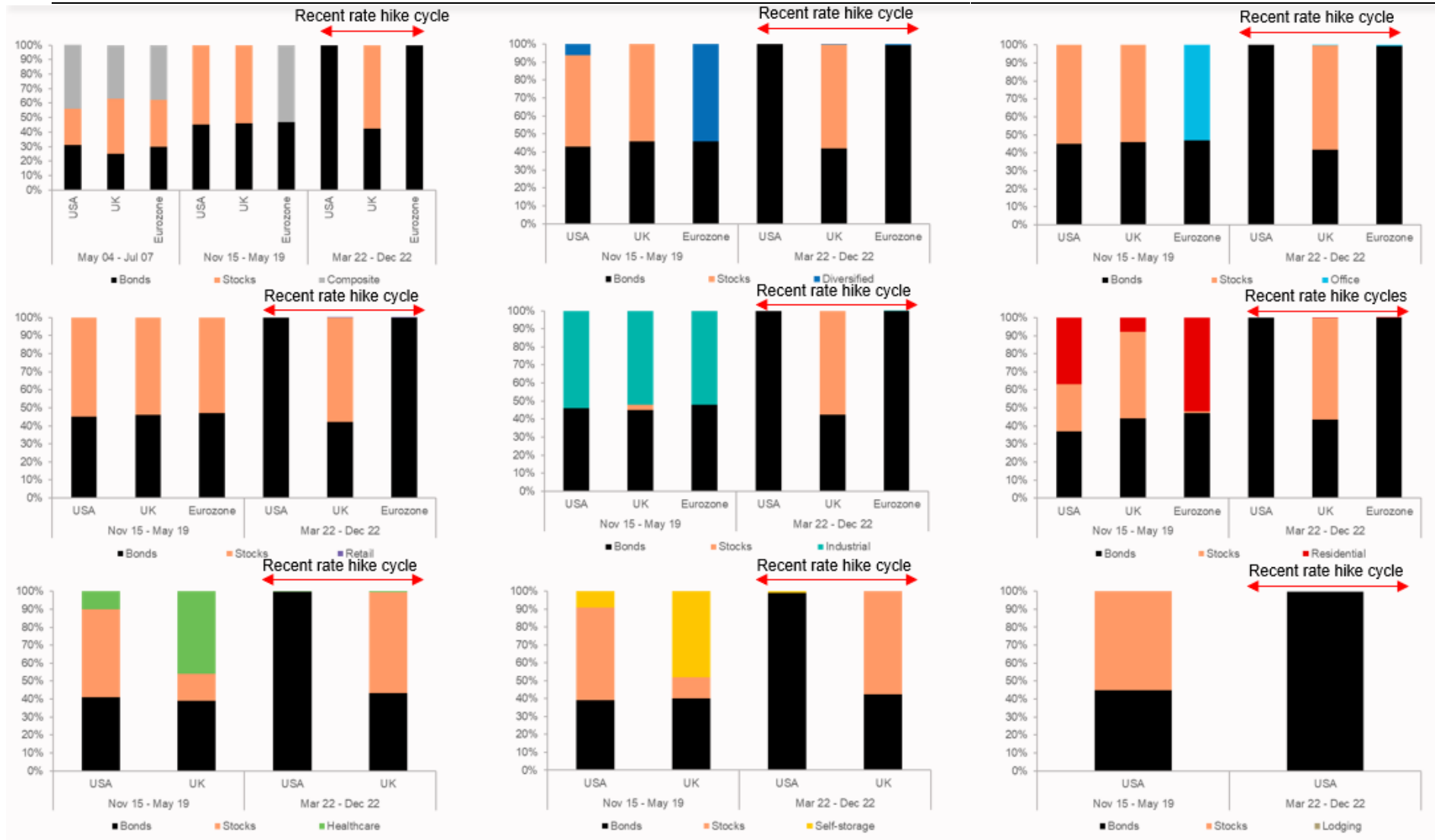
Conclusions

Global investors have been aware of recent investment risk in the scale of fund rate increases and the depth of yield curve inversion. The inevitable increase in interest rates undeniably presents both potential investment risks and opportunities to a wide range of CRE stakeholders. This research therefore examines the risk management and institutional investment opportunities of interest rate cycles on global LRE sub-sectors. The first research theme addresses the interest rate sensitivity of LRE sub-sectors with the use of different interest rate proxies, particularly for 10y-2y spread, a leading indicator of projecting economic recession risk (FRBSF, 2022). The second research theme assesses institutionalized portfolio allocation weightings to global LRE sub-sectors across different phases of interest rate cycles. Five markets were examined in this research, including the Developed Europe, Eurozone, USA, UK and Globe. The main findings are summarized as follows:

First, the study empirically validates the disparities in the magnitude and direction of the sensitivity to interest rate level and volatility of LRE across sectors and markets. These may be attributed to distinct risk-return attributes of different real estate sectors, and the investment distinctions among these five markets.

Second, self-storage and residential were the most sensitive sectors to both 3mth T-bill rates and 10y GBY changes across Developed Europe, the Eurozone, USA and UK. Diversified and retail were susceptible to 3mth T-bill rates across all markets, while industrial was vulnerable to 10y GBY. Besides, office, diversified and residential were significantly and positively sensitive to 10y-2y spread swings across all markets. This implies that office, diversified and residential responded negatively to rising possibilities of economic recession risk projected by yield curve inversion (FRED, 2023). Unexpected results in office may be attributed to hybrid working strategies in global office markets in the post-COVID context, resulting in increases in global office vacancy rates (Hoesli and Malle, 2022; JLL, 2023).

Third, industrial/office empirically equipped strong interest rate risk aversion and hedging benefits to 10y-2y spread changes in the USA. Lodging was empirically immune to interest rate proxies in the USA and Globe. Healthcare behaved divergently across three markets. In the USA, healthcare empirically featured strong interest rate risk aversion and hedging benefits to both 10y GBY and 10y-2y spread. However, healthcare was vulnerable to 3mth T-bill rates in the Developed Europe and UK, as well as 10y GBY in Developed Europe.

Fourth, the impacts of US monetary policy on global LRE sub-sectors were assessed in respect to global finance and economies empirically influenced by the spillovers of US monetary policy, particularly the recent tightening fund rates at an unprecedentedly rapid pace (Caldara et al., 2022). The findings are broadly consistent with the baseline results, in which global industrial/office and healthcare had empirically strong interest rate risk aversion and hedging benefits, whilst global lodging was immune to interest rate proxies in the USA.

Fifth, LTV was significantly negative with the mainstream sub-sectors, such as diversified, office and retail, in Developed Europe. This may be attributed to these sectors' high level of LTV. On the opposite, LTV was significantly and positively signed in industrial, self-storage and residential. These indicate that industrial, self-storage and residential delivered higher total returns boosted by higher leverages.

Sixth, the study empirically confirms the dynamic response of LRE markets and sectors to interest rate cycles. The results highlight the value of selecting markets and specific LRE sectors with the potential to deliver higher returns throughout interest rate changes.

Seventh, during the interest rate cut cycles, real estate markets showed unique responses. Some LRE sectors, such as retail and office, showed portfolio allocation dynamics across different markets. The Eurozone and Developed Europe markets showed largely comparable allocation patterns in many of the LRE sectors. It can be seen that some LRE sectors were resilient or benefitted during rate cuts, but others registered comparatively lower performance. Thus, it highlights the need for real estate investors to understand the impact on market- and sector-specific characteristics during monetary changes.

Eighth, as the global economy reacts to interest rate increases, it is clear that certain LRE sectors such as healthcare, self-storage and industrial benefitted the most. These sectors offered comparatively stable returns, superior risk-adjusted performance and stronger hedge against risks imposed by the tightening of monetary policy. In contrast, the results highlight the more cautious portfolio allocation approach to other LRE sectors.

Ninth, the results suggest that during varying interest rate cycles, sector-specific LRE often shows higher allocation percentages in comparison to diversified LRE. The optimistic allocation in sectors such as industrial, self-storage and healthcare shows the need for investors to tailor their portfolios to capitalize on sectoral trends.

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Consistent with previous studies (e.g. Lin et al., 2019a; 2019b; 2020), naïve LRE diversification strategy via diversified LRE may be simpler and offer broad market exposure, but it reduces the potential gains from high-performing sector-specific LRE (Newell and Marzuki, 2023). The finding suggests institutional investors should actively make their own sectoral portfolio diversification decisions by investing in different real estate types of LRE, rather than passively relying on a diversified portfolio with multiple real estate sectors.

Whilst the private real estate market is the main route for global institutional CRE investors, private real estate can be projected by public real estate (Hoesli et al., 2015). The practical use of the results is extremely valuable and insightful for a wide range of CRE investors, particularly a higher-for-longer interest rate environment being expected in 2024 due to inflation continuously above the target range (Federal Reserve, 2023). In particular, the use of interest rate proxies, including 3mth T-bill, 10yr GBY and 10y-2y spread, can empirically forecast the next period's interest rates in each case. First, the first theme is expected to inform global buy-side and sell-side CRE asset managers of distressed asset investment strategies in pitching NPA across sectors and markets in the stock pitching and due diligence processes. In addition, the results provide global conventional and alternative CRE lenders implementing debt investment strategies in global private credit markets, with the quantitative interest rate sensitivity of LRE sub-sectors to empirically identify where loans are at greater risk and ensure margins are sufficient to compensate for the scale of fund rate increases and the depth of yield curve inversion across global capital markets. Second, the second theme acknowledges global buy-side asset managers of well-informed TAA strategies in portfolio construction of LRE across sectors and markets in rate hike cycles, particularly highlighting portfolio return enhancement capabilities of LRE sub-sectors in institutional investors' multi-asset portfolios across the markets. These findings provide buy-side and sell-side asset managers with empirical evidence on quantitative market and sector selections of LRE across the markets in both rate hike and rate cut cycles. Lastly, this research contributes to the academic literature by validating the sectoral effect and specialization value in LRE markets across the Developed Europe, Eurozone, USA, UK and Globe from the dimensions of interest rate risk management, investment performance and institutionalized portfolio construction strategy.

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Appendix

Appendix 1. Descriptive statistics for LRE Sub-sector total returns: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial	Industrial/Office	Self-Storage	Residential	Lodging	Healthcare
Developed Europe	Mean (%)	0.334	0.531	0.002	0.477		1.106	0.307		0.405
	Maximum (%)	19.937	22.194	56.619	55.524		49.925	30.846		28.961
	Minimum (%)	-25.991	-22.289	-44.788	-33.634		-24.857	-42.509		-19.553
	Std. deviation (%)	5.691	5.356	7.939	8.204		7.987	7.700		6.155
	Skewness	-0.576	-0.376	0.760	0.577		0.734	-0.483		0.016
	Kurtosis	6.229	6.736	19.276	14.870		9.652	9.368		5.835
	Jarque-Bera	99.384***	122.846***	2,260.321***	1,203.074***		392.432***	350.879***		68.012***
Eurozone	Mean (%)	0.399	0.384	0.311	1.076			0.291		
	Maximum (%)	30.452	21.509	58.848	33.040			30.640		
	Minimum (%)	-35.318	-22.526	-42.985	-40.908			-39.529		
	Std. deviation (%)	6.333	5.563	7.939	7.111			7.738		
	Skewness	-0.730	-0.499	1.117	-0.876			-0.523		
	Kurtosis	10.172	5.750	20.287	10.375			7.787		
	Jarque-Bera	453.093***	72.387***	2,569.903***	486.041***			203.103***		
US	Mean (%)	0.585	0.407	0.607	1.041	0.649	1.233	0.856	0.058	0.839
	Maximum (%)	43.338	33.948	43.645	71.311	39.588	21.929	21.667	66.600	27.459
	Minimum (%)	-31.831	-32.453	-42.851	-56.189	-37.634	-22.244	-26.420	-36.009	-33.484
	Std. deviation (%)	7.751	7.282	8.251	10.267	8.246	6.471	6.386	10.540	7.114
	Skewness	-0.225	-0.205	-0.595	0.323	-0.216	-0.256	-0.763	1.070	-0.647
	Kurtosis	10.178	7.653	11.824	19.255	7.563	3.876	5.784	12.440	6.667
	Jarque-Bera	437.514***	184.525***	670.587***	2,238.460***	177.694***	8.717***	85.260***	792.442***	127.892***
UK	Mean (%)	0.152	0.533	-0.755	0.486		1.231	0.744		0.488
	Maximum (%)	24.315	25.962	28.398	60.237		44.736	64.637		32.780
	Minimum (%)	-25.100	-26.418	-63.988	-38.432		-28.901	-60.500		-16.493
	Std. deviation (%)	6.245	6.859	9.738	8.782		7.710	11.650		5.578
	Skewness	-0.256	-0.467	-1.505	0.619		0.348	1.110		0.660
	Kurtosis	5.482	5.238	11.870	16.339		8.448	14.352		8.808
	Jarque-Bera	54.332***	49.729***	742.108***	1,518.017***		255.172***	1,131.616***		300.054***
Global	Mean (%)	0.360	0.421	0.472	0.715		1.263	0.786	0.589	0.836
	Maximum (%)	19.764	16.899	23.489	35.931		22.953	19.275	65.242	18.091
	Minimum (%)	-23.303	-20.939	-39.088	-47.998		-15.822	-17.988	-38.030	-31.315
	Std. deviation (%)	5.105	5.011	6.272	7.514		6.319	5.436	9.832	6.773
	Skewness	-0.553	-0.588	-1.125	-1.551		0.005	-0.395	1.053	-0.675
	Kurtosis	6.518	5.426	11.959	15.474		3.214	4.301	13.502	5.685
	Jarque-Bera	115.043***	61.486***	721.726***	1,397.529***		0.387	19.588***	970.232***	76.405***

Note: * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

Sources: Authors' compilation/analysis

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Appendix 2. Eurozone GARCH-M results: Jan 2006 - Dec 2022

	Diversified	Office	Retail	Industrial	Residential
3mth T-Bill Rates					
Mean equation					
Const	0.014(1.109)	-0.028(-2.299)**	-0.021(-6.173)***	0.010(1.772)*	0.022(2.485)**
GARCH term	-6.561(-0.760)	-16.730(-1.795)*	3.445(3.783)***	4.358(2.703)***	0.145(1.860)*
Market	0.953(22.190)***	0.781(16.318)***	0.986(13.512)***	0.382(6.040)***	0.607(9.018)***
IR(μ_j)	-0.134(-1.892)*	-0.072(-0.535)	-0.219(-1.262)	-0.255(-1.142)	-1.038(-3.945)***
Variance equation					
Const	0.000(0.548)	0.002(2.222)**	0.000(1.757)*	0.000(1.659)*	0.000(0.510)
Arch	0.035(2.497)**	0.188(3.234)***	0.197(2.900)***	0.076(4.110)***	0.020(2.188)**
GARCH	0.938(2.120)**	0.766(2.556)**	0.786(6.389)***	0.921(15.940)***	0.966(3.258)***
Market Vol	-1.496(-0.802)	-1.834(-0.955)	-0.828(-0.402)	-3.137(-1.221)	-0.610(-0.239)
IR Vol(v_{2j})	-433.327(-0.904)	319.448(1.711)*	-110.436(-2.264)**	-1,731.598(-1.732)*	-3,016.955(-3.518)***
Eurozone — Diversified	Diversified	Office	Retail	Industrial	Residential
10y GBY					
Mean equation					
Const	0.021(1.025)	-0.052(-2.426)**	-0.104(-5.153)***	0.000(0.002)	0.004(0.247)
GARCH term	-6.979(-0.848)	-0.842(-2.122)**	2.006(6.822)***	1.356(0.777)	1.511(0.998)
Market	0.961(20.613)***	0.828(20.414)***	0.861(12.019)***	0.375(5.774)***	0.602(8.403)***
IR(μ_j)	-0.049(-0.287)	-0.045(-0.259)	-0.245(-1.266)	-0.448(-1.755)*	-0.370(-1.674)*
Variance equation					
Const	0.000(0.302)	0.001(2.676)***	0.001(4.370)***	0.000(1.718)*	0.000(0.561)
Arch	0.022(2.296)**	0.283(1.711)*	0.172(6.905)***	0.098(3.900)***	0.036(3.404)***
GARCH	0.954(2.381)**	0.706(2.161)**	0.792(5.840)***	0.891(13.311)**	0.946(6.445)***
Market Vol	-0.962(-0.543)	-0.116(-0.063)	-6.538(-5.414)***	-4.633(-1.663)*	-0.935(-0.361)
IR Vol(v_{2j})	-2,018.964(-0.571)	-2,602.459(-0.891)	-5,824.355(-1.850)*	6,418.148(1.401)	-2,826.985(-0.611)

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

Sources: Author'' compilation/analysis

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Appendix 3. Eurozone GARCH-M results: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial	Residential
Eurozone	*10Y-2Y Spread*					
	Mean equation					
	Const	-0.050(-3.673)***	-0.028(-1.929)*	-0.089(-8.676)***	0.008(1.864)*	0.012(1.364)
	GARCH term	-4.054(-0.510)	-8.215(-1.825)*	2.011(9.768)***	1.485(0.828)	-1.081(-0.542)
	Market	0.960(20.335)***	0.797(19.042)***	0.905(14.522)***	0.407(6.314)***	0.633(8.614)***
	IR(μ_j)	0.883(3.243)***	0.214(1.699)*	0.211(0.501)	0.546(1.253)	1.803(4.751)***
	Variance equation					
	Const	0.001(3.598)***	0.001(2.052)**	0.001(6.507)***	0.000(1.876)*	0.000(1.673)*
	Arch	0.099(2.988)***	0.030(2.214)**	0.160(5.996)***	0.105(4.071)***	0.350(2.162)**
	GARCH	0.900(3.209)***	0.949(1.879)*	0.829(4.718)***	0.883(10.675)***	0.633(3.228)***
	Market Vol	-3.884(-2.869)***	-0.319(-0.190)	-6.542(-3.139)***	-5.028(-1.674)*	-7.555(-0.326)
	IR Vol(v_{2j})	-3.777(-2.473)**	26.805(0.220)	-3.230(-2.591)***	-30.859(-0.210)	-37.904(-2.358)**

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

Sources: Author'' compilation/analysis

Appendix 4. Global GARCH-M 3mth T-bill rates results: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial
	Mean equation				
	Const	-0.003(-0.273)	-0.058(-6.890)***	-0.354(-2.214)**	0.001(0.109)
	GARCH term	1.590(0.149)	-0.009(-11.872)**	-0.057(-2.245)**	0.045(0.028)
	Market	0.919(18.981)***	0.802(15.095)***	0.948(15.498)***	0.985(15.542)***
	IR(μ_j)	0.091(0.613)	-0.269(-2.163)**	-0.423(-2.198)**	-0.009(-0.042)
	Variance equation				
	Const	0.000(0.840)	0.002(4.754)***	0.000(14.746)***	0.000(1.472)
	Arch	0.217(2.404)**	0.135(2.237)**	0.002(1.727)*	0.363(2.950)***
	GARCH	0.718(2.779)***	0.837(4.020)***	0.970(4.814)***	0.570(2.321)**
	Market Vol	0.091(0.613)	-1.842(-1.369)	-1.679(-1.102)	2.055(0.771)
	IR Vol(v_{2j})	-509.395(-1.967)**	-475.430(-1.651)*	-272.487(-0.803)	-731.695(-2.469)**
Global		**Self-Storage**	**Residential**	**Lodging**	**Healthcare**
	Mean equation				
	Const	-0.161(-1.740)*	0.127(8.506)***	-0.021(-3.413)***	-0.002(-0.117)
	GARCH term	-0.031(-1.953)*	0.018(3.453)***	2.306(1.307)	1.319(0.271)
	Market	0.401(5.116)***	0.712(11.235)***	1.454(18.245)***	0.840(10.993)***
	IR(μ_j)	-0.636(-2.590)***	-0.277(-2.580)***	0.105(0.437)	0.169(0.651)
	Variance equation				
	Const	0.000(10.468)***	0.000(5.685)***	0.000(2.650)***	0.001(1.221)
	Arch	0.003(1.705)*	0.079(4.517)***	0.269(3.837)***	0.143(2.193)**
	GARCH	0.980(3.594)***	0.912(8.112)***	0.688(9.084)***	0.785(4.052)***
	Market Vol	-1.269(-0.586)	-2.040(-2.188)**	5.108(2.570)***	-0.675(-0.282)
	IR Vol(v_{2j})	-404.183(-1.369)	-439.858(-1.937)*	-271.264(-0.924)	104.039(0.284)

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

Sources: Authors' compilation/analysis

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Appendix 5. Global GARCH-M 10y GBY results: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial
	Mean equation				
	Const	0.003(0.283)	-0.164(-1.529)	-0.364(-0.685)	0.033(2.297)**
	GARCH term	0.354(0.055)	-0.025(-1.588)*	-0.599(-0.693)	-0.674(-0.377)
	Market	0.899(17.838)***	0.793(14.796)***	0.983(11.396)***	1.019(14.353)***
	$IR(\mu_j)$	0.138(0.653)	-0.390(-1.723)*	-0.032(-0.089)	-0.383(-1.326)
	Variance equation				
	Const	0.000(0.994)	0.000(1.765)*	0.000(1.197)	0.000(1.314)
	Arch	0.121(1.702)*	0.022(1.799)*	0.343(3.015)***	0.361(3.029)***
	GARCH	0.841(1.734)*	0.966(7.454)***	0.598(2.358)**	0.585(2.007)**
	Market Vol	0.492(0.365)	-2.205(-1.690)*	-2.734(-1.656)*	2.923(1.109)
	$IR\ Vol(v_{2j})$	-2,189.835(-2.407)**	-2,238.858(-2.612)***	-104.815(-0.041)	-5,681.898(-1.882)*
Global		**Self-Storage**	**Residential**	**Lodging**	**Healthcare**
	Mean equation				
	Const	-0.614(-1.585)	0.382(0.101)	-0.032(-2.858)***	-0.002(-0.120)
	GARCH term	-0.114(-1.697)*	0.056(4.535)***	2.152(1.131)	-0.435(-0.144)
	Market	0.375(4.364)***	0.731(11.898)***	1.472(18.697)***	0.819(11.182)***
	$IR(\mu_j)$	-0.361(-0.903)	-0.569(-1.734)*	0.335(1.057)	0.549(1.752)*
	Variance equation				
	Const	0.001(3.774)***	0.000(0.949)	0.000(2.271)**	0.000(1.941)*
	Arch	0.013(1.975)**	0.011(2.032)**	0.264(3.551)***	0.000(2.321)**
	GARCH	0.962(4.700)***	0.949(8.050)**	0.699(8.770)***	0.986(16.018)***
	Market Vol	0.706(0.347)	-1.439(-0.806)	3.980(1.759)*	1.317(0.721)
	$IR\ Vol(v_{2j})$	-6,722.220(-2.898)***	-2,501.401(-1.656)*	988.413(0.406)	-2,231.484(-0.603)

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

Sources: Authors' compilation/analysis

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Appendix 6. Global GARCH-M 10Y-2Y Spread results: Jan 2006 - Dec 2022

		Diversified	Office	Retail	Industrial
	Mean equation				
	Const	-0.002(-0.291)	-0.245(-2.291)**	-0.297(-3.853)***	0.005(0.721)
	GARCH term	1.152(0.125)	-0.036(-2.314)**	-0.047(-3.912)***	1.133(0.696)
	Market	0.928(18.729)***	0.825(15.043)***	1.015(18.423)***	0.951(14.163)***
	IR(μ_j)	0.000(0.001)	0.602(1.940)*	-0.065(-0.152)	0.289(0.833)
	Variance equation				
	Const	0.000(0.881)	0.000(4.567)***	0.000(1.292)	0.000(1.416)
	Arch	0.122(1.798)*	0.005(4.507)**	0.032(2.681)***	0.327(3.291)***
	GARCH	0.862(4.156)***	0.949(6.314)***	0.957(5.282)***	0.646(2.455)**
	Market Vol	-1.433(-0.922)	-3.006(-1.839)*	-5.983(-3.740)***	1.538(0.562)
	IR Vol(v_{2j})	-436.237(-2.501)**	-448.601(-0.377)	-1,853.884(-1.678)*	-3,237.490(-2.056)**
Global		**Self-Storage**	**Residential**	**Lodging**	**Healthcare**
	Mean equation				
	Const	-0.037(-0.546)	0.296(4.352)***	-0.022(-3.206)***	0.002(0.208)
	GARCH term	-0.071(-0.629)	0.046(4.276)***	2.099(1.089)	-1.669(-0.575)
	Market	0.422(5.190)***	0.832(13.244)***	1.491(17.242)***	0.825(10.813)***
	IR(μ_j)	1.113(2.408)**	0.226(0.854)	-0.051(-0.099)	-0.141(-0.336)
	Variance equation				
	Const	0.000(9.511)***	0.000(4.523)***	0.000(2.385)**	0.000(1.925)*
	Arch	0.006(1.900)*	0.008(2.575)***	0.260(3.275)***	0.000(2.072)**
	GARCH	0.977(9.737)***	0.965(9.112)***	0.696(8.315)***	0.987(12.247)***
	Market Vol	-1.385(-0.696)*	-4.299(-2.847)***	2.901(1.235)	-1.287(-0.636)
	IR Vol(v_{2j})	-1,575.780(-0.996)	-2,346.261(-3.140)***	1,739.057(1.093)	2,876.001(1.692)*

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level

Sources: Authors' compilation/analysis

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Appendix 7. Developed Europe GARCH-M 3mth T-bill rates results: Oct 2010 - Dec 2022

		Diversified	Office	Retail	Industrial
	Mean equation				
	Const	0.014(0.519)	-0.096(-4.883)***	-0.011(-0.606)	-0.019(-0.523)
	GARCH term	-0.652(-2.082)**	-1.056(-1.717)*	1.040(6.151)***	-3.009(-1.807)*
	Market	0.698(17.112)***	0.720(20.335)***	0.767(15.156)***	0.592(10.724)***
	IR(μ_j)	-0.331(-2.047)**	-1.680(-2.448)*	-1.182(-2.365)**	-2.134(-2.044)**
	Variance equation				
	Const	0.000(1.764)*	0.001(7.232)***	0.000(2.577)***	0.000(0.383)
	Arch	0.291(8.664)***	0.044(5.037)***	0.070(8.037)***	0.074(2.154)**
	GARCH	0.693(5.182)***	0.936(9.570)***	0.929(4.300)***	0.909(6.959)***
	Market Vol	-1.769(-0.818)	-3.813(-1.812)*	-5.204(-2.243)**	1.502(0.535)
	IR Vol(v_{2j})	-1,033.867(-0.714)	-1,062.804(-1.124)	-487.550(-0.333)	701.168(0.280)
	LTV	-0.063(-1.850)*	-0.140(-1.751)*	-0.044(-2.982)***	0.110(1.656)*
Developed		Self-Storage	Residential	Healthcare	
Europe	*Mean equation*				
	Const	0.113(0.982)	0.027(0.590)	0.068(1.672)*	
	GARCH term	0.586(1.377)	-0.001(-0.351)	-3.753(-2.300)**	
	Market	0.595(7.537)***	0.536(9.160)***	0.286(4.073)***	
	IR(μ_j)	-2.977(-1.771)*	-1.459(-2.037)**	1.144(0.839)	
	Variance equation				
	Const	0.000(2.310)**	0.001(1.664)*	0.000(2.511)**	
	Arch	0.056(2.185)**	0.459(1.984)*	0.009(2.308)**	
	GARCH	0.927(4.356)***	0.524(6.687)***	0.981(7.208)***	
	Market Vol	-1.204(-0.424)*	0.795(0.265)	0.731(0.273)	
	IR Vol(v_{2j})	-299.355(-0.972)	-1,112.001(-0.388)	-1,252.264(-1.746)*	
	LTV	0.173(1.711)*	0.083(0.887)	-0.024(-0.384)	

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level
Sources: Authors' compilation/analysis

Appendix 8. Developed Europe GARCH-M 10y GBY results: Oct 2010 - Dec 2022

		Diversified	Office	Retail	Industrial
	Mean equation				
	Const	0.013(0.410)	-1.675(-0.525)	-0.038(-1.658)*	-0.004(-0.104)
	GARCH term	-0.419(-2.056)**	-0.565(-1.742)*	1.025(4.072)***	-1.381(-1.777)*
	Market	0.709(15.433)***	0.750(21.471)***	0.769(15.065)***	0.603(11.427)***
	IR(μ_j)	-0.204(-0.551)	-1.437(-1.872)*	-0.013(-0.032)	-0.855(-1.751)*
	Variance equation				
	Const	0.000(2.018)**	0.000(2.885)***	0.001(2.721)***	0.000(0.487)
	Arch	0.096(3.868)***	0.001(2.528)**	0.018(7.447)***	0.087(2.119)**
	GARCH	0.873(9.125)***	0.974(5.745)***	0.964(4.007)***	0.892(6.225)*
	Market Vol	-2.338(-2.219)**	-2.001(-0.713)	-4.690(-2.230)**	0.351(0.124)
	IR Vol(v_{2j})	2777.985(0.569)	1,036.561(1.054)	7,708.196(1.689)***	-1,274.313(-0.169)
	LTV	-0.079(-2.138)*	0.027(0.167)	-0.060(-2.023)**	0.125(1.676)*
Developed Europe		**Self-Storage**	**Residential**	**Healthcare**	
	Mean equation				
	Const	1.199(0.317)	0.034(0.356)	0.042(1.718)*	
	GARCH term	0.243(0.330)	-0.002(-0.356)	-3.611(-2.101)**	
	Market	0.610(8.850)***	0.498(7.508)***	0.208(2.992)***	
	IR(μ_j)	-1.247(-1.666)*	-0.152(-2.302)**	0.089(0.167)	
	Variance equation				
	Const	0.000(4.589)***	0.001(3.795)***	0.000(3.597)***	
	Arch	0.002(3.173)***	0.251(2.730)***	0.072(2.490)**	
	GARCH	0.979(8.672)***	0.734(2.734)***	0.910(8.856)***	
	Market Vol	-3.153(-1.186)	-1.671(-0.552)	3.478(1.807)	
	IR Vol(v_{2j})	8,224.950(1.145)	-9,099.582(-1.352)	-4,665.910(-1.899)*	
	LTV	0.110(1.726)*	0.144(2.142)**	0.029(0.565)	

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level
Sources: Authors' compilation/analysis

European Public
Real Estate Association

Square de Meeus, 23
1000 Brussels, Belgium

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F +32 (0) 2739 1020

W www.epra.com
E info@epra.com

Appendix 9. Developed Europe GARCH-M 10Y-2Y Spread results: Oct 2010 - Dec 2022

	Diversified	Office	Retail	Industrial
Mean equation				
Const	0.003(0.111)	-0.111(-0.851)	-0.106(-3.003)***	0.027(0.971)
GARCH term	-1.537(-2.210)**	-2.477(-1.770)*	0.802(5.841)***	-3.549(1.688)**
Market	0.725(15.360)***	0.747(16.130)***	0.684(7.731)***	0.607(11.188)***
IR(μ_j)	0.210(1.742)**	0.041(2.055)**	0.222(2.437)**	0.575(0.775)
Variance equation				
Const	0.000(2.505)**	0.000(1.920)*	0.001(3.938)***	0.000(0.453)
Arch	0.090(4.815)***	0.057(6.969)***	0.070(1.857)*	0.075(1.737)*
GARCH	0.876(9.563)***	0.925(2.674)***	0.924(4.094)***	0.914(7.409)***
Market Vol	-2.703(-1.658)*	-3.445(-1.367)	-1.403(-0.395)	-1.175(-0.433)
IR Vol(v_{2j})	-11.182(-1.719)*	-18.857(-1.756)*	0.535(0.021)	6.165(0.558)
LTV	-0.017(-2.556)***	-0.040(-0.298)	-0.155(-1.768)*	0.041(0.607)

Developed Europe

	Self-Storage	Residential	Healthcare
Mean equation			
Const	0.171(1.674)*	-0.115(-1.246)	0.044(1.717)*
GARCH term	-2.792(-1.738)*	-0.018(-1.233)	-3.234(-2.228)**
Market	0.645(8.329)***	0.511(7.715)***	0.280(4.134)***
IR(μ_j)	0.083(0.086)	0.098(2.134)**	0.151(1.216)
Variance equation			
Const	0.000(2.173)**	0.001(2.163)**	0.000(1.837)*
Arch	0.046(2.287)**	0.334(1.807)*	0.011(2.253)**
GARCH	0.943(5.062)***	0.647(2.549)**	0.981(4.618)***
Market Vol	-4.760(-1.899)*	-1.133(-0.453)	2.240(1.024)
IR Vol(v_{2j})	8.360(0.354)	26.903(1.350)	17.189(1.307)
LTV	-0.016(-0.133)	0.018(0.273)	0.001(0.028)

Note: () Z-statistics; * Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level
Sources: Authors' compilation/analysis

Appendix 10. Risk-adjusted performance of US LRE sub-sectors

Average Annual Return	Bonds	Stocks	Composite	Diversified	Office	Retail	Industrial	Residential	Healthcare	Self-Storage	Lodging
Dec 2000 - Apr 2004	4.55%	-3.83%	14.81%								
May 2004 - Jul 2007	4.53%	11.02%	20.66%								
Aug 2007 - Oct 2015	2.84%	6.81%	6.31%	2.58%	3.57%	6.18%	-2.98%	10.32%	12.02%	20.03%	-0.35%
Nov 2015 - May 2019	2.37%	10.34%	6.63%	9.04%	4.91%	-1.44%	20.51%	10.84%	9.12%	6.56%	4.90%
Jun 2019 - Feb 2022	1.36%	20.60%	8.53%	-0.37%	2.42%	2.18%	26.05%	12.86%	1.46%	22.39%	-1.52%
Annual Downside Risk	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**	**Healthcare**	**Self-Storage**	**Lodging**
Dec 2000 - Apr 2004	1.45%	12.41%	12.07%								
May 2004 - Jul 2007	0.73%	5.60%	11.92%								
Aug 2007 - Oct 2015	1.85%	12.40%	20.63%	22.07%	21.06%	22.65%	31.62%	19.39%	18.76%	17.43%	26.39%
Nov 2015 - May 2019	1.13%	9.16%	9.20%	10.71%	10.78%	10.97%	11.67%	9.61%	12.47%	11.62%	15.18%
Jun 2019 - Feb 2022	1.23%	13.45%	17.48%	22.73%	16.51%	28.07%	13.97%	16.78%	22.56%	15.32%	26.71%
Sortino Ratio	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**	**Healthcare**	**Self-Storage**	**Lodging**
Dec 2000 - Apr 2004	3.13	-0.03	0.10								
May 2004 - Jul 2007	6.20	0.16	0.13								
Aug 2007 - Oct 2015	1.54	0.04	0.02	0.01	0.01	0.02	-0.01	0.04	0.05	0.09	0.00
Nov 2015 - May 2019	2.10	0.09	0.06	0.07	0.04	-0.01	0.13	0.09	0.06	0.05	0.03
Jun 2019 - Feb 2022	1.11	0.12	0.04	0.00	0.01	0.01	0.14	0.06	0.01	0.11	0.00

Sources: Authors' compilation/analysis

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1000 Brussels, Belgium

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Appendix 11. Risk-adjusted performance of Developed European LRE sub-sectors

Average Annual Return	Bonds	Stocks	Composite	Diversified	Office	Retail	Industrial	Residential	Healthcare	Self-Storage
Dec 2000 - Apr 2004	4.66%	-0.32%	9.29%							
May 2004 - Jul 2007	3.86%	23.60%	23.67%							
Aug 2007 - Oct 2015	3.35%	0.29%	3.81%	3.59%	7.13%	3.04%	-2.48%	2.71%	3.46%	6.63%
Nov 2015 - May 2019	1.11%	3.09%	1.97%	0.33%	5.92%	-13.03%	11.24%	15.39%	3.40%	10.49%
Jun 2019 - Feb 2022	0.25%	10.05%	5.38%	5.79%	2.59%	-12.88%	27.30%	4.78%	7.67%	24.09%
Annual Downside Risk	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**	**Healthcare**	**Self-Storage**
Dec 2000 - Apr 2004	1.16%	14.49%	10.34%							
May 2004 - Jul 2007	0.95%	6.88%	10.51%							
Aug 2007 - Oct 2015	2.89%	16.02%	14.06%	14.30%	12.32%	14.98%	23.32%	23.28%	15.80%	19.70%
Nov 2015 - May 2019	0.56%	9.18%	8.46%	8.86%	9.04%	10.82%	10.18%	10.66%	8.43%	12.83%
Jun 2019 - Feb 2022	0.47%	14.57%	15.98%	18.45%	16.46%	31.28%	13.88%	13.20%	11.34%	17.81%
Sortino Ratio	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**	**Healthcare**	**Self-Storage**
Dec 2000 - Apr 2004	4.02	0.00	0.07							
May 2004 - Jul 2007	4.05	0.26	0.17							
Aug 2007 - Oct 2015	1.16	0.00	0.02	0.02	0.05	0.02	-0.01	0.01	0.02	0.03
Nov 2015 - May 2019	2.00	0.03	0.02	0.00	0.05	-0.11	0.09	0.11	0.03	0.07
Jun 2019 - Feb 2022	0.54	0.05	0.03	0.03	0.01	-0.04	0.15	0.03	0.05	0.10

Sources: Authors' compilation/analysis

Appendix 12. Risk-adjusted performance of UK LRE sub-sectors

Average Annual Return	Bonds	Stocks	Composite	Diversified	Office	Retail	Industrial	Residential	Healthcare	Self-Storage
Dec 2000 - Apr 2004	4.79%	-5.28%	10.15%							
May 2004 - Jul 2007	4.66%	14.78%	20.11%							
Aug 2007 - Oct 2015	3.08%	3.66%	1.70%	2.32%	9.37%	-0.99%	-4.26%	0.95%	4.22%	7.41%
Nov 2015 - May 2019	1.35%	7.61%	-2.32%	-6.08%	-1.70%	-20.80%	14.83%	6.76%	9.95%	17.49%
Jun 2019 - Feb 2022	0.66%	4.94%	7.47%	3.07%	0.00%	-38.99%	25.91%	5.85%	3.56%	23.50%
Annual Downside Risk	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**	**Healthcare**	**Self-Storage**
Dec 2000 - Apr 2004	0.78%	11.84%	12.26%							
May 2004 - Jul 2007	0.78%	5.94%	11.68%							
Aug 2007 - Oct 2015	2.36%	11.13%	16.86%	16.02%	17.68%	18.82%	25.78%	32.48%	13.10%	20.30%
Nov 2015 - May 2019	0.60%	6.63%	9.41%	10.45%	16.08%	15.12%	8.12%	8.88%	6.57%	10.05%
Jun 2019 - Feb 2022	0.71%	12.06%	14.97%	18.90%	17.49%	45.39%	13.26%	16.99%	9.79%	16.03%
Sortino Ratio	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**	**Healthcare**	**Self-Storage**
Dec 2000 - Apr 2004	6.15	-0.04	0.07							
May 2004 - Jul 2007	6.01	0.19	0.13							
Aug 2007 - Oct 2015	1.31	0.03	0.01	0.01	0.04	0.00	-0.01	0.00	0.03	0.03
Nov 2015 - May 2019	2.23	0.09	-0.02	-0.05	-0.01	-0.13	0.14	0.06	0.12	0.13
Jun 2019 - Feb 2022	0.93	0.03	0.04	0.01	0.00	-0.09	0.15	0.03	0.03	0.11

Sources: Authors' compilation/analysis

Appendix 13. Risk-adjusted performance of Eurozone LRE sub-sectors

Average Annual Return	Bonds	Stocks	Composite	Diversified	Office	Retail	Industrial	Residential
Dec 2000 - Apr 2004	4.66%	-10.52%	12.93%					
May 2004 - Jul 2007	3.86%	20.78%	26.51%					
Aug 2007 - Oct 2015	3.35%	1.64%	4.42%	2.30%	1.30%	7.03%	7.72%	3.13%
Nov 2015 - May 2019	1.11%	3.71%	6.05%	11.98%	6.48%	-9.89%	26.87%	16.94%
Jun 2019 - Feb 2022	0.25%	9.31%	0.22%	-3.81%	1.32%	-10.38%	23.35%	4.10%
Annual Downside Risk	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**
Dec 2000 - Apr 2004	1.16%	16.61%	9.33%					
May 2004 - Jul 2007	0.95%	7.24%	11.20%					
Aug 2007 - Oct 2015	2.89%	13.92%	14.58%	15.12%	14.59%	14.93%	21.04%	23.23%
Nov 2015 - May 2019	0.56%	9.23%	8.74%	7.03%	8.62%	10.65%	10.61%	11.41%
Jun 2019 - Feb 2022	0.47%	14.35%	16.09%	23.87%	16.39%	30.10%	15.38%	13.08%
Sortino Ratio	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**
Dec 2000 - Apr 2004	4.02	-0.06	0.11					
May 2004 - Jul 2007	4.05	0.22	0.18					
Aug 2007 - Oct 2015	1.16	0.01	0.02	0.01	0.01	0.04	0.03	0.01
Nov 2015 - May 2019	2.00	0.03	0.06	0.13	0.06	-0.08	0.19	0.12
Jun 2019 - Feb 2022	0.54	0.05	0.00	-0.01	0.01	-0.03	0.11	0.03

Sources: Authors' compilation/analysis

Appendix 14. Risk-adjusted performance of Global LRE sub-sectors

Average Annual Return	Bonds	Stocks	Composite	Diversified	Office	Retail	Industrial	Residential	Healthcare	Self-Storage	Lodging
Dec 2000 - Apr 2004	0.76%	-4.23%	3.32%								
May 2004 - Jul 2007	0.37%	15.67%	21.14%								
Aug 2007 - Oct 2015	0.33%	4.13%	5.60%	2.14%	5.85%	7.18%	-3.05%	10.48%	14.03%	22.19%	2.21%
Nov 2015 - May 2019	0.24%	8.16%	6.05%	4.94%	6.19%	-1.19%	18.39%	12.17%	8.48%	6.48%	4.97%
Jun 2019 - Feb 2022	0.06%	15.78%	5.52%	-0.27%	1.63%	-0.93%	23.47%	10.20%	1.54%	21.81%	-3.45%
Annual Downside Risk	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**	**Healthcare**	**Self-Storage**	**Lodging**
Dec 2000 - Apr 2004	6.17%	12.08%	10.41%								
May 2004 - Jul 2007	4.24%	5.85%	9.72%								
Aug 2007 - Oct 2015	5.54%	11.92%	14.62%	14.45%	13.64%	15.49%	25.59%	15.12%	17.33%	15.53%	24.31%
Nov 2015 - May 2019	4.94%	8.23%	7.16%	6.63%	7.72%	8.68%	8.60%	8.93%	11.69%	12.51%	14.13%
Jun 2019 - Feb 2022	3.58%	12.21%	15.82%	16.19%	15.20%	25.65%	12.97%	14.15%	20.79%	14.53%	27.34%
Sortino Ratio	**Bonds**	**Stocks**	**Composite**	**Diversified**	**Office**	**Retail**	**Industrial**	**Residential**	**Healthcare**	**Self-Storage**	**Lodging**
Dec 2000 - Apr 2004	0.12	-0.03	0.03								
May 2004 - Jul 2007	0.09	0.21	0.17								
Aug 2007 - Oct 2015	0.06	0.03	0.03	0.01	0.03	0.04	-0.01	0.06	0.06	0.11	0.01
Nov 2015 - May 2019	0.05	0.08	0.07	0.06	0.06	-0.01	0.16	0.11	0.06	0.04	0.03
Jun 2019 - Feb 2022	0.02	0.10	0.03	0.00	0.01	0.00	0.14	0.06	0.01	0.11	-0.01

Sources: Authors' compilation/analysis

Appendix 15. LRE sub-sectors average allocations in optimum downside-risk portfolio: Interest rate cut cycles

		Composite	Diversified	Office	Retail	Industrial	Residential	Healthcare	Self-storage	Lodging
Panel A: Interest rate cut cycles										
	Global	70.74%								
	US	53.65%								
Dec 2000 - Apr 2004	UK	52.46%								
	Eurozone	54.81%								
	Developed Europe	54.72%								
	Global	51.80%	0.46%	56.18%	57.47%	0.00%	63.93%	59.90%	62.02%	1.21%
	US	0.03%	0.00%	0.00%	0.00%	0.00%	44.34%	48.29%	53.56%	0.00%
Aug 2007 - Oct 2015	UK	0.22%	0.07%	56.04%	0.02%	0.00%	0.05%	51.24%	55.22%	
	Eurozone	58.43%	2.52%	0.84%	57.86%	55.59%	0.28%			
	Developed Europe	58.87%	58.90%	45.48%	2.50%	0.62%	0.17%	57.37%	56.42%	
	Global	0.17%	0.31%	0.31%	0.10%	50.53%	0.10%	0.00%	49.61%	0.00%
	US	0.00%	0.00%	0.00%	0.00%	44.32%	0.00%	0.03%	39.34%	0.18%
Jun 2019 - Feb 2022	UK	48.26%	0.02%	0.02%	0.02%	52.22%	28.50%	23.08%	51.68%	
	Eurozone	0.03%	0.05%	0.05%	0.03%	2.05%	3.02%			
	Developed Europe	0.06%	0.05%	0.08%	0.03%	51.44%	0.01%	24.42%	50.73%	

Sources: Authors' compilation/analysis

Appendix 16. LRE sub-sectors average allocations in optimum downside-risk portfolio: Interest rate hike cycles

		Composite	Diversified	Office	Retail	Industrial	Residential	Healthcare	Self-storage	Lodging
Panel B: Interest rate hike cycles										
	Global	46.73%								
	US	44.51%								
May 2004 - Jul 2007	UK	37.46%								
	Eurozone	38.32%								
	Developed Europe	37.99%								
	Global	24.24%	5.96%	19.83%	0.89%	66.01%	57.11%	51.42%	16.10%	1.05%
	US	0.00%	6.13%	0.00%	0.00%	53.90%	37.46%	10.64%	8.69%	0.01%
Nov 2015 - May 2019	UK	0.07%	0.06%	0.00%	0.00%	52.16%	7.78%	46.25%	48.30%	
	Eurozone	52.76%	53.65%	52.83%	0.05%	52.00%	51.94%			
	Developed Europe	0.00%	0.00%	52.40%	0.01%	51.95%	52.13%	42.15%	51.42%	

Sources: Authors' compilation/analysis