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Listed Real Estate as an Inflation Hedge across Regimes

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Executive Summary

Due to the high levels of money supply increases by central banks in response to the COVID-19 pandemic, the high levels of debt, and military confrontations, we are experiencing large price swings in energy and commodity markets and a global economic slack. In October 2022, inflation in the euro area rose to 9.9% year-on-year, the highest level since the introduction of the Euro currency. In the UK, the figure has just become a double-digit one. In the U.S., the latest figure suggests a slightly lower rate (about 8%), but still a figure that is markedly higher than those of the recent past. Central banks like the European Central Bank, the Bank of England, or the Federal Reserve are already attempting to curb the massive inflation with higher interest rates. With the unexpectedly strong boost to inflation, further interest rate increases were announced and implemented. This clearly provides for a distressed economic background that presents challenges in determining the allocation of a portfolio across the various asset classes.

In this context, it is important to take a fresh look at listed real estate's capability to hedge against changes in purchasing power. Whereas much research had been carried out on this topic in the 1990s and 2000s, the question must be revisited using the current circumstances and state-of-the-art estimation techniques. It is also important to take advantage of the longer time series that are now available for many asset classes. Against this background, this paper aims at deepening our understanding of the inflation-hedging characteristics of listed real estate and of a wide array of other asset classes. This is undertaken for five economies, considering both the expected and unexpected inflation components, accounting for both crisis and non-crisis periods, and testing various models including some that aim at finding the optimal allocation to listed real estate in the context of achieving a minimum rate of real return on a portfolio. Obviously, the topic of listed real estate as a hedge against inflation and more generally of the inflation-hedging ability of various asset classes is of great interest to long-term institutional investors (particularly pension funds, which usually operate under inflation-linked liability constraints) and individual investors, for whom real-term capital preservation is a minimal objective.

Using monthly return data for listed real estate companies from 1990 to 2021 for five economies (the US, UK, Eurozone, Japan, and Australia), our paper overall finds inflation-hedging properties for listed real estate (LRE). In more specific terms, listed real estate assets are a reliable hedge against inflation in the long-term, but mainly based on expected inflation. The reason for this can be attributed to the fact that many commercial leases are inflation-adjusted, resulting in a positive adjustment in the capital value of assets. For the Eurozone and Japan, the evidence is even stronger as those countries experience long-term positive inflation hedging against both expected and unexpected inflation. Further, in non-crisis periods, LRE may provide an adequate level of protection against inflation in the short-term, however the level of protection decreases during periods of economic turmoil. According to our analysis at the sectoral level, office properties have positive protection characteristics against expected and unexpected inflation in the United States, the United Kingdom, and the Eurozone. The evidence for other sectors is not as clear cut, albeit the sector-level analyses are performed over a shorter period than the aggregate analyses due to data availability.

Our paper also demonstrates that LRE can play a significant role in the inflation-hedging portfolio of an investor. This is achieved by considering a portfolio target real return of 3 percent per annum over a two-year period. The average allocations for the US, UK, Japan, Australia, and the Eurozone over the entire period are 6.35%, 19.21%, 16.02%, 48.81%, and 31.21%, respectively, clearly highlighting the importance of holding listed real estate investments in a mixed-asset portfolio. We maintain that optimizing across asset classes using expected shortfall as the risk measurement provides for more realistic and less extreme allocations to listed real estate than when the classic mean-variance approach is used, as using variance as the risk measurement may not correspond best to investors' objectives. The inflation-hedging portfolio provides a higher risk-adjusted return (Sharpe ratio) than the mean-variance approach for the US, Japan, and the Eurozone. It also achieves a lower shortfall probability and a higher average expected return than the mean-variance portfolio in all five regions.

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1. Introduction

Due to the high levels of money supply increases by central banks in response to the COVID-19 pandemic, the high levels of debt, and military confrontations, we are experiencing large price swings in energy and commodity markets and a global economic slack. In October 2022, inflation in the euro area rose to 9.9% year-on-year, the highest level since the introduction of the Euro currency. Central banks like the European Central Bank or the Federal Reserve are already attempting to curb the massive inflation with higher interest rates. With the unexpectedly strong boost to inflation, further interest rate increases were announced and implemented. As a result, it is important to take a fresh look at real estate's capability to hedge against changes in purchasing power using state-of-the-art estimation techniques. Against this background, this paper aims to deepen our understanding of the inflation-hedging characteristics of real estate and other asset classes. It is of particular interest to long-term institutional investors (particularly pension funds, which usually operate under inflation-linked liability constraints) and individual investors, for whom real-term capital preservation is a minimal objective.

Some assets are more suited to hedging inflation than others, depending on the country, sector, or time horizon. Real estate has been regarded as one of the best inflation hedges by two mechanisms: (1) Rent or lease payments (tenant leases contain rent escalation clauses and/or pass expense increases through to tenants) and (2) Land values and building costs (land values and building costs typically rise with inflation) (Ruhmann and Woolston, 2011). However, empirical evidence, especially for listed real estate, is mixed. Gyourko and Linneman (1988) find that REITs may protect against expected inflation but not against unexpected inflation. In contrast, Park et al. (1990) find that equity REITs are negatively associated with expected and unexpected inflation. One reason why REITs serve as a paradoxical hedge, according to Titman and Warga (1989), is that they are the catalyst, rather than the response, to changes in the rate of inflation. Contemporaneous returns on equity REITs, in particular, anticipate the rate of inflation in the future. Glascock et al. (2002) find that the observation that REIT returns are perverse inflation hedges is spurious. The observed negative relationship between REIT returns and inflation is a manifestation of the effects of changes in monetary policies. For direct real estate, Hoesli et al. (1997) show that while the capital appreciation component of real estate returns offers a hedge against unexpected inflation, the income component does not. Hartzell et al. (1987) and Gyourko and Linneman (1988) find that most income-producing properties exhibit a moderately strong positive relationship with unanticipated inflation in addition to expected inflation. Much of the research is outdated, both in terms of the characteristics of markets and the methods that are used, and there is a need to revisit this important topic.

This paper extends the literature in two ways. First, we allow for non-linear inflation-hedging characteristics. Most previous literature combines the Fama and Schwert (1977) framework (which distinguishes the expected and unexpected inflation components) and the cointegration technique (which differentiates long-term equilibrium and short-term dynamics) (see, e.g., Hoesli and Hamelink, 1997, Liu et al., 1997, Hoesli et al., 2008, and many others). However, all these studies assume a stable equilibrium, which may be violated by the change in the monetary policy and business cycles. For instance, Glascock et al. (2002) show that the relation between REIT returns and inflation can be influenced by monetary policies. Demary and Voigtländer (2009) argue that offices partly protect against inflation because worsening economic perspectives (inflation) alleviate the demand for office space. By splitting the sample period, National and Low (2000) find that the inflation-hedging characteristics of assets differ in different inflationary environments, indicating time-varying inflation-hedging characteristics. Beckmann and Czudaj (2013) show that the adjustment of gold prices to inflation is characterized by regime dependence, implying that the usefulness of gold as an inflation hedge crucially depends on the time horizon. Given the long-lasting low-interest-rate environment and the increased uncertainty in the global economy, the inflation-hedging characteristics of real estate may differ from previous periods.

Second, this project compares the hedging characteristics across asset classes, including real estate, stocks, and gold using an inflation hedging portfolio. The hedging ability of other assets, such as infrastructure (Bitsch et al., 2010, Wurstbauer and Schäfers, 2015), stocks (Bodie, 1976), gold (Lucey et al., 2017), and white precious metals (Bampinas and Panagiotidis, 2015, Bilgin et al., 2018) has been intensively studied in the literature. Regarding real estate, many studies also exist, as highlighted above, and previous literature has often focused on whether differences exist across property types (Hoesli, 1994, Ganesan and Chiang, 1998, National and Low, 2000). However, there is still a lack of conclusive evidence regarding the inflation-hedging ability across different asset classes, i.e., in a diversified portfolio. Most of the research has been done within a mean-variance framework.

However, using variance as the risk measure may not be what corresponds best to investors' objectives, as variance treats both upside and downside risk as the same. Because investors usually consider the upside risk to be favorable, the use of variance seems inappropriate. In reality, listed real estate returns have been shown to be non-normal (Hutson and Stevenson, 2010, Giannotti and Mattarocci, 2013). Lizieri et al. (2022) also show that the mean-variance approach often yields extreme and unrealistic asset allocations to listed real estate. Given that investors may only consider downside risk, we use a more realistic measurement of risk – the expected shortfall, which focuses on the risk of being far below the expected real return (i.e., the downside risk). A shortfall probability risk measure for portfolio optimizations has been conducted before, for example, by Leibowitz and Henriksson (1989), Leibowitz and Kogelman (1991), Lucas and Klaassen (1998), Smith and Gould (2007), and Brière and Signori (2012). In this paper, we apply this measurement to construct an inflation-hedging portfolio.

Using monthly return data for listed real estate companies from 1990 to 2021 for five economies, our paper confirms the inflation-hedging properties for listed real estate (LRE). Listed real estate assets are a reliable hedge against inflation in the long-term, but mainly based on expected inflation. The reason for this can be attributed to the fact that many commercial leases are inflation-adjusted, resulting in a positive adjustment in the capital value. In all four regions, listed real estate shows long-term positive inflation hedging against expected inflation. In Eurozone and Japan, we also see long-term positive inflation hedging against unexpected inflation. Further, in non-crisis periods, LRE may provide an adequate level of protection against inflation in the short-term. However, the level of protection decreases during periods of economic turmoil. According to our analysis at the sectoral level, office properties have positive protection characteristics against expected and unexpected inflation in the United States, the United Kingdom, and the Eurozone in the long term. In the short-term, the US office, US healthcare, and UK industrial sectors show some positive inflation-hedging properties. Finally, we demonstrate that LRE can play a significant role in the inflation-hedging portfolio of an investor. The average allocations for the US, UK, Japan, Australia, and the Eurozone over the entire period are 6.35%, 19.21%, 16.02%, 48.81%, and 31.21%, respectively. The inflation-hedging portfolio also provides a higher risk-adjusted return than the mean-variance approach for the US, UK, Japan, and the Eurozone.

The remainder of the paper is organized as follows. We next discuss the data and methods we use to test the inflation-hedging ability of the various asset classes. The following section presents our results. The next section discusses inflation-hedging portfolios and compares those with traditional mean-variance portfolios. A final section concludes.

2. Data and Method

a. Data Description

Data were compiled for the US, the Eurozone, the UK, Japan, and Australia. Its length and scope were largely determined by the availability of real estate and macroeconomic data. We use time-series variables that are available monthly from 1990 to the end of 2021. LRE total return indexes come from the European Public Real Estate Association (EPRA). Stock total return indexes are obtained from Refinitiv Datastream. Specifically, these are the S&P 500 index for the US, the FTSE 250 index for the UK, the STOXX 600 index for the Eurozone, the Nikkei 500 index for Japan, and the S&P/ASX 200 index for Australia. Additionally, we also include the price of gold, silver, and oil in US Dollars, along with the total return index of the S&P GSCI Agriculture and the real three-month Treasury Bill rates, which is a proxy for the risk-free rate, as well as the nominal GDP.[1]

Table 1 displays the corresponding summary statistics of our data. The index values make it possible to infer that the highest average total return is recorded the US with 11.27% annually, while Japan experienced the lowest with 1.36% annually. The Eurozone has an average total return of 7.15% annually, which is significantly higher than in the UK (5.28% annually). The US faces the highest average expected inflation rate of 2.85%, while Japan

[1] Because GDP is only available on a quarterly basis, we use temporal disaggregation. Temporal disaggregation methods are used to disaggregate and interpolate a low frequency time series to a higher frequency series. Using real GDP provides similar results.

came across with the lowest rate of 1.63%. In the US, the average unexpected inflation rate is almost equal to zero, while Japan underwent a negative rate of unexpected inflation (-1.28%).

Table 1: Summary Statistics

	Mean	Std.	Max.	Min.	SP	Obs.
			Panel A: US			
LRE	3097.881	2461.337	9906.180	200.640	1990/01	384
Stocks	1422.951	900.947	4725.79	304.59	1990/01	384
Oil	48.099	28.516	134.630	11.380	1990/01	384
Gold	805.261	520.977	1947.400	256.000	1990/01	384
Silver	12.306	8.702	42.100	3.580	1990/01	384
Agricultural Commodities	272.200	90.940	564.600	150.500	1990/01	384
GDP (mio. USD)	13,289,102	4,949,983	24,163,226	5,856,250	1990/01	384
Interest rate	2.229	2.066	8.329	0.000	1990/01	384
EI index	166.218	40.609	248.352	100.000	1990/01	384
UI index	94.233	3.907	100.376	86.617	1990/01	384
			Panel B: EU			
LRE	2567.590	1936.891	7063.900	438.270	1995/01	336
Stocks	297.887	78.945	486.755	118.530	1995/01	336
Oil	53.215	28.154	134.630	11.38	1995/01	336
Gold	886.539	528.508	1947.400	256.000	1995/01	336
Silver	12.306	8.702	42.100	3.580	1990/01	336
Agricultural Commodities	272.200	90.940	564.600	150.500	1990/01	336
GDP (mio. EUR)	9,021,085	1,915,900	12,663,153	5,614,511	1995/01	336
Interest rate	1.563	1.642	6.390	-0.311	1995/01	336
EI index	139.631	24.990	187.099	100.000	1995/01	336
UI index	103.855	2.551	107.679	96.813	1995/01	336
			Panel C: UK			
LRE	1872.619	1021.158	4133.870	353.500	1990/01	384
Stocks	6054.645	5057.831	19114.280	644.06	1990/01	384
Oil	48.099	28.516	134.630	11.380	1990/01	384
Gold	805.261	520.977	1947.400	256.000	1990/01	384
Silver	12.306	8.702	42.100	3.580	1990/01	384
Agricultural Commodities	272.200	90.940	564.600	150.500	1990/01	384

GDP (mio. GBP)	1,640,917	285,568	2,130,386	1,167,190	1990/01	384
Interest rate	3.245	3.273	15.198	0.015	1990/01	384
EI index	157.240	32.343	218.385	100.000	1990/01	384
UI index	97.901	1.610	102.118	94.664	1990/01	384
Panel D: Japan						
LRE	2362.835	1190.297	4900.260	869.760	1990/01	384
Stocks	1378.353	352.079	2737.570	719.490	1990/01	384
Oil	48.099	28.516	134.630	11.380	1990/01	384
Gold	805.261	520.977	1947.400	256.000	1990/01	384
Silver	12.306	8.702	42.100	3.580	1990/01	384
Agricultural Commodities	272.200	90.940	564.600	150.500	1990/01	384
GDP (mio. JPY)	499,635,182	36,882,773	560,806,963	408,421,413	1990/01	384
Interest rate	0.948	1.906	8.288	-0.629	1990/01	384
EI index	131.601	19.080	168.429	99.649	1990/01	384
UI index	83.678	11.231	101.742	66.492	1990/01	384
Panel E: Australia						
LRE	1397.711	843.556	3295.590	217.310	1992/06	355
Stocks	3105.073	2051.325	8557.381	484.540	1992/06	355
Oil	50.178	28.641	134.630	11.380	1992/06	355
Gold	840.915	526.048	1947.400	256.000	1992/06	355
Silver	12.306	8.702	42.100	3.580	1990/01	355
Agricultural Commodities	272.200	90.940	564.600	150.500	1990/01	355
GDP (mio. AUD)	1,103,652	545,518	2,259,806	406,777	1992/06	355
Interest rate	3.060	1.785	7.343	0.005	1992/06	355
EI index	167.052	38.692	236.536	108.989	1992/06	355
UI index	95.636	1.982	98.998	91.667	1992/06	355

Notes: US stands for United States of America, EU stands for Eurozone, UK for United Kingdom, JPN for Japan, and AU for Australia. LRE denotes the FTSE/EPRA/NAREIT real estate stock total return index. Stocks denotes for each country the corresponding total return of the stock market index. Oil denotes the oil price in US Dollars. Gold denotes the gold price in US Dollars. Silver denotes the silver price in US Dollars. Agricultural Commodities denotes the S&P GSCI Agriculture total return index. GDP stands for GDP of each country. Interest rate are the 3-month treasury bill rates. EI index and UI index stand for an index of expected and unexpected inflation, respectively. SP denotes the starting point of the time series and Obs. displays the number of observations.

b. Inflation Decomposition

We decompose the observed inflation (I_t) into expected inflation (EI_t) and unexpected inflation (UI_t). Expected inflation is the inflation element that economic agents expect to arise. It is what they have already embedded in their economic choice. Unexpected inflation is the surprise component of inflation which people haven't incorporated in their pricing and costing. We follow Fama and Schwert's (1977) framework to make the decomposition. We can define inflation based on the prior anticipated inflation rate, adjusted for differences between actual inflation and the prior expectation for each period. This leads to a univariate time series approach using Box-Jenkins / ARIMA (1,0,1) procedures to inflation:

$$EI_t = \alpha + \rho I_{t-1} + \varepsilon_t,$$
$$\varepsilon_t = \Theta\varepsilon_{t-1} + e_t. \quad (1)$$

where α, ρ, and Θ are parameters. The fitted value for EI_t is taken as the expected inflation and the residual, e_t, is interpreted as unexpected inflation. In Appendix 1, we show the unconditional correlation matrix of EI_t, UI_t, and I_t.

c. Stationarity and Cointegration

Using the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test for stationarity, we show that all US series are I(1), indicating stationarity in first differences. Similarly, series for the UK, EU, Japan, and Australia are I(1) and therefore, in first-difference stationary. The results are shown in Appendix 2.

Considering that the variables are I(1) series, we further perform the cointegration test using the trace test. The trace test investigates the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors. To determine ranks and estimate coefficients, maximum likelihood estimation is used. Accordingly, likelihood ratio tests are as follows:

$$\lambda_{Trace} = -T\sum_{i=1}^{k}\ln(1-\lambda_i) \quad (2)$$

where T is the sample size and λ represents the estimated eigenvalues of the reduced rank of the matrix π.[2] In the process, the sequential test strategy begins with r=0 and is continued until the null hypothesis for the 5% significance level cannot be rejected for the first time. The related value of r ultimately corresponds to the cointegration rank. In this way, there are (n-r) stochastic trends in the system.

d. Markov-Switching Vector Error Correction Model (MS-VECM)

An MS-VECM is used to examine the relationship between the price of assets and expected and unexpected inflation. The parameters of this model are designed to take a constant value in each regime and to shift discretely from one regime to the other with different switching probabilities. The switches between states are assumed to follow an exogenous stochastic process. Consider an M-regime *p*th order MS-VECM, which in general allows for regime shifts in the vector of intercept terms, the autoregressive part, the long-run matrix, and the variance-covariance matrix of the errors:

$$\Delta Y_t = v(s_t) + \Gamma(L)(s_t)\Delta Y_{t-1} + \Pi(s_t)Y_{t-1} + \varepsilon_t, \quad (3)$$

where Δ denotes the difference operator, Y_t represents an N-dimensional vector of time series, $Y_t = [R_t, EI_t, UI_t, X_t]$ and R_t is a vector of asset returns, including stocks, LRE, gold, silver and commodities. X_t are

[2] The coefficients of the co-integrating relationships (co-integration vectors) and of the error correction term are contained in the matrix π, with $\pi = \alpha\beta'$, where β represents a (n×r) matrix of the r co-integrating vectors. The (n×r) matrix α contains the so-called loading parameter, i.e., those coefficients that describe the contribution of the r long-term relationships in the individual equations.

economic control variables such as GDP, real interest rates, and oil prices. $v(s_t)$ denominates a K-dimensional vector of regime-dependent intercept terms. ε_t is a vector of error terms with regime-dependent variance-covariance matrix $\sum(s_t)$, $\varepsilon_t \sim NIID(0, \sum(s_t))$. $\Gamma(L)(s_t)$ is the N×N matrix for the state-dependent short-run dynamics. The stochastic regime-generating process is assumed to be an ergodic, homogenous, and irreducible first-order Markov chain with a finite number of regimes, $s_t \in \{1, \dots, M\}$, and constant transition probabilities:

$$p_{ij} = \Pr(s_{t+1} = j | s_t = i), p_{ij} > 0, \sum_{j=1}^{M} p_{ij} = 1 \ \forall i, j \in \{1, \dots, M\} . \quad (4)$$

The first expression of Eq. (4) gives the probability of switching from regime i to regime j at time t + 1 which is independent of the history of the process. p_{ij} is the element in the ith row and the jth column of the M × M matrix of the transition probabilities *P*. In this paper, we consider two regimes.

3. Empirical Results

a. Long-Term Hedging Properties

Based on the Johansen cointegration test, we identify two cointegration relationships in the US, the UK, and Japan, while the Eurozone has three cointegration relationships. For Australia, no rank could be determined, hence Australia does not have a co-integrating relationship. Table 2 also reports long-term relationships (β-vectors). In each model with a cointegration matrix, the first vector is normalized to the LRE returns, while the second vector is normalized to the general stock market performance. In the case of the Eurozone, the third vector is normalized to the oil price developments.

The MS-VECM representation given in Eq. (3) has been estimated for each country while enabling each parameter to switch between two regimes, including the intercept, the autoregressive elements, the residual variance-covariance matrix, and, most notably, the adjustment parameters to deviations from long-run relationships. Results regarding the long-term relationships of the MS-VECM are presented in Table 2, while Table 3 illustrates the short-term results.

In all models, we find significant long-term relationships between the performance of listed real estate markets and both expected and unexpected inflation. In the long term, LRE can positively hedge against expected inflation in the US, the UK, the Eurozone, and Japan. This can be explained by the fact that many commercial leases may be inflation-adjusted. As a result, the cash flows of commercial properties are expected to increase with inflation. A percent increase in expected inflation is related to a 0.124 percent, a 0.019 percent, a 0.287 percent, and a 0.061 percent increase in expected inflation in the US, the UK, the Eurozone, and Japan, respectively.

For the long-term hedging against unexpected inflation, the results are slightly mixed. In the Eurozone and Japan, LRE positively hedges against unexpected inflation. A percent increase in unexpected inflation is related to a 0.478 percent and a 0.065 percent increase in the return, in the Eurozone and Japan, respectively. However, in US and UK, LRE is not significantly related to unexpected inflation in the long-term relationship. This is consistent with most prior literature, which also finds mixed results in terms of the hedging ability of LRE against unexpected inflation. For instance, Limmack and Ward (1988) found that office and retail properties offered no significant hedge against unexpected inflation.

Moreover, we always find a significantly negative long-term coefficient between stock returns and expected and/or unexpected inflation, indicating that general stocks do not provide an effective long-term hedge against inflation. This finding is in line with previous literature. For instance, using Swiss data, Hoesli (1994) shows that real estate hedges better in the long run than stocks. When the inflation rate is divided into expected and unexpected inflation, stocks exhibit negative coefficients for both expected and unexpected inflation. Meanwhile, the coefficient for unexpected inflation is positive for real estate.

With respect to the long-term equilibrium relationships, we find a positive long-term relationship between LRE returns and oil price in the US and the UK. Furthermore, we observe a positive long-term relationship between the gold price and LRE returns in the US, while we find a negative relationship in the EU. We discover a significant negative long-term elasticity of silver price on LRE returns in the US, the EU, and Japan. In the US and the UK, agricultural commodities have a negative long-term relationship with LRE returns, whereas the EU and Japan show a positive long-term relationship between LRE returns and agricultural commodities. Moreover, we find a negative long-term elasticity of interest rates on LRE returns in the UK, which can be explained by the fact that increasing capital costs lead to lower demand for real estate and, therefore, to lower returns. Besides, we find a negative relationship between LRE returns and GDP in all four economies.[3]

b. Short-Term Hedging Properties

The short-term relationships and the matrices of transition are reported for both regimes in Table 3. The MS-VECM model identifies the transmission matrix from one regime to another for each country. In the US, the probability of staying in Regime 1 is 95.1%, while the probability of switching to Regime 2 is 4.9%. It suggests the dominance of the first regime. Switching from Regime 2 to Regime 1 shows a probability of 18.3%, while staying in Regime 2 shows a probability of 81.7%. The associated probabilities for the Eurozone, the UK, Japan, and Australia are comparable.

To better understand the two regimes, Figure 1 illustrates the switching process for each country. The blue line shows the probability of switching to Regime 1, and the grey area indicates that the probability of Regime 1 is larger than 50%. For comparison purposes, we also illustrate the LRE return in each graph (dashed line). As shown in Figure 1, it is quite obvious that Regime 1 captures the non-crisis and Regime 2 the times of turbulence, particularly for the US, the UK, the Eurozone, and Australia. For instance, crises like the global financial crisis (GFC), the dot-com bubble, or the COVID-19 pandemic appear to lead to a switching process to Regime 1. Meanwhile, we also see a remarkable decrease in LRE returns in Regime 2. However, for Japan, we see that this is not obvious. In the case of Japan, the specific economic development can provide an explanation. A collapse of the asset price bubble in Japan in 1991 resulted in a period of economic stagnation. Between 1995 and 2007, the nominal GDP fell from 5.33 trillion to 4.36 trillion US Dollars. From the early 2000s, the Bank of Japan set out to encourage economic growth through quantitative easing, which indicates the special role of Japan as an economy.

We report the estimation coefficients in Table 3. In the US, we see a significant short-term impact of expected and unexpected inflation on LRE performance in Regime 1 (non-crisis periods). In contrast, unexpected inflation has a significant negative impact on LRE returns in Regime 2 (crisis periods). In other words, in the short term, LRE can hedge against expected and unexpected inflation, but the hedging ability becomes negative during the crisis period. In the UK, expected inflation has a significant positive impact on LRE returns in the short term in Regime 1 (non-crisis periods), but a non-significant impact in Regime 2 (crisis periods). The hedging ability is accordingly lost in times of crisis. In the Eurozone, we find significant perverse hedging characteristics in both regimes. For Australia, we see a positive significant short-term impact of expected inflation on LRE in Regime 1, but perverse hedging attributes in Regime 2.

[3] The negative long-term relationship between GDP and LRE is contradictory to our expectation, which may be due to the merged crises during the sample period. To test our argument, we add a crisis dummy into the long-term relationship equations, and the coefficients for GDP become positive. However, the coefficients for expected and unexpected inflation in the long-term relationships remain very robust. So we keep our baseline model as the one without crisis dummy. Detailed results are available upon request.

Table 2: Long-Term Equilibrium Relationships (β -vectors)

Country	Rank	$r_{LRE,t-1}$	$r_{stock,t-1}$	$r_{oil,t-1}$	$r_{gold,t-1}$	$r_{silver,t-1}$	$r_{agri,t-1}$	GDP_{t-1}	ir_{t-1}	EI_{t-1}	UI_{t-1}
US	**2**	1.000	0.000	0.356**	1.811***	-1.445***	-1.315***	-0.077***	0.113	0.124***	-0.074
		(0.000)	(0.000)	(0.179)	(0.296)	(0.291)	(0.406)	(0.010)	(0.083)	(0.027)	(0.152)
		0.000	1.000	0.333**	1.099***	-0.123	0.185	0.025***	-0.119***	-0.148***	-0.470***
		(0.000)	(0.000)	(0.152)	(0.251)	(0.248)	(0.346)	(0.008)	(0.037)	(0.023)	(0.130)
EU	**3**	1.000	0.000	0.000	-2.932***	-1.123*	2.569***	-0.117***	-0.135	0.287***	0.478***
		(0.000)	(0.000)	(0.000)	(0.985)	(0.649)	(0.834)	(0.021)	(0.148)	(0.056)	(0.104)
		0.000	1.000	0.000	7.026***	-0.715	-3.488***	0.090***	-0.413***	-0.377***	-0.574***
		(0.000)	(0.000)	(0.000)	(1.246)	(0.821)	(1.054)	(0.027)	(0.187)	(0.071)	(0.131)
		0.000	0.000	1.000	5.609**	2.242	-3.210*	0.203***	-0.578*	-0.737***	-1.970***
		(0.000)	(0.000)	(0.000)	(2.216)	(1.461)	(1.875)	(0.048)	(0.332)	(0.126)	(0.234)
UK	**2**	1.000	0.000	0.022***	-0.032	-0.546	-1.176**	-0.058***	-0.173***	0.019**	-0.175
		(0.000)	(0.000)	(0.008)	(0.431)	(0.342)	(0.552)	(0.012)	(0.035)	(0.010)	(0.137)
		0.000	1.000	0.007*	0.035	-0.602***	0.378	-0.045***	-0.053***	-0.008	-0.327***
		(0.000)	(0.000)	(0.004)	(0.238)	(0.189)	(0.305)	(0.007)	(0.019)	(0.006)	(0.076)
JPN	**2**	1.000	0.000	0.012	-0.775	-1.049***	1.495***	-0.088***	0.005	0.061***	0.065***
		(0.000)	(0.000)	(0.008)	(0.535)	(0.406)	(0.499)	(0.021)	(0.054)	(0.027)	(0.042)
		0.000	1.000	-0.016***	-0.592**	0.128	0.501**	-0.063***	-0.123***	-0.042***	-0.100***
		(0.000)	(0.000)	(0.004)	(0.254)	(0.193)	(0.237)	(0.010)	(0.026)	(0.013)	(0.020)

Notes: US stands for United States of America, EU stands for Eurozone, UK for United Kingdom, JPN for Japan. The analysis of the US, EU, UK, and Japan is conducted by using an unrestricted constant. $R_{LRE,t-1}$ denotes the FTSE/EPRA/NAREIT real estate stock total return index. $r_{stock,t-1}$ denotes for each country the corresponding total return of the stock market index. $r_{oil,t-1}$ denotes the oil price in US Dollars. $r_{gold,t-1}$ denotes the gold price in US Dollars. $r_{silver,t-1}$ denotes the silver price in US Dollars. Australia is not reported because the rand of listed real estate, stocks, oil, gold, silver, agricultural, GDP, interest rate, expected and unexpected inflation in Australia is zero, indicating that these variables are not co-integrated. $r_{agri,t-1}$ denotes the total return index of S&P GSCI Agriculture. GDP_{t-1} stands for GDP of each country. ir_{t-1} are the 3-month treasury bill rates. EI_{t-1} and UI_{t-1} stand for expected and unexpected inflation, respectively. Rank denotes the rank of π matrix. Standard errors are included in the parentheses. ***. **, * denotes significance level at 1%, 5% or 10%, respectively.

Table 3: Short-term Coefficients and Transition Probability Matrix

Country		Short-term coefficients for Regime 1 and 2														Transition probability matrix P	
		$\Delta r_{LRE,t-1}$	$\Delta r_{stock,t-1}$	$\Delta r_{oil,t-1}$	$\Delta r_{gold,t-1}$	$\Delta r_{silver,t-1}$	$\Delta r_{agri,t-1}$	ΔGDP_{t-1}	Δir_{t-1}	ΔEI	ΔUI	ECT1	ECT2	ECT3		Regime 1	Regime 2
U.S.	Regime 1	-0.015 (0.070)	0.064 (0.073)	-0.074** (0.028)	-0.069 (0.078)	-0.012 (0.051)	-0.001 (0.005)	0.001 (0.001)	0.022 (0.018)	0.0231* (0.012)	0.025* (0.013)	0.006 (0.008)	0.009 (0.011)		Regime 1	0.951	0.183
	Regime 2	-0.666*** (0.170)	1.041*** (0.296)	0.205** (0.097)	0.456 (0.411)	-0.436** (0.222)	0.291 (0.200)	0.011*** (0.004)	-0.186*** (0.069)	-0.010 (0.035)	-0.168** (0.067)	0.033 (0.026)	-0.018 (0.032)		Regime 2	0.049	0.817
EU	Regime 1	-0.217 (0.279)	0.570** (0.269)	0.007 (0.006)	0.704 (0.627)	-0.427 (0.325)	0.107 (0.194)	0.005 (0.014)	-0.030 (0.126)	-0.112* (0.067)	-0.188** (0.089)	0.004 (0.123)	0.017 (0.026)	-0.001 (0.001)	Regime 1	0.811	0.037
	Regime 2	-0.045 (0.075)	0.181*** (0.069)	0.000 (0.001)	-0.111 (0.080)	-0.017 (0.045)	0.067 (0.047)	0.001 (0.002)	0.009 (0.021)	-0.027*** (0.011)	-0.036** (0.016)	-0.019*** (0.005)	-0.012 (0.013)	0.000 (0.000)	Regime 2	0.189	0.963
UK	Regime 1	-0.032 (0.063)	0.006 (0.080)	-0.001 (0.001)	-0.165*** (0.060)	-0.001 (0.012)	0.146** (0.061)	0.001 (0.001)	-0.024 (0.019)	0.018*** (0.006)	-0.007 (0.012)	0.016*** (0.004)	0.001 (0.024)		Regime 1	0.959	0.270
	Regime 2	0.001 (0.026)	0.587** (0.296)	0.002 (0.006)	0.435 (0.349)	-0.271 (0.221)	-1.125* (0.591)	0.086** (0.036)	0.004 (0.087)	-0.017 (0.224)	-0.122 (0.083)	-0.141** (0.070)	0.236* (0.126)		Regime 2	0.041	0.730
JPN	Regime 1	-0.315*** (0.077)	0.288*** (0.087)	-0.001 (0.001)	-0.707*** (0.100)	0.211*** (0.055)	0.099* (0.055)	-0.004 (0.0038)	0.015 (0.034)	-0.030** (0.015)	-0.056*** (0.015)	0.013* (0.008)	-0.043** (0.017)		Regime 1	0.900	0.040
	Regime 2	-0.203*** (0.054)	0.947*** (0.095)	0.002 (0.002)	0.311** (0.158)	-0.145 (0.090)	0.086 (0.088)	0.004 (0.005)	-0.014 (0.049)	-0.011 (0.021)	0.021 (0.024)	-0.044*** (0.013)	-0.003 (0.025)		Regime 2	0.100	0.960
AUS	Regime 1	-0.125** (0.063)	0.041 (0.066)	-0.002** (0.001)	-0.0710 (0.060)	-0.008 (0.034)	-0.008 (0.049)	-0.002*** (0.001)	-0.027* (0.015)	0.014** (0.008)	0.015 (0.018)				Regime 1	0.990	0.106
	Regime 2	-0.689** (0.271)	0.971* (0.553)	0.003 (0.006)	0.663 (0.768)	-0.236 (0.512)	-1.726*** (0.472)	-0.000 (0.011)	0.613*** (0.170)	-0.129** (0.063)	0.388 (0.465)				Regime 2	0.010	0.894

Notes: US stands for United States of America, EU stands for Eurozone, UK for United Kingdom, JPN for Japan, and AU for Australia. We only report the equation for LRE returns. $r_{LRE,t-1}$ denotes the FTSE/EPRA/NAREIT real estate stock total return index. $r_{stock,t-1}$ denotes for each country the corresponding total return of the stock market index. $r_{oil,t-1}$ denotes the oil price in US Dollars. $R_{gold,t-1}$ denotes the gold price in US Dollars. $r_{silver,t-1}$ denotes the silver price in US Dollars. $r_{agri,t-1}$ denotes the total return index of S&P GSCI Agriculture. GDP_{t-1} stands for GDP of each country. ir_{t-1} are the 3-month treasury bill rates. EI_{t-1} and UI_{t-1} stand for expected and unexpected inflation, respectively. ECT1, ECT2, and ECT3 are the coefficients of error correction terms. Regime 1 and 2 are reported. The transition matrix P reports the transition probabilities of the stochastic process.

To provide a better intuitive overview, we illustrate the restricted[4] time-varying short-term impact of expected and unexpected inflation on LRE returns based on the smoothed transmission probability and the coefficient in each regime:

$$EI_t = p_1 * coefEI_1 + (1 - p_1) * coefEI_2 \tag{5}$$
$$UI_t = p_1 * coefUI_1 + (1 - p_1) * coefUI_2 \tag{6}$$

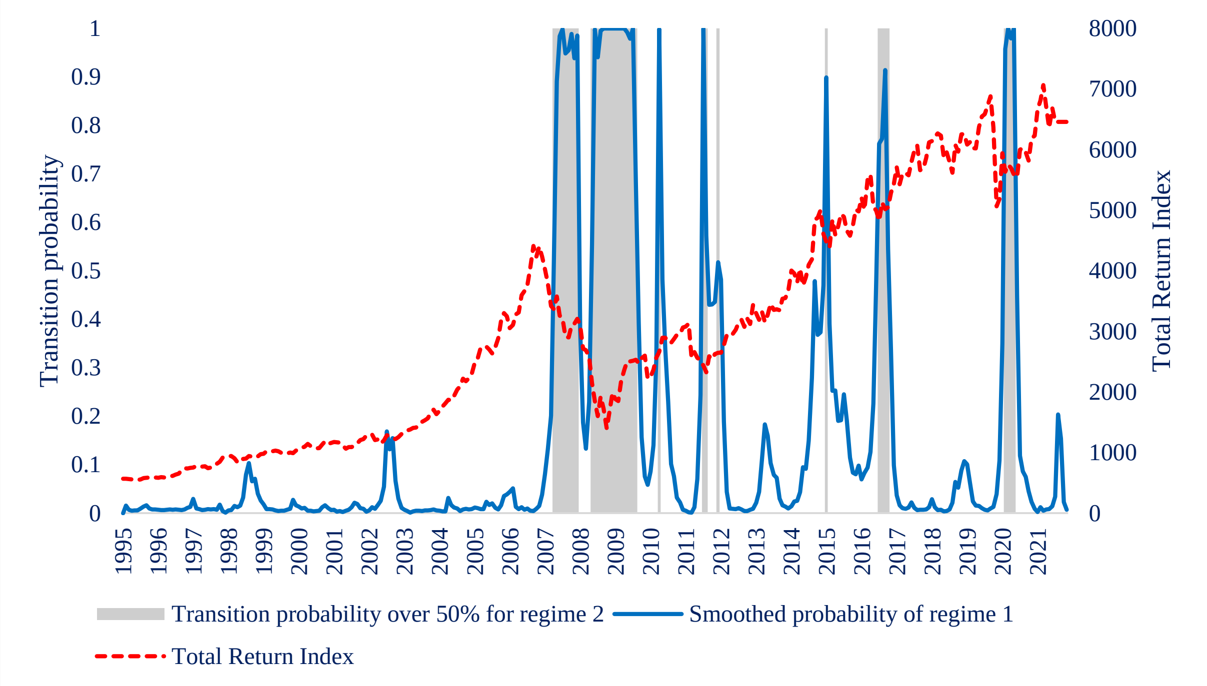
We illustrate the time-varying coefficients if at least one coefficient is significant in Regime 1 or 2.. Hence, we show the time-varying coefficient of expected and unexpected inflation in the Eurozone (Figure 2a and 2b), that of expected inflation in Australia (Figure 2c), expected and unexpected inflation in the US (Figures 2d and 2e), that of expected inflation in the UK (Figure 2f), and those of Japan (Figure 2g and 2h).

First, in the US, UK, and Australia, we find that during non-crisis periods, LRE provides good protection against expected and/or unexpected inflation in the short term. However, the relationship becomes negative or zero during the crisis period. As shown in Figures 2d and 2e, the coefficient in the US varies between 0.023 and 0.000 for expected inflation (between 0.025 and -0.150 for unexpected inflation, respectively). In Regime 1 (non-crisis period), the coefficient remains positive. But in Regime 2 (e.g., 2007, 2009-2010, etc.), the coefficient becomes zero or negative. In the UK, as shown in Figure 2f, the coefficient of expected inflation varies from 0.018 to -0.000 and behaves similarly to that for the US. While in Regime 1 (non-crisis periods) the coefficient remains positive, Regime 2 leads to coefficients assigned the value zero (e.g., 1992, 1993, 2007-2009, etc.). As illustrated in Figure 2c, in Australia, the coefficient of expected inflation varies from 0.02 to -0.12. While in Regime 1 (non-crisis periods) the coefficient remains positive, Regime 2 leads to negative coefficients (e.g., 2008-2009, 2020, etc.). This finding is consistent with previous literature. For instance, focusing on the short-term relationship, Bond and Seiler (1998) find that residential real estate is a significant hedge against both expected and unexpected inflation using data for the US covering the 1969-1994 period. However, our analysis shows that the short-term inflation-hedging ability of LRE can be perverse during crisis periods.

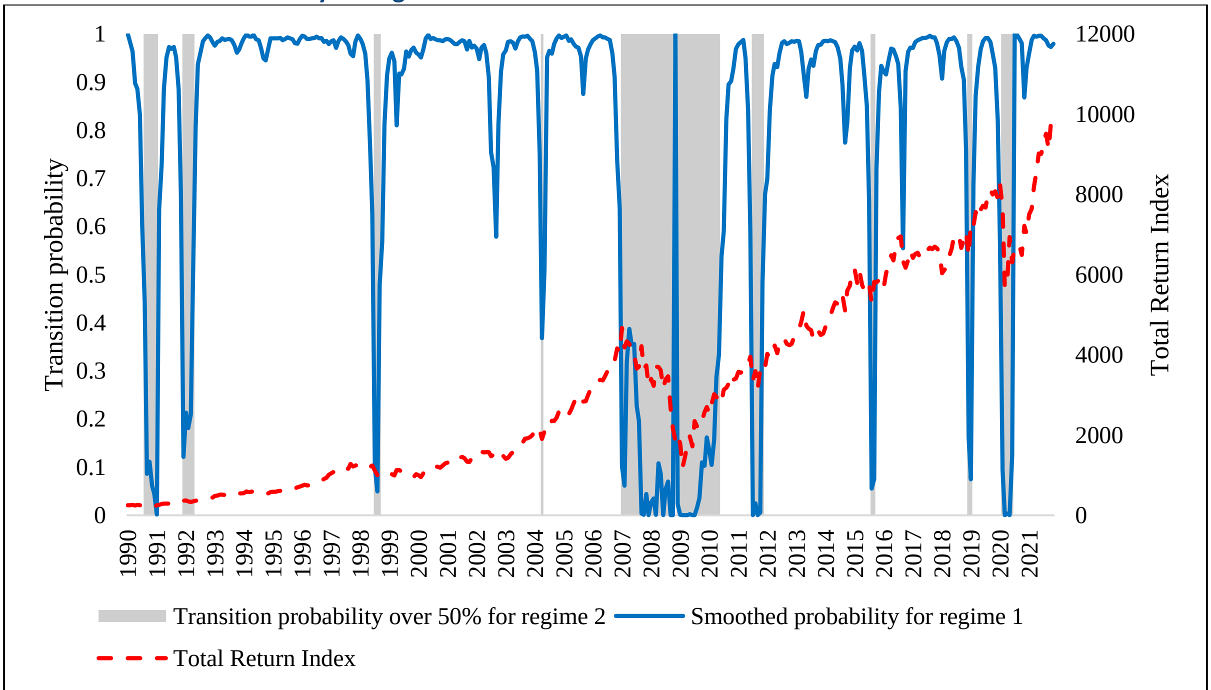
[4] If the estimated coefficient is statistically insignificant, we restrict this coefficient to be zero.

Figure 1: Transition Probability and Total Returns

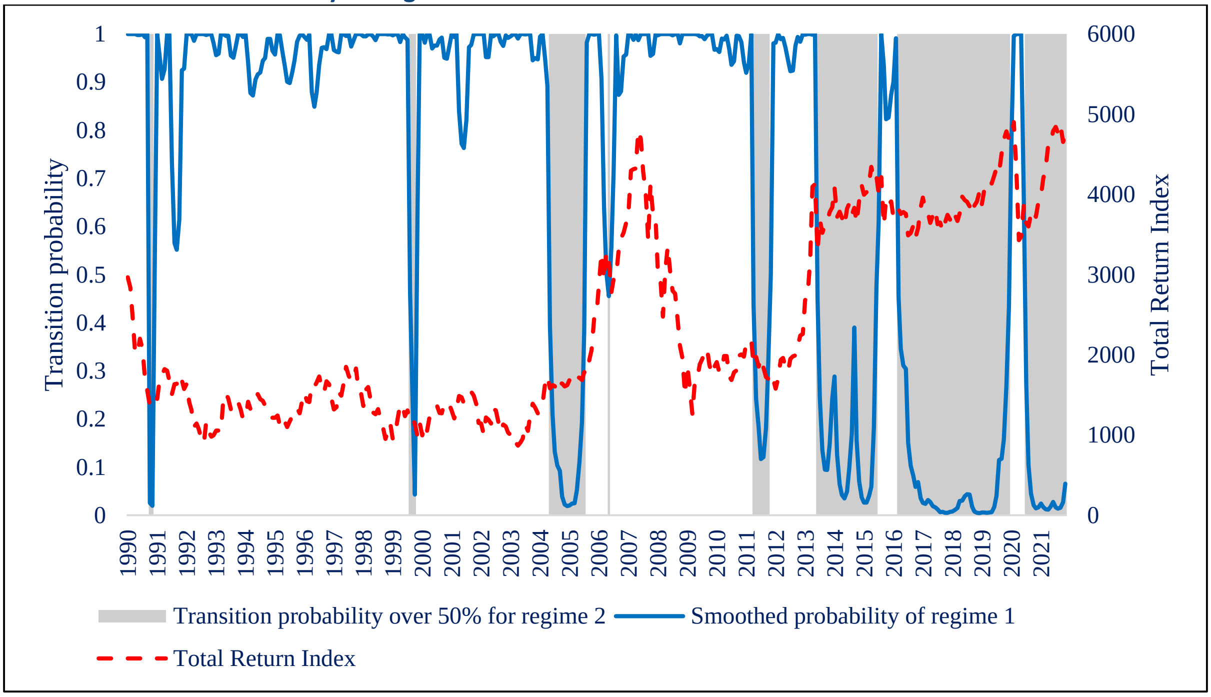
a. EU Smoothed Probability of Regime 1



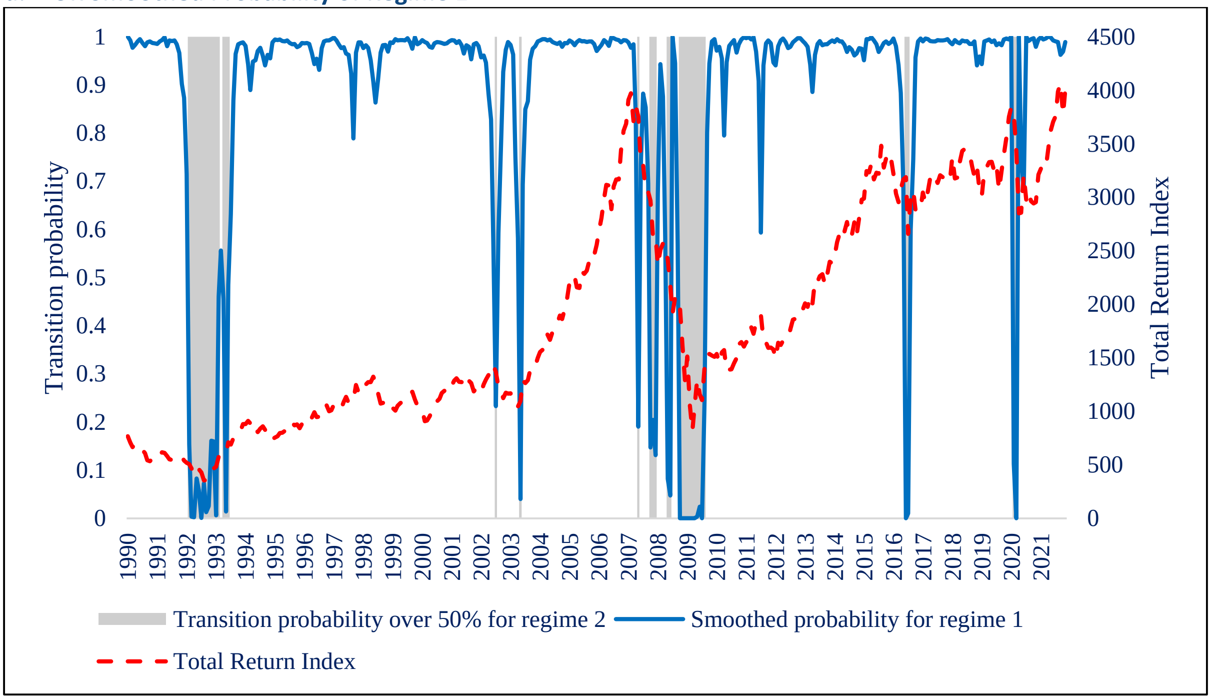
b. US Smoothed Probability of Regime 1



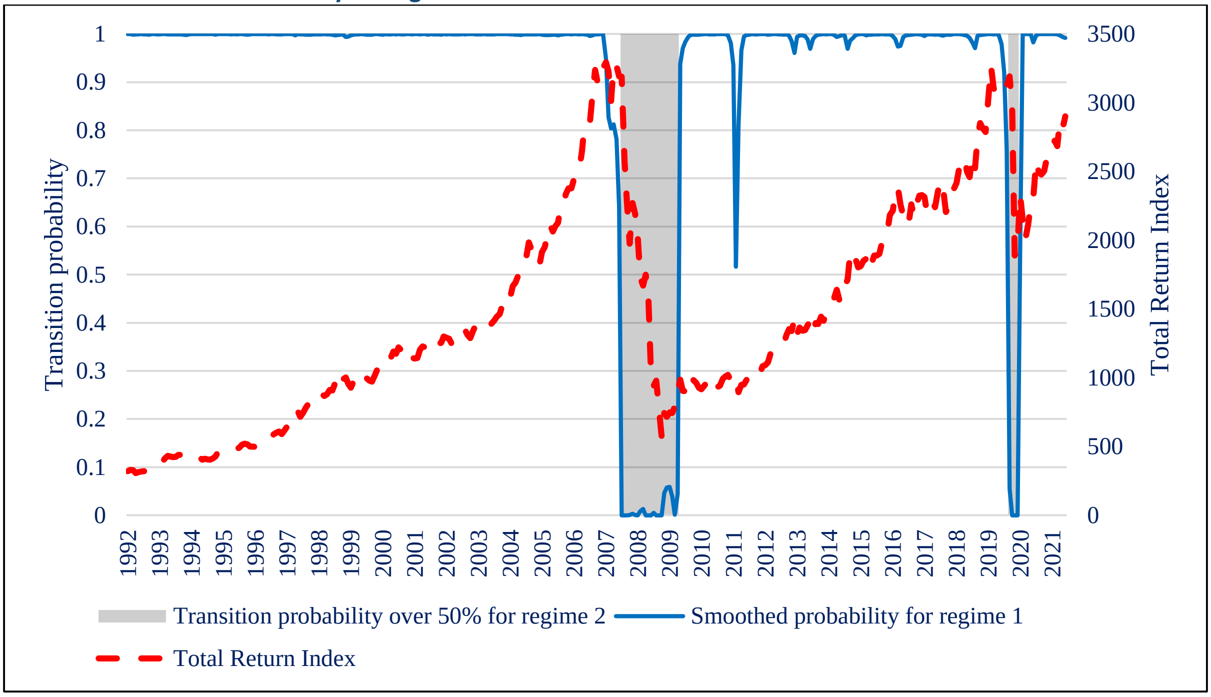
c. JPN Smoothed Probability of Regime 1



d. UK Smoothed Probability of Regime 1



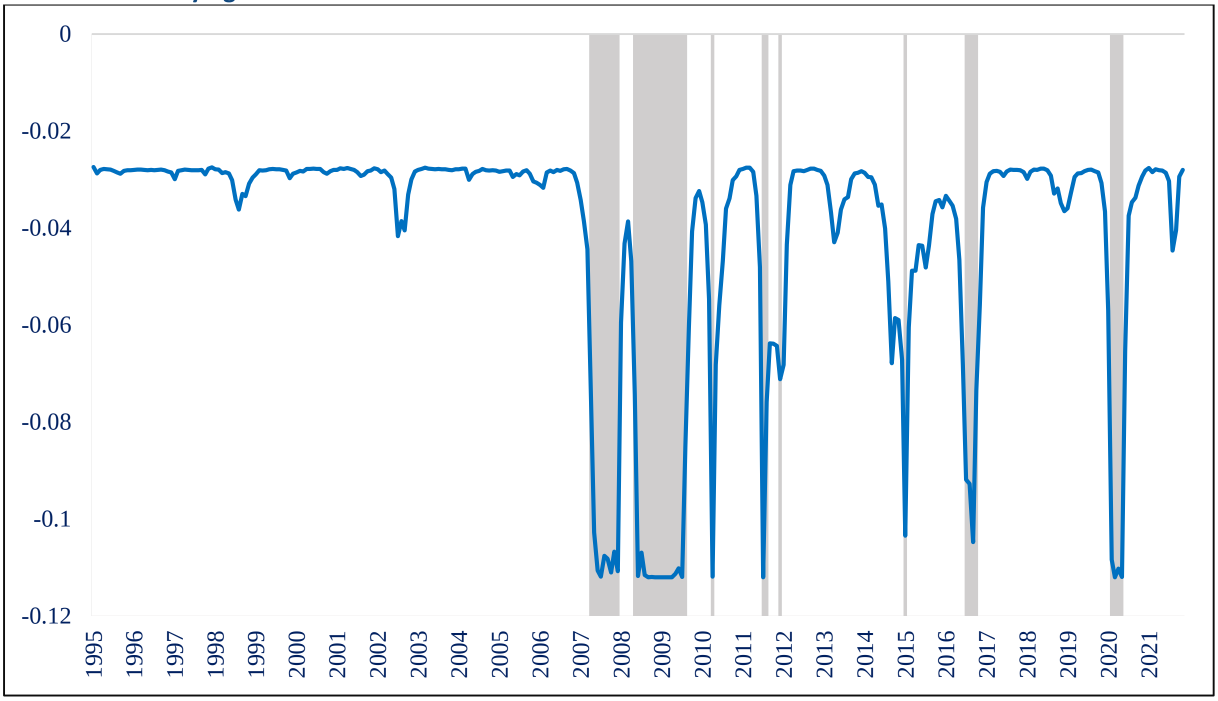
e. AUS Smoothed Probability of Regime 1



Second, in the EU and Japan, the short-term relationship between inflation and LRE is negative, even during non-crisis periods. As shown in Figures 2a and 2b, the coefficient in the Eurozone varies between -0.02 and -0.12. In Regime 1 (non-crisis period), the coefficient is slightly negative. But in Regime 2 (e.g., 2007, 2009-2010, etc.), the coefficient becomes even more strongly negative. The negative relationship between expected/unexpected inflation for EU LRE seems counterintuitive. One reason might be that the Eurozone is a federation of states, and thus many factors can interfere with creating a clear picture. Another reason might be that the leasing practices and regulations are quite different across countries. In Japan, the coefficient of expected inflation ranges from -0.010 to -0.030, and the coefficient of unexpected inflation varies between 0.020 and -0.04. One explanation could be the long-lasting mild deflation in Japan since the latter half of the 1990s. The negative relationship between LRE and inflation has also been documented in the literature. For instance, by examining REIT data from the US covering the period 1972-1992, Yobaccio et al. (1995) find that REITs are perverse hedges against unexpected inflation.

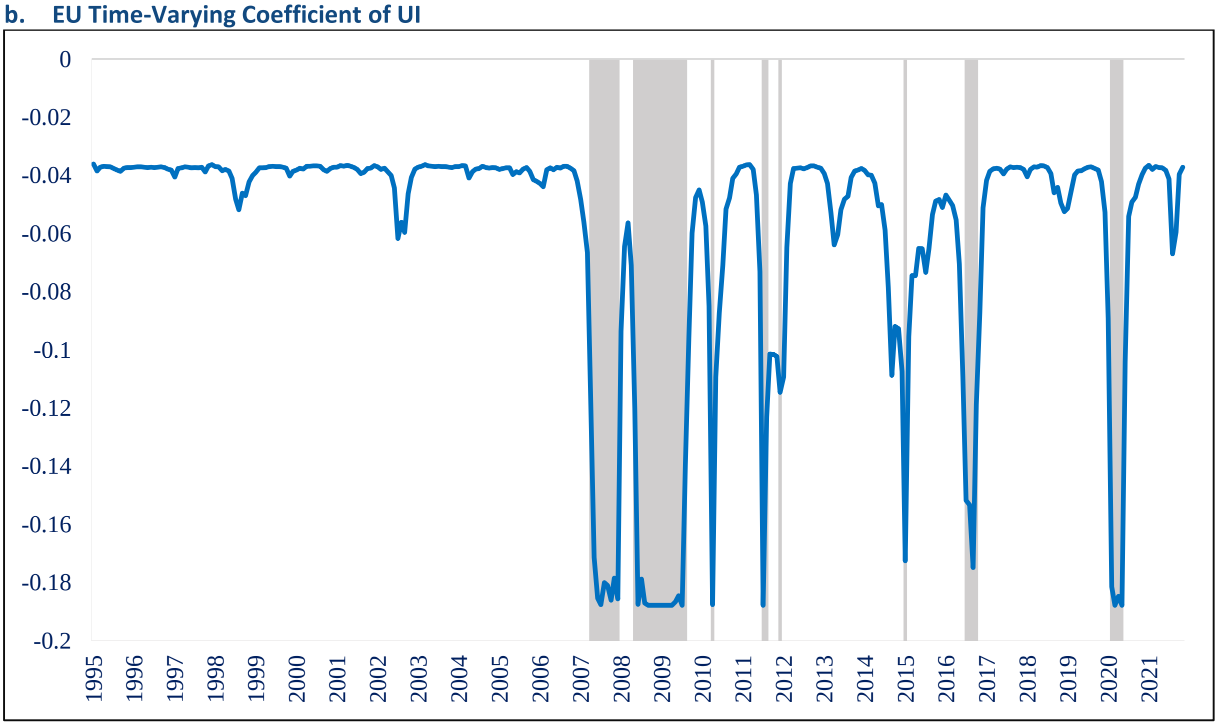
Figure 2: Time-Varying Short-Term Impact of Inflation on Real Estate Equity Returns

a. EU Time-Varying Coefficient of EI



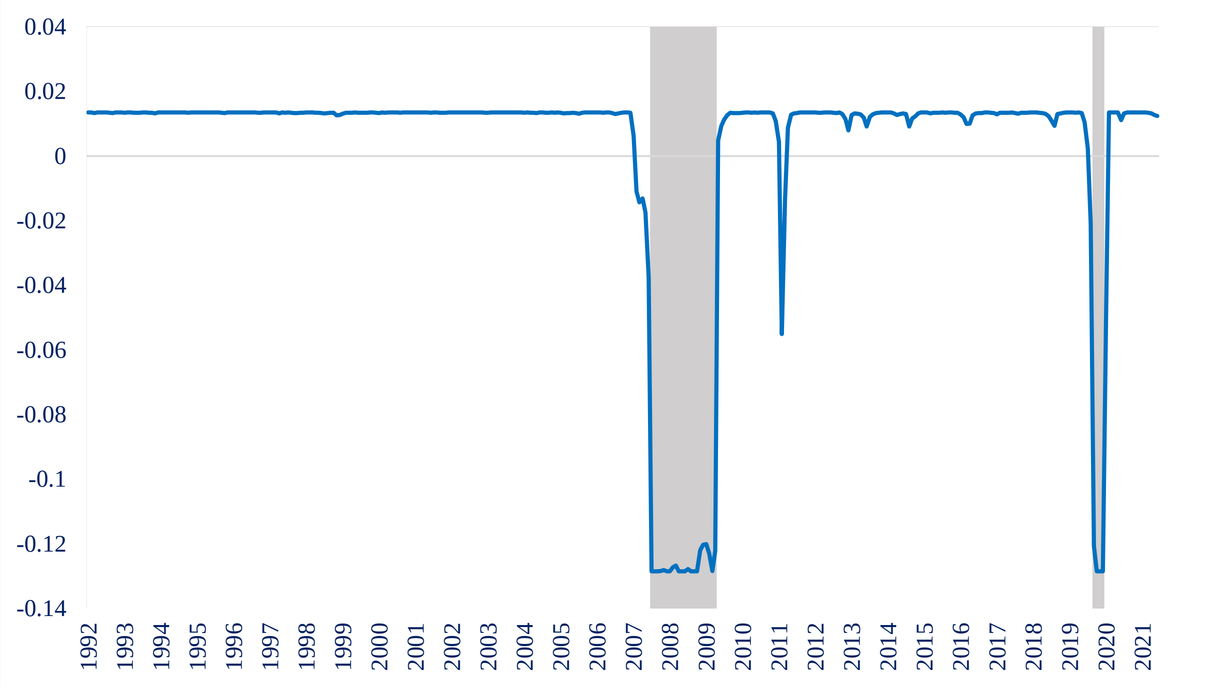
Note: The time-varying coefficient is calculated by multiplying the smoothed probability of Regime 1 with the coefficient of expected or unexpected inflation in Regime 1 plus the smoothed probability of Regime 2 multiplied by the coefficient of expected or unexpected inflation in Regime 2.. If the estimated coefficient in Equation (3) is statistically insignificant, it is restricted to zero in the estimation of time-varying coefficient (Equations 5 and 6).

b. EU Time-Varying Coefficient of UI



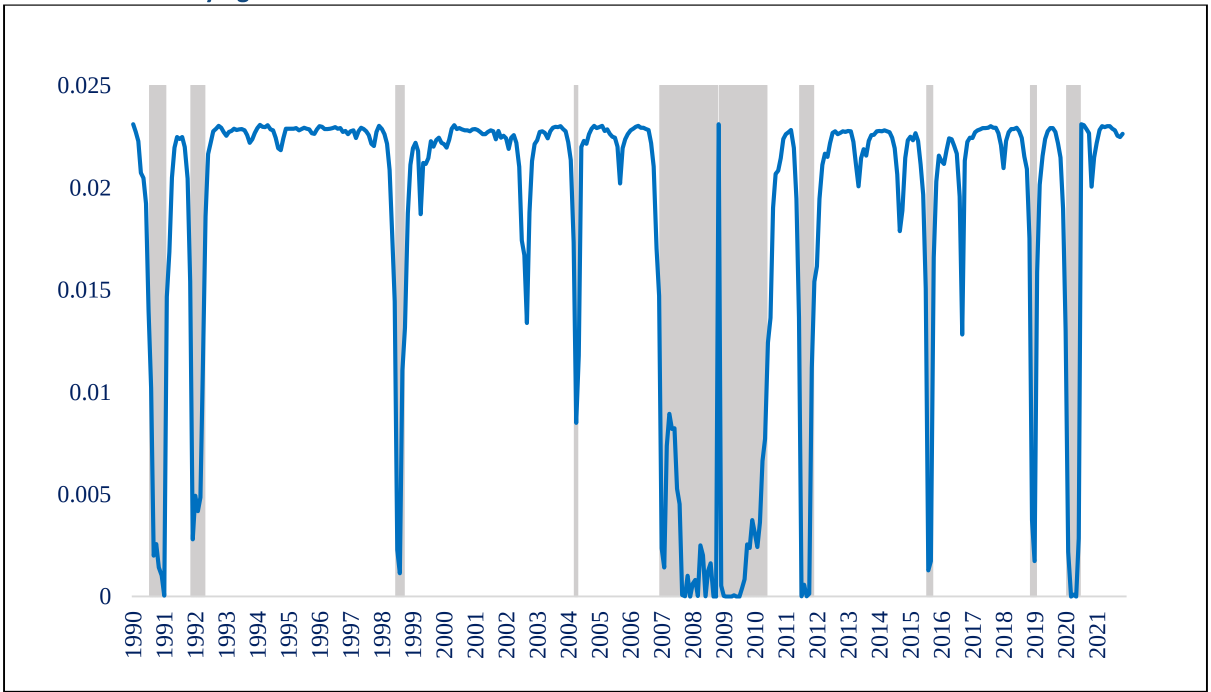
Note: The time-varying coefficient is calculated by multiplying the smoothed probability of Regime 1 with the coefficient of expected or unexpected inflation in Regime 1 plus the smoothed probability of Regime 2 multiplied by the coefficient of expected or unexpected inflation in Regime 2. If the estimated coefficient in Equation (3) is statistically insignificant, it is restricted to zero in the estimation of time-varying coefficient (Equations 5 and 6).

c. AUS Time-Varying Coefficient of EI



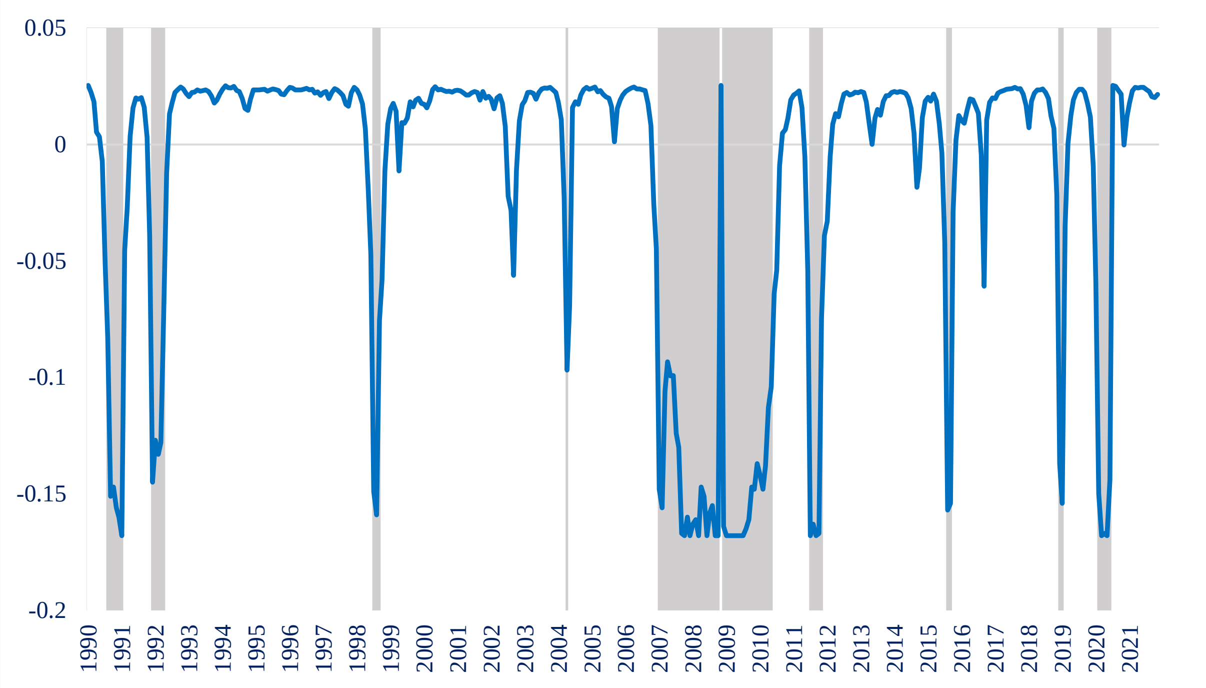
Note: The time-varying coefficient is calculated by multiplying the smoothed probability of Regime 1 with the coefficient of expected or unexpected inflation in Regime 1 plus the smoothed probability of Regime 2 multiplied by the coefficient of expected or unexpected inflation in Regime 2. If the estimated coefficient in Equation (3) is statistically insignificant, it is restricted to zero in the estimation of time-varying coefficient (Equations 5 and 6).

d. U.S. Time-Varying Coefficient of EI



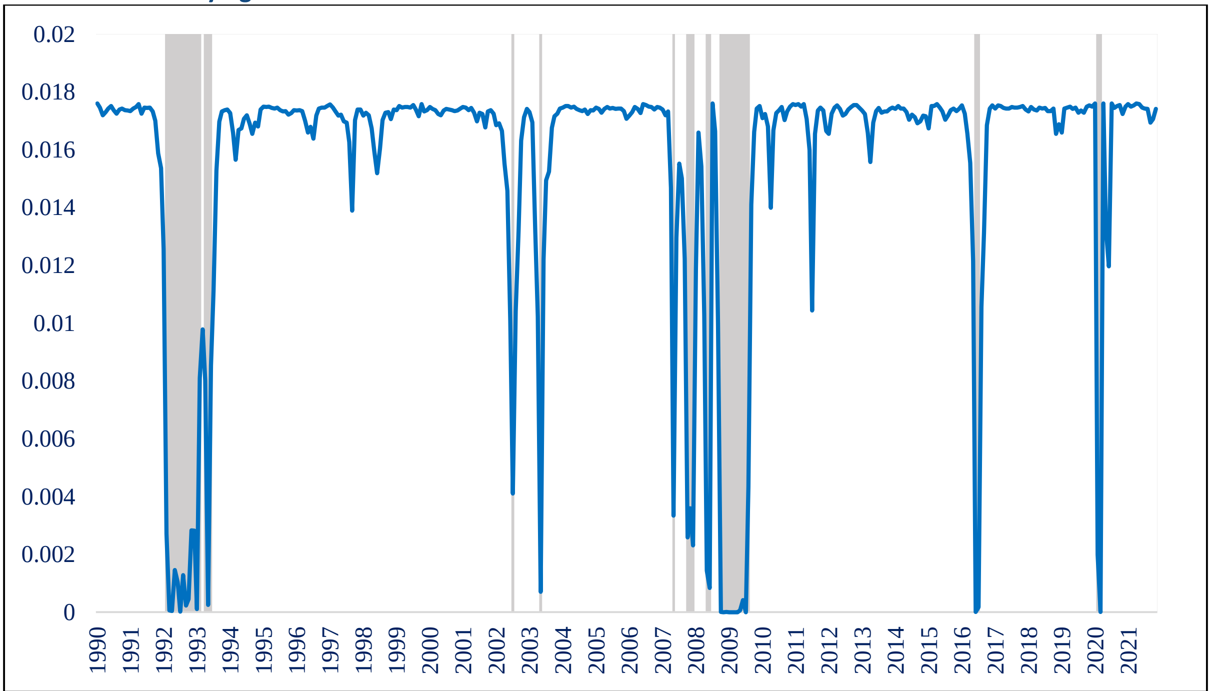
Note: The time-varying coefficient is calculated by multiplying the smoothed probability of Regime 1 with the coefficient of expected or unexpected inflation in Regime 1 plus the smoothed probability of Regime 2 multiplied by the coefficient of expected or unexpected inflation in Regime 2. If the estimated coefficient in Equation (3) is statistically insignificant, it is restricted to zero in the estimation of time-varying coefficient (Equations 5 and 6).

e. U.S. Time-Varying Coefficient of UI



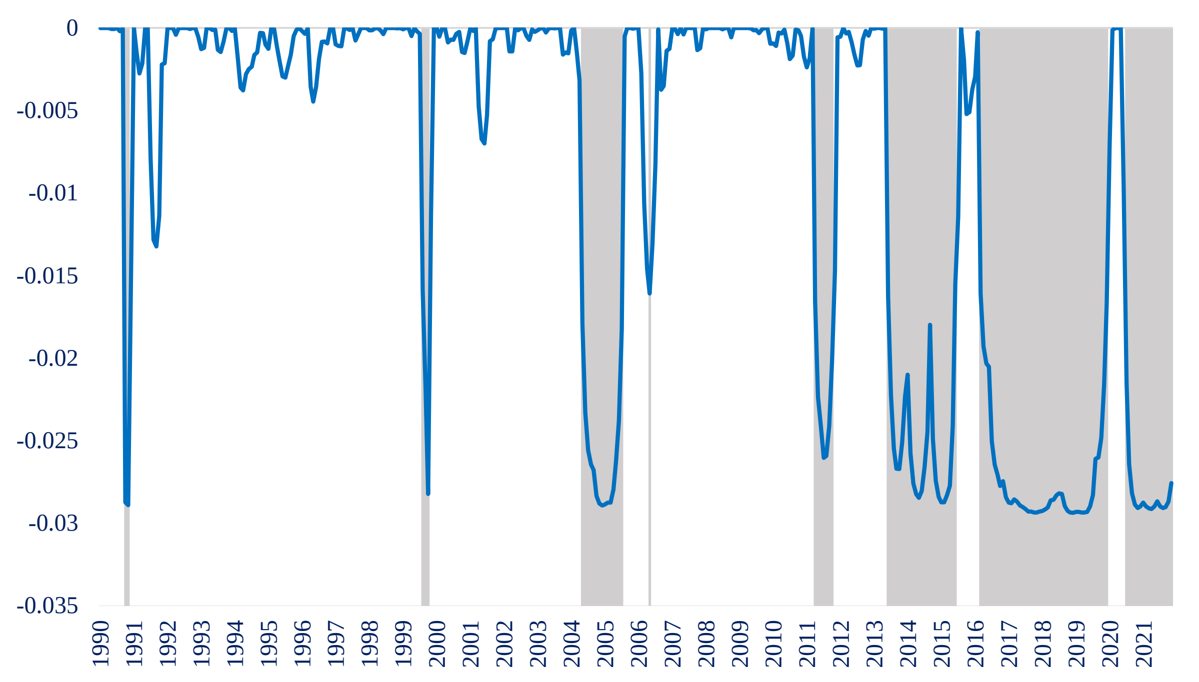
Note: The time-varying coefficient is calculated by multiplying the smoothed probability of Regime 1 with the coefficient of expected or unexpected inflation in Regime 1 plus the smoothed probability of Regime 2 multiplied by the coefficient of expected or unexpected inflation in Regime 2. If the estimated coefficient in Equation (3) is statistically insignificant, it is restricted to zero in the estimation of time-varying coefficient (Equations 5 and 6).

f. U.K. Time-Varying Coefficient of EI



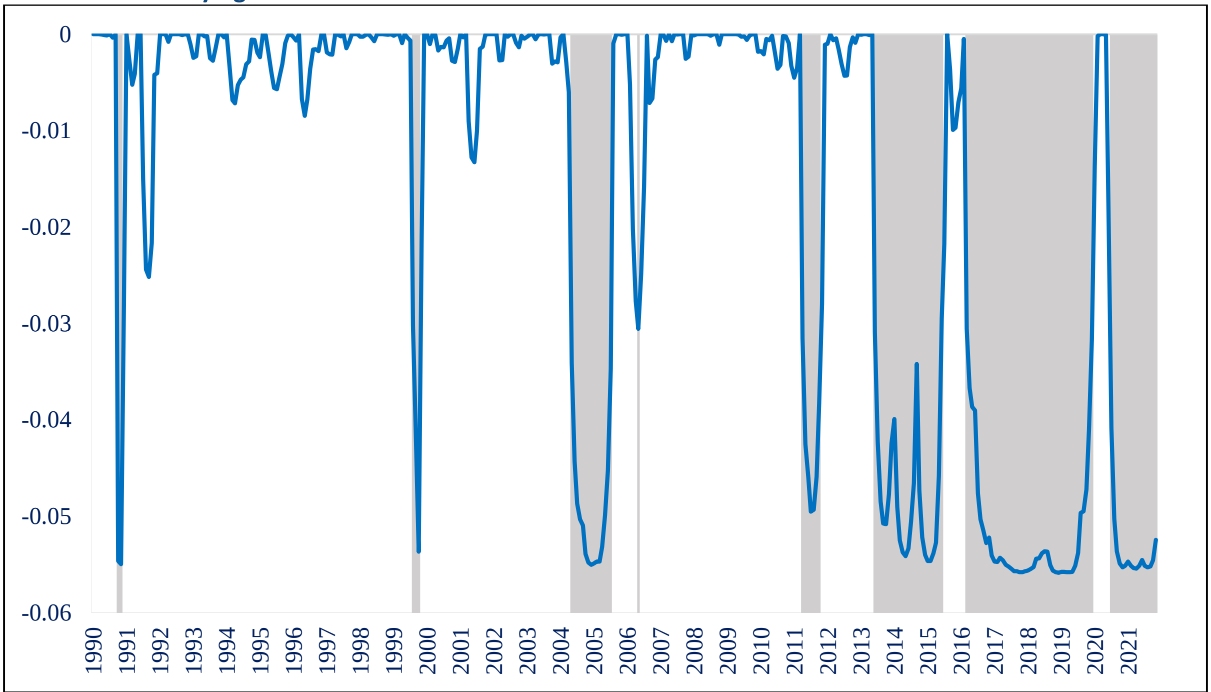
Note: The time-varying coefficient is calculated by multiplying the smoothed probability of Regime 1 with the coefficient of expected or unexpected inflation in Regime 1 plus the smoothed probability of Regime 2 multiplied by the coefficient of expected or unexpected inflation in Regime 2. If the estimated coefficient in Equation (3) is statistically insignificant, it is restricted to zero in the estimation of time-varying coefficient (Equations 5 and 6).

g. JPN Time-Varying Coefficient of EI



Note: The time-varying coefficient is calculated by multiplying the smoothed probability of Regime 1 with the coefficient of expected or unexpected inflation in Regime 1 plus the smoothed probability of Regime 2 multiplied by the coefficient of expected or unexpected inflation in Regime 2. A coefficient that is not significant is assigned the value 0 and is multiplied by its associated transmission probability.

h. JPN Time-Varying Coefficient of UI

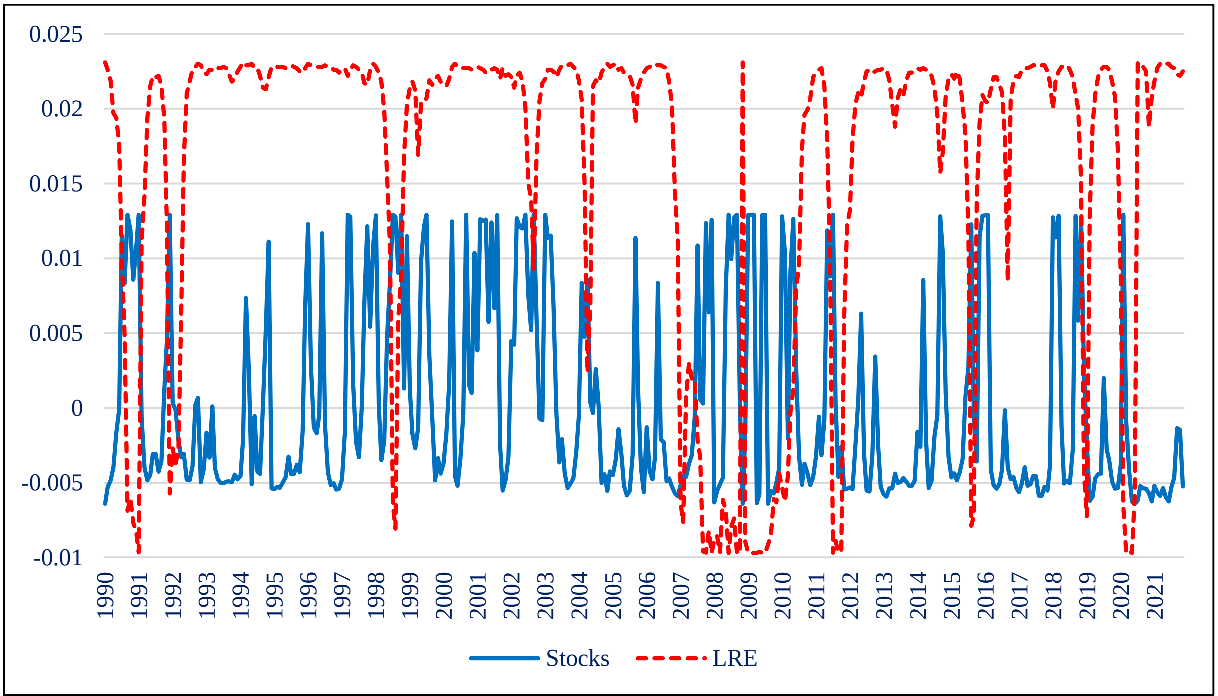


Note: The time-varying coefficient is calculated by multiplying the smoothed probability of Regime 1 with the coefficient of expected or unexpected inflation in Regime 1 plus the smoothed probability of Regime 2 multiplied by the coefficient of expected or unexpected inflation in Regime 2. A coefficient that is not significant is assigned the value 0 and is multiplied by its associated transmission probability.

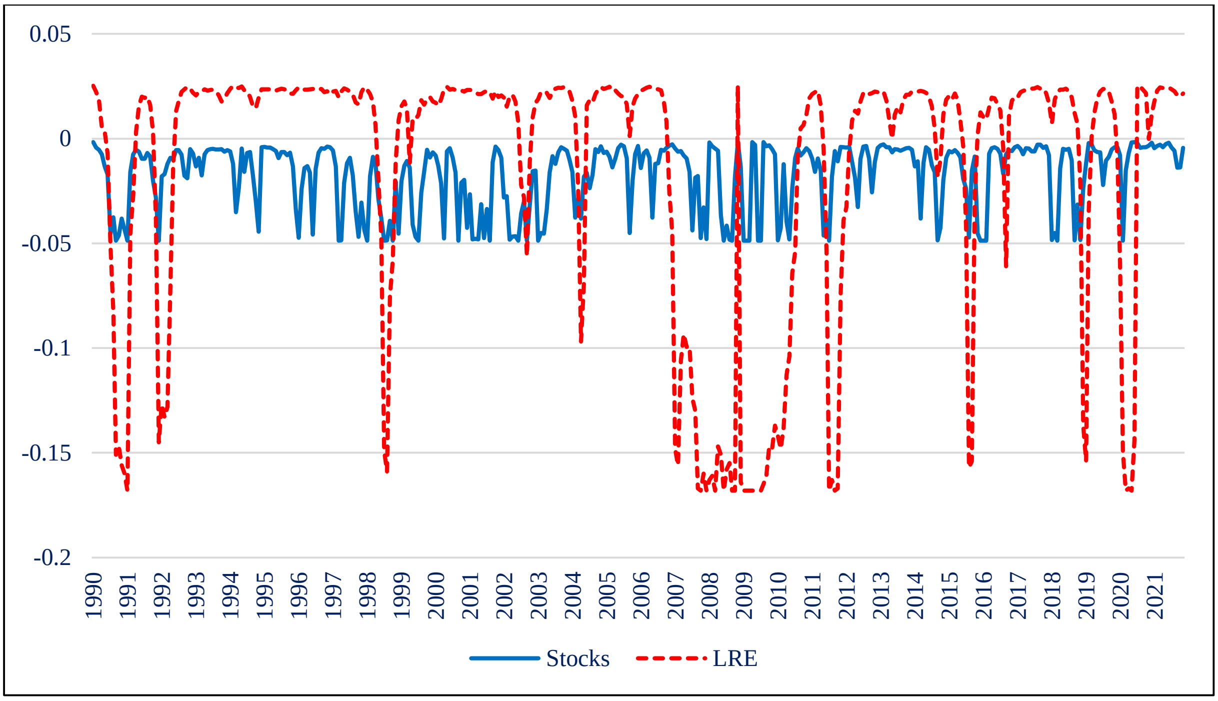
If we compare the short-term hedging ability of LRE with that of stocks, we can see that LRE provides better inflation hedging than stocks also in the short term. Figure 3 compares the time-varying coefficients of EI and UI for stock and LRE returns for the US and UK markets. The red dotted line shows the coefficient for LRE, and the blue line indicates the coefficient for stocks. In the US, compared to stocks, LRE reacts more positively to expected and unexpected inflation, especially during non-crisis periods (Figures 3a and 3b). We can see a significant positive coefficient of expected inflation on stocks and LRE as well, while stocks have a smaller magnitude (Figure 3a). In the UK, LRE also shows better hedging properties concerning expected inflation, as compared to stocks. Regarding unexpected inflation, LRE has an insignificant relationship, while stocks exhibit a negative relationship. Overall, LRE provides better inflation-hedging abilities than stocks in the US and UK. However, LRE in the EU, Japan, and Australia do not show better short-term inflation hedging properties compared to stocks, as shown in Appendix 3.

Figure 3: Time-varying coefficients of LRE and Stocks

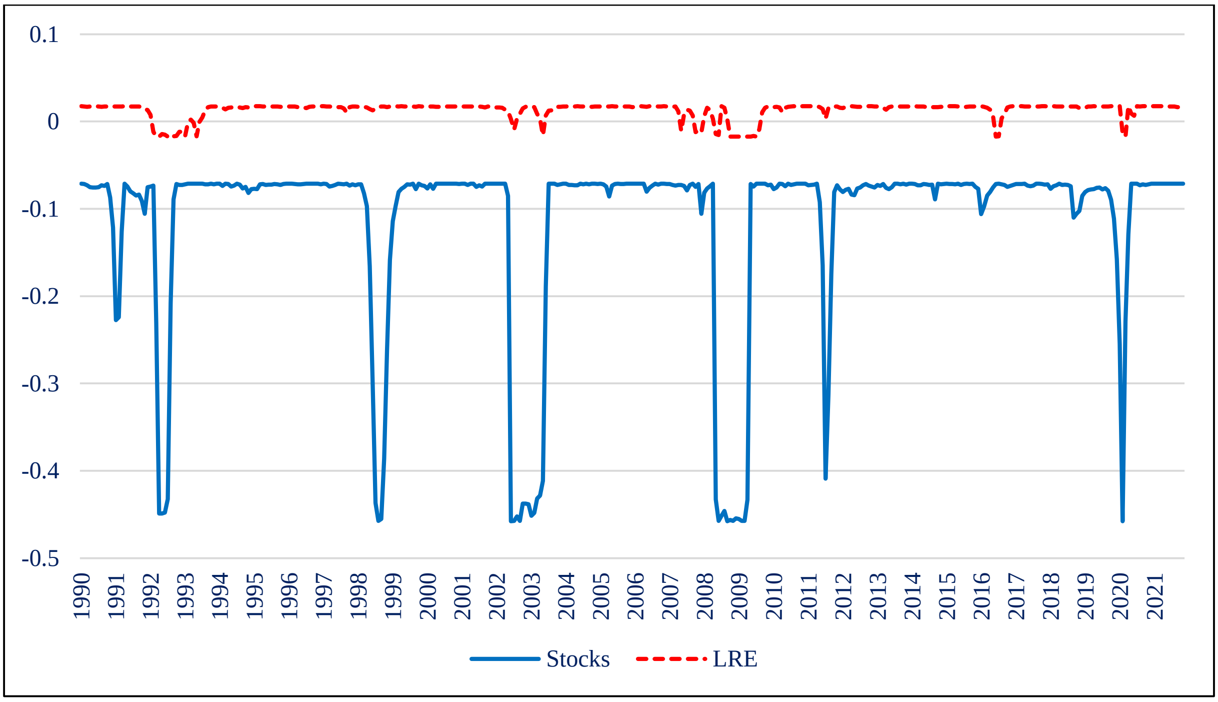
a. US Time-Varying Coefficient of EI



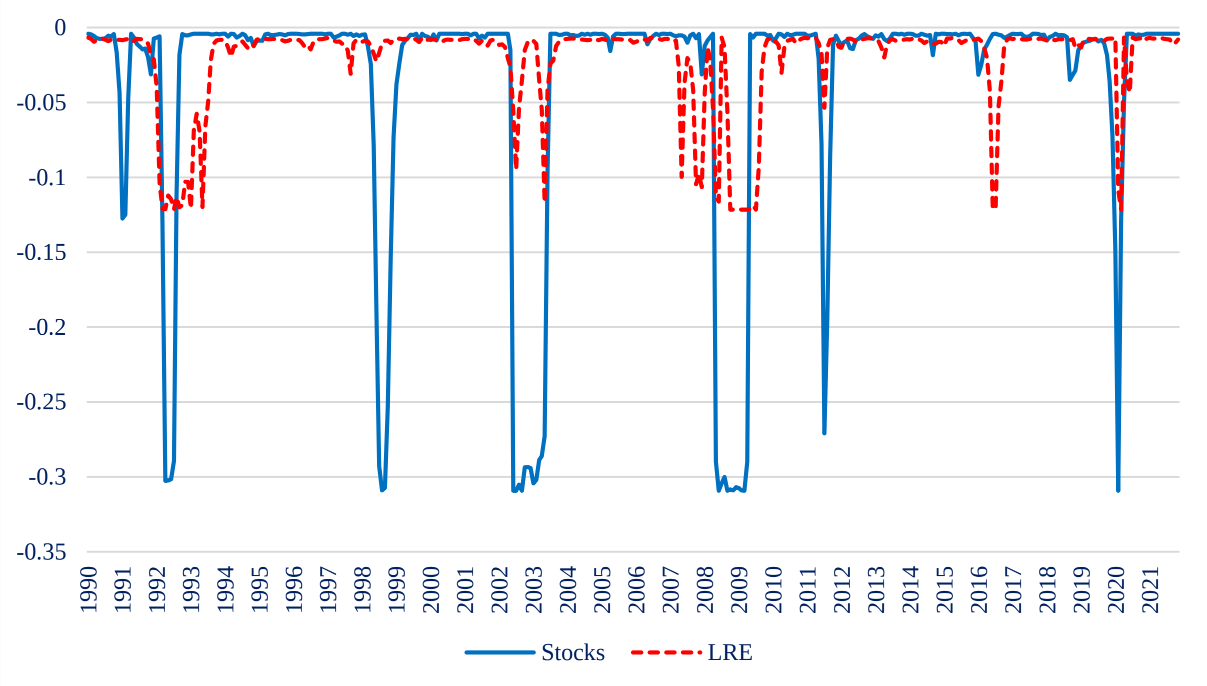
b. US Time-Varying Coefficient of UI



c. UK Time-Varying Coefficient of EI



d. UK Time-Varying Coefficient of UI



c. Sector Analysis

We extend our analysis by conducting sector-specific modelling. Our MS-VECM approach is applied to the traditional real estate sectors of offices, industrial, retail, residential, and the emerging sector of healthcare. The sectoral analysis is limited to the US, the UK, and the Eurozone due to limited data availability.[5]

Appendix 6 displays the results for sectoral long-term equilibrium relationships (β-vectors). In the long term, office LRE provides positive long-term hedging against expected and unexpected inflation in all three regions. Besides, the emerging sector of healthcare also provides a positive hedge against expected and unexpected inflation in the Eurozone and the UK, while it has a negative impact on unexpected inflation in the US. Moreover, retail appears to be a good hedge against expected inflation, while residential and industrial properties do not appear to be suitable sectors for inflation protection in the long run. Furthermore, the results for residential LRE are mixed. In the EU, the long-term coefficients for expected and unexpected inflation on residential LRE are both negative, while in the UK, the coefficient of expected inflation is also negative, but the coefficient for unexpected inflation is positive.

In Appendix 7 to 9, we illustrate the time-varying short-term coefficients of expected and unexpected inflation. Positive short-term inflation hedging ability is only found in the office sector in the US (expected inflation), healthcare in the US (both expected and unexpected inflation), and the industrial sector in the UK (both expected and unexpected inflation). In other sectors, we find an insignificant or even significant negative relationship between inflation changes and LRE returns. The results sometimes are not in line with the results using the aggregate index. This is because we have a much shorter observation period for the sector analysis, from 2006 to 2021. In such a short period, the regime switching VECM model could be unstable.

[5] The corresponding descriptive statistics are displayed in Appendix 4. Results of conducting the Kwiatowski-Phillips-Schmidt-Shin (KPSS) test are shown in Appendix 5.

4. Inflation Hedging Portfolios

In this section, we construct an inflation-hedging portfolio described in Brière and Signori (2012). We examine the case of an investor wishing to hedge inflation over her investment horizon with a target real return. We determine optimal allocations that minimize the shortfall probability under the constraint that real returns exceed the investor's desired target.

$$Min_w\ P\left(\sum_{i=1}^{n} w_i R_{iT} < \pi_T + \overline{R}\right) \quad (7)$$

$$E\left[\sum_{i=1}^{n} w_i R_{iT} - \left(\pi_T + \overline{R}\right)\right] > 0 \quad (8)$$

$$\sum_{i=1}^{n} w_i = 1 \quad (9)$$

$$w_i \geq 0 \quad (10)$$

Where $R_T = (R_{1T}, R_{2T}, \dots, R_{nT})$ is the annualized return of the n assets in the portfolio over the investment horizon T; $w = (w_1, w_2, \dots, w_n)$ is the part of the capital invested in the asset I; π_T is the annual inflation rate during that horizon T; and $\overline{R}$ is the target real return in excess of inflation. E is the expectation operator concerning the probability distribution P of the asset returns.

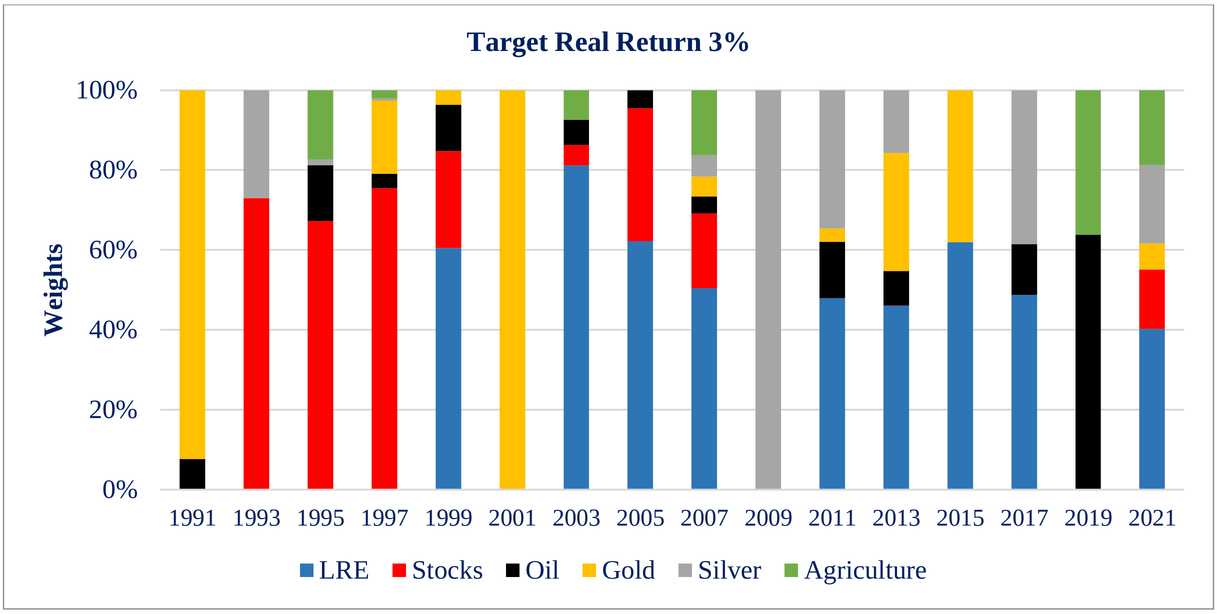
We present optimal portfolios using the shortfall probability approach for the US, UK, Eurozone, Japan, and Australia for a target real return of 3% and an investment horizon of T (T = 2 years, rebalancing every two years).[6] Figure 4 illustrates the calculated weights over time for each country. As expected, the weights for LRE vary over time. In four regions, the EU, the UK, Japan, and Australia, we find a relatively higher weight for LRE during the period from 2003 to 2007 and from 2011 to 2015, compared to other time periods. This might be explained by the rapid growth of LRE in these regions during the abovementioned period. In contrast, during the GFC, the precious metal silver had the highest weight in each country's portfolio, whereas gold had significant portfolio shares during the dot-com bubble. This is also in line with our expectations, as precious metals are always considered good investments during crisis periods. This is also consistent with our MS-VECM results. During the crisis period, listed real estate shows a poor hedging property.

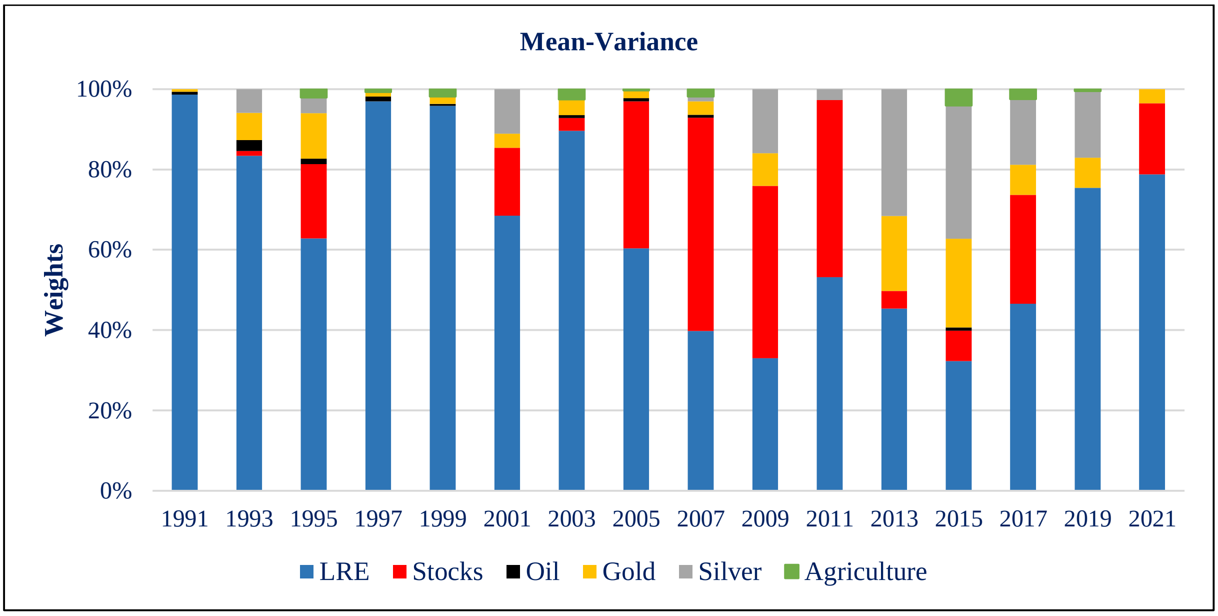
The inflation-hedging portfolios suggest different weights compared to the classic mean-variance approach. To undertake this comparison, we also present the results of optimal portfolios based on the mean-variance criterion for each country. In the US and Australia, the inflation-hedging portfolio indicates significantly higher weights for LRE compared to the standard mean-variance portfolio. This is in line with the desired inflation-hedging properties of LRE. For instance, for the US, over the 2017 to 2018 period, the mean-variance portfolio suggests 2% for US LRE, but the inflation-hedging portfolio suggests 15%. On average, over the entire sample period, the inflation hedging portfolios suggest 6.4% and 48.8% weights for the US and Australia, respectively. Meanwhile, the mean-variance portfolios suggest only 3.2% and 19.5%, respectively, for the two countries. In the UK and Japan, the weights for LRE in the inflation-hedging portfolio are slightly lower than those in the mean-variance portfolios. On average, the weights for LRE are around 20% and 16% for the UK and Japan, respectively. In the EU, however, the inflation hedging portfolio suggests significantly lower weights for LRE (31.2%) than with the mean-variance method (66.2%). This might be explained by the relatively poor short-term inflation hedging properties of Eurozone LRE. Lizieri et al. (2022) also find extremely high allocations to LRE in the Eurozone using the MV approach. Therefore, they propose an uncertainty aversion approach and determine the optimal allocation to listed real estate to be between 20% and 30%. Our inflation-hedging portfolio generates similar allocations to listed real estate as their uncertainty aversion approach.

[6] The results pertaining to the average weight of LRE in an optimal portfolio composition over a 2-year, 5-year, 10-year, and 30-year investment horizon for the Eurozone are shown in Appendix 10. In addition, the results for a variety of target real returns are presented for the Eurozone. As shown in Appendix 10, the weights for listed real estate varies between 17.67% and 46.89% with the change in the investment horizon. Besides, with the increase in the target real return from 0% to 3%, the weights for listed real estate decrease from 56.93% to 31.21%.

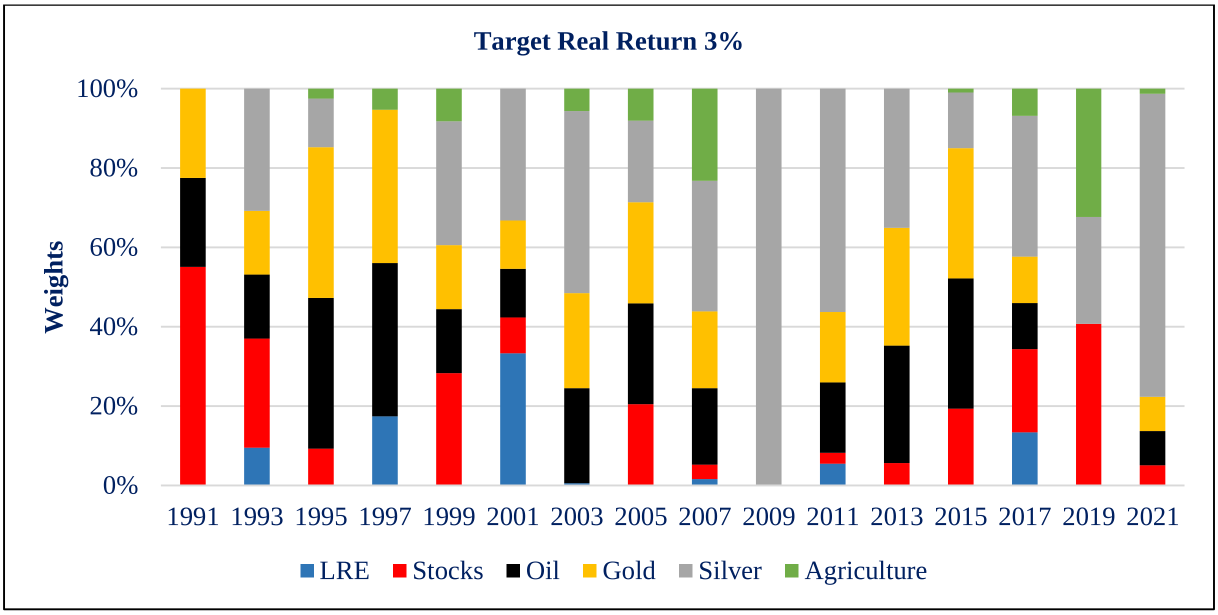
Figure 4: Portfolio Optimizations [Rebalancing every 2 years]

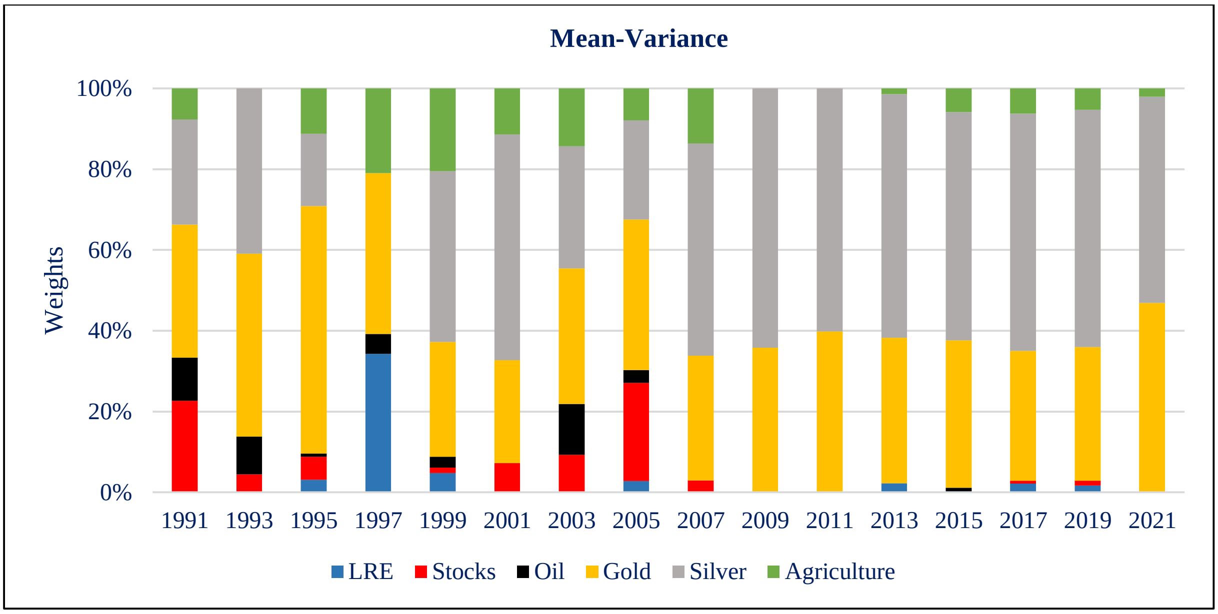
a. Weights of Shortfall Probability and Mean-Variance for the Eurozone



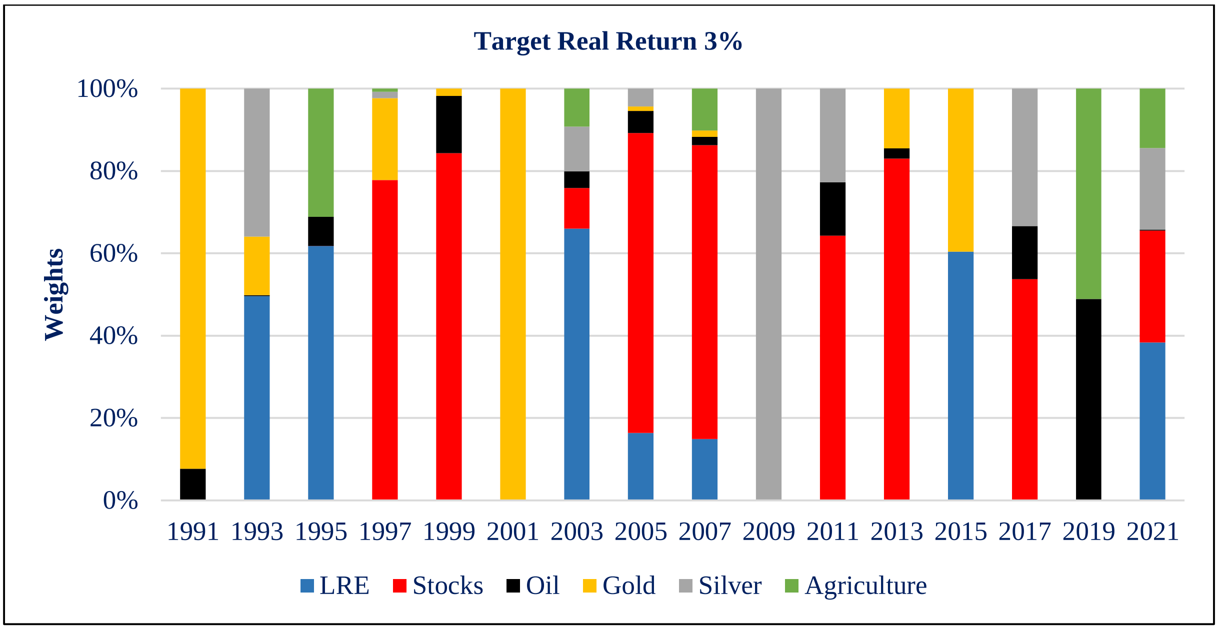


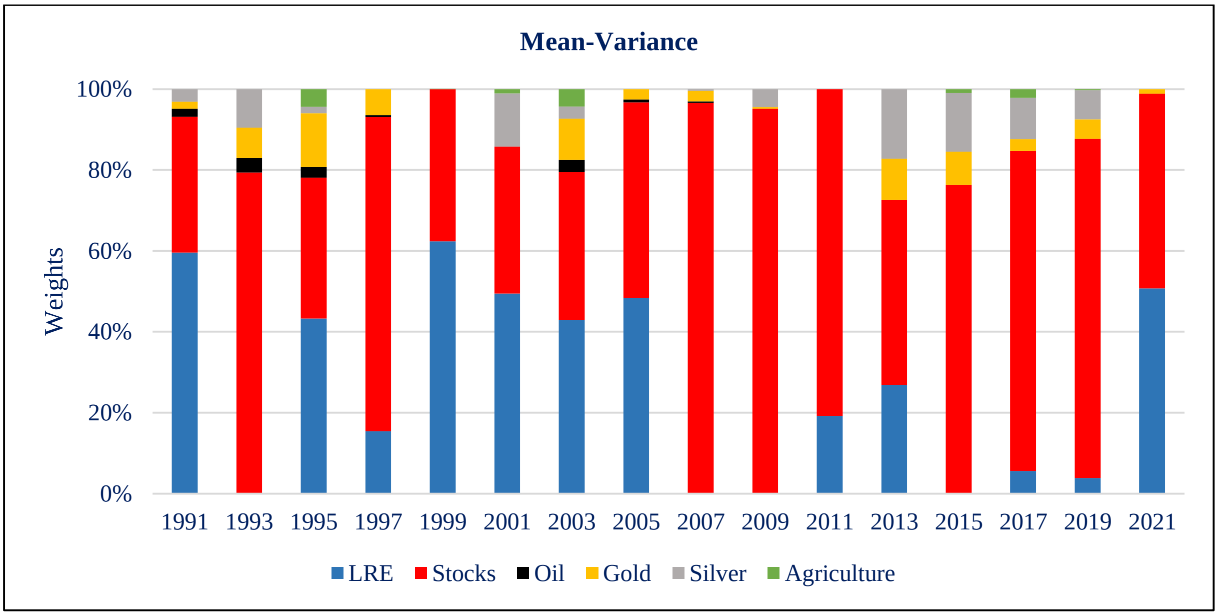
b. Weights of Shortfall Probability and Mean-Variance for the US



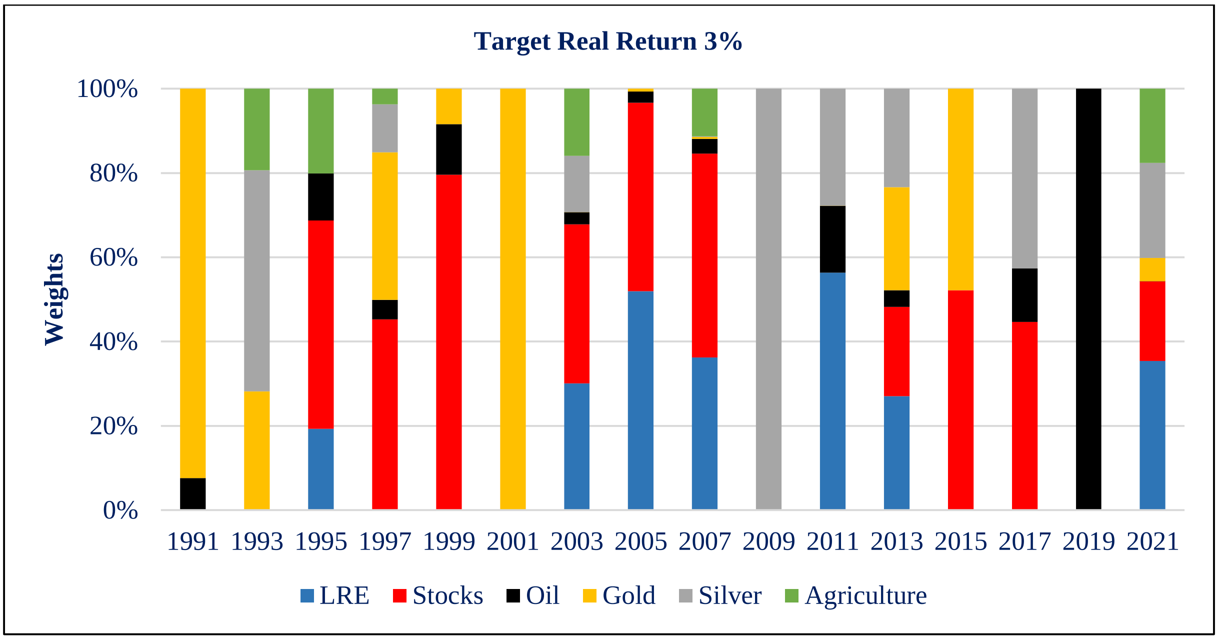


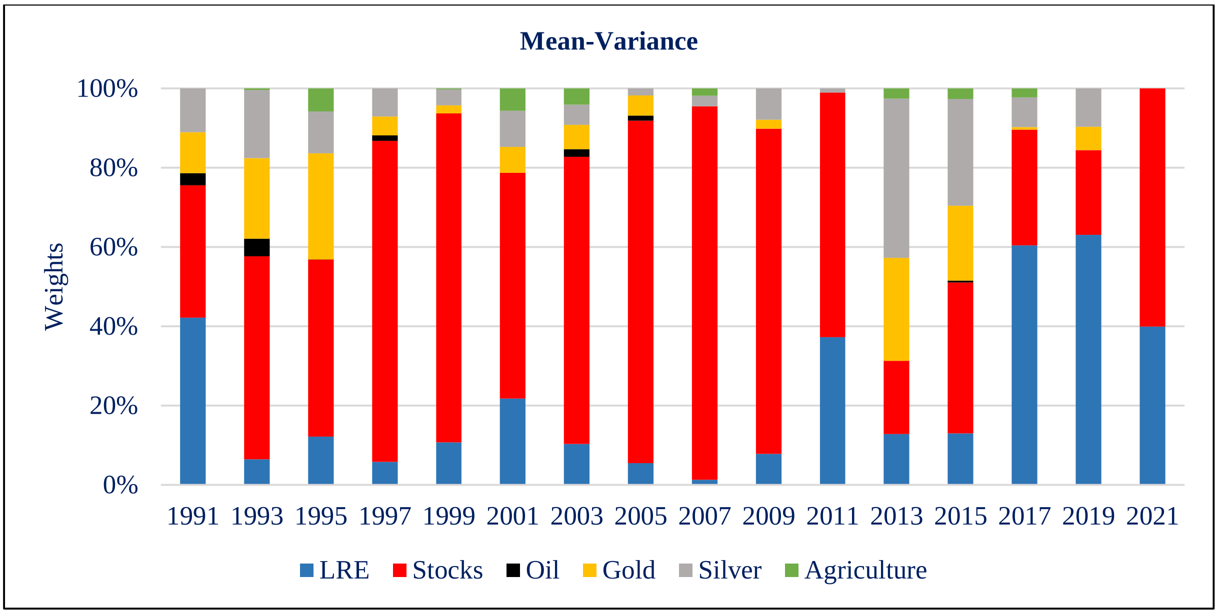
c. Weights of Shortfall Probability and Mean-Variance for the UK



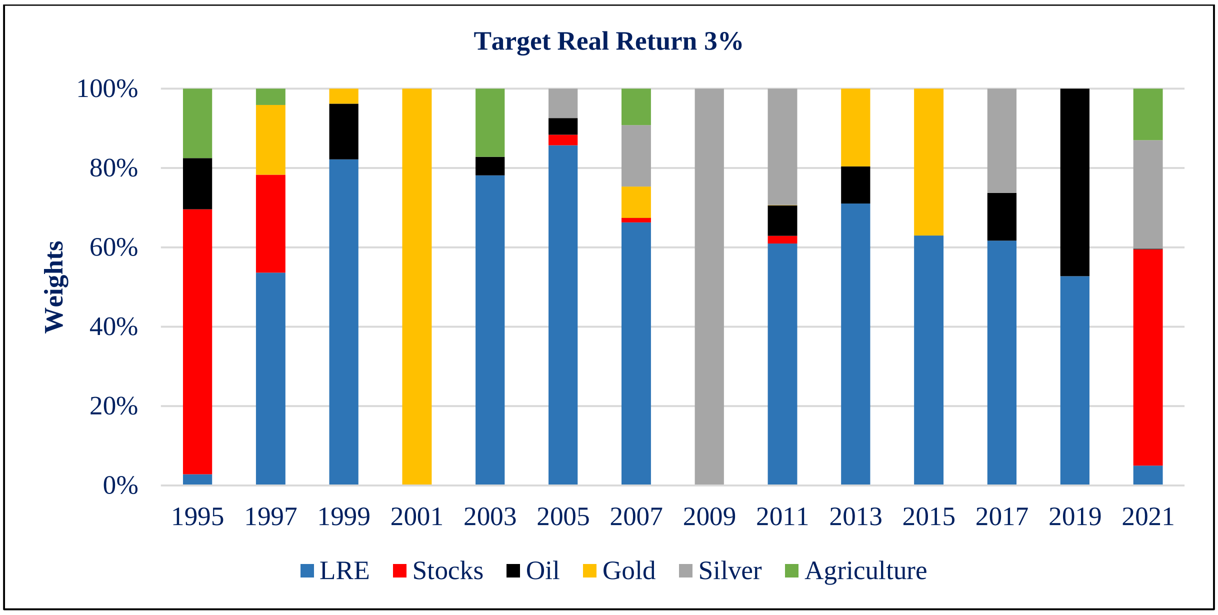


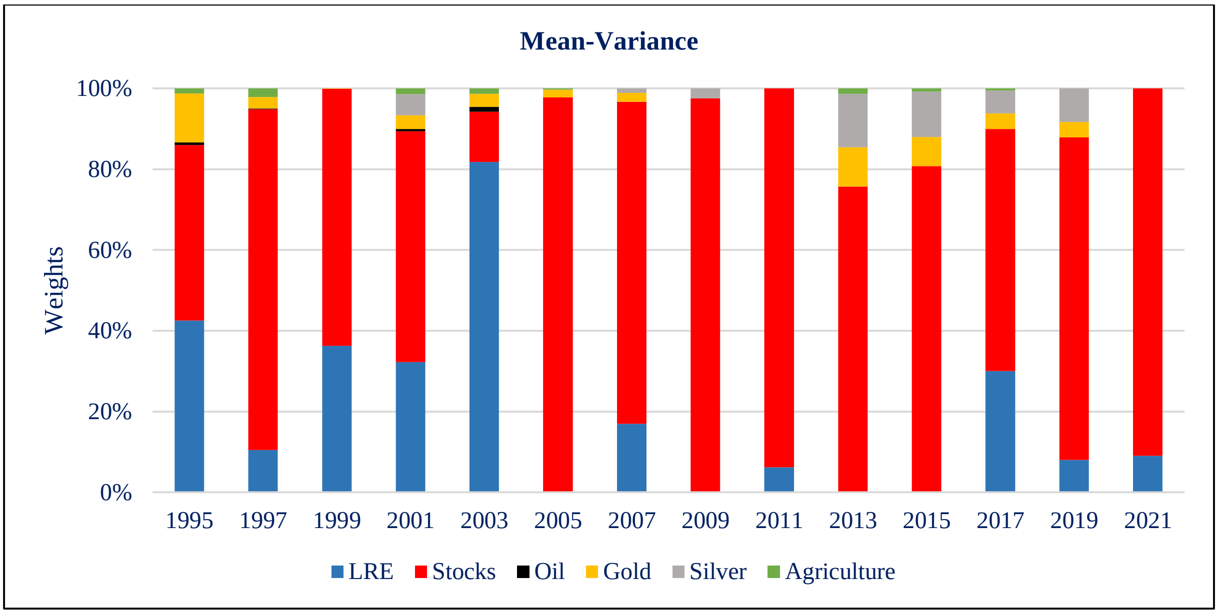
d. Weights of Shortfall Probability and Mean-Variance for Japan





e. Weights of Shortfall Probability and Mean-Variance for Australia





Moreover, the inflation-hedging portfolios provide higher expected returns than the mean-variance portfolios. Table 4 reports the summary statistics of the portfolios, averaging across all years. As shown in Table 4, inflation-hedging portfolios achieve an average annual expected return between 3.97% (Australia) and 5.73% (US), while the average annual expected return in the mean-variance portfolio is less than 1%. In Japan, the mean-variance portfolio even has a negative average expected return. If we consider the risk, as measured by the variance, the inflation-hedging portfolios also achieve a higher Sharpe ratio than mean-variance portfolios in US, Eurozone, and Japan. If we measure the risk by the probability of shortfall, as shown in Table 4, in all regions, the inflation-hedging portfolio achieves a smaller probability of shortfall, meanwhile a higher average expected return than the mean-variance portfolio.

Table 4: Average Summary Statistics of Portfolios with 2-year-Investment Horizon over the Entire Sample Period

	LRE Weight	Shortfall Probability	Mean	SD	Sharpe Ratio
EU					
Inflation Hedging (r=3%)	31.21%	4.59%	4.27%	23.61%	18.09%
Mean-Variance	66.28%	11.33%	0.51%	5.95%	13.62%
US					
Inflation Hedging (r=3%)	6.35%	2.93%	5.73%	24.60%	23.29%
Mean-Variance	3.20%	19.20%	0.23%	14.21%	1.92%
UK					
Inflation Hedging (r=3%)	19.21%	4.54%	4.02%	22.05%	18.23%
Mean-Variance	26.74%	10.86%	0.84%	5.92%	19.84%
Japan					
Inflation Hedging (r=3%)	16.02%	4.69%	4.08%	27.53%	14.82%
Mean-Variance	21.90%	11.28%	-0.12%	6.43%	1.22%
Australia					
Inflation Hedging (r=3%)	48.81%	3.63%	3.97%	21.59%	18.39%
Mean-Variance	19.54%	7.43%	0.86%	4.05%	27.30%

Note: The weights of LRE, the shortfall probability, the mean of portfolio returns, the standard deviation of portfolio returns (SD), and the Sharpe ratios of portfolios are the average values over the entire sample period

5. Conclusion

Since last year, inflation has again become a global concern. Hence, it is very important for investors to understand the inflation-hedging ability of the different asset classes. Using listed real estate company stock return data from 1990 to 2021 in five regions, we examine five major economies, including the US, the UK, the Eurozone, Australia, and Japan, to determine whether listed real estate can be used to hedge against inflation. Overall, our study confirms the desired inflation-hedging properties of LRE. Our main findings can be summarized as follows.

First, listed real estate is a good hedge against inflation, but mainly for expected inflation and in the long term. This can be explained by the fact that many commercial leases are inflation-adjusted, which leads to a positive adjustment in the capital value. As a result, LRE performance can also respond positively to expected inflation. Moreover, because most commercial leases are long-term, the hedging capability of listed real estate assets is particularly striking over a long-time horizon. Moreover, in the long term, LRE provides better hedging against inflation than stocks.

Second, the short-term hedging ability moves toward being negative during crisis periods. In non-crisis periods, LRE provides good protection against inflation, but the ability becomes negative in times of turbulence. On the other hand, this will also indicate that if deflation happens during the crisis, LRE performance will not be adversely affected by deflation. From an investor's perspective, the efficiency of LRE as an inflation hedge is highly dependent on the time horizon.

Third, the inflation hedging ability of LRE also varies across countries. Long-term positive inflation hedging against both expected and unexpected inflation is detected only in the Eurozone and Japan. In the US and the UK, although LRE provides long-term hedging against expected inflation, we see no hedging or perverse hedging characteristics against unexpected inflation. Expected inflation shows the highest long-term elasticity to real estate equity returns in the Eurozone, amounting to 0.29%. Furthermore, the Eurozone has the highest long-term elasticity of unexpected inflation to LRE returns, amounting to 0.48%. In the short term, LRE in the US, the UK, and Australia provide short-term positive inflation hedging against expected inflation, by a 0.023, 0.018, and 0.014 percent increase with a one percent increase in expected inflation, respectively. Only in the US, LRE provides inflation protection against unexpected inflation in non-crisis periods, by 0.025 percent increase with a one percent increase in unexpected inflation.

Fourth, the sectoral analysis for the US, the UK, and the Eurozone indicates long-term positive hedging characteristics against expected and unexpected inflation for office properties. Additionally, healthcare properties appear to provide a good protection against expected and unexpected inflation in the UK and the Eurozone, while it acts as a perverse hedge against unexpected inflation in the US. Furthermore, in the US and the UK, retail properties appear to be a good hedging instrument against expected inflation.

Fifth, our inflation-hedging portfolios provide more realistic and less extreme allocations to listed real estate than when the classic mean-variance approach is used. The mean-variance approach uses variance as the risk measurement, which may not correspond best to investors' objectives. Instead, the inflation-hedging portfolio uses the expected shortfall as the risk measure, which focuses on the risk of being far below the expected real return (i.e., the downside risk). Based on an inflation-hedging portfolio, listed real estate plays a significant role in an investor's portfolio. The average percentages of the portfolios for the US, UK, Japan, Australia, and the Eurozone over the entire period are 6.35%, 19.21%, 16.02%, 48.81%, and 31.21%, respectively, clearly highlighting the benefits of holding listed real estate for investors. The inflation-hedging portfolio also shows a desirable performance. It provides a higher risk-adjusted return (Sharpe ratio) than the mean-variance approach for the US, Japan, and the Eurozone. It also achieves a lower shortfall probability and a higher average expected return than the mean-variance portfolio in all five regions.

Bibliography

BAMPINAS, G. & PANAGIOTIDIS, T. 2015. Are gold and silver a hedge against inflation? A two century perspective. International Review of Financial Analysis, 41, 267-276.

BECKMANN, J. & CZUDAJ, R. 2013. Gold as an inflation hedge in a time-varying coefficient framework. The North American Journal of Economics and Finance, 24, 208-222.

BILGIN, M. H., GOGOLIN, F., LAU, M. C. K. & VIGNE, S. A. 2018. Time-variation in the relationship between white precious metals and inflation: A cross-country analysis. Journal of International Financial Markets, Institutions and Money, 56, 55-70.

BITSCH, F., BUCHNER, A. & KASERER, C. 2010. Risk, return and cash flow characteristics of infrastructure fund investments. EIB papers, 15, 106-136.

BODIE, Z. 1976. Common stocks as a hedge against inflation. Journal of Finance, 31, 459-470.

BOND, M. & SEILER, M. 1998. Real estate returns and inflation: an added variable approach. Journal of Real Estate Research, 15, 327-338.

BRIÈRE, M. & SIGNORI, O. 2012. Inflation-hedging portfolios: Economic regimes matter. Journal of Portfolio Management, 38, 43-58.

DEMARY, M. & VOIGTLÄNDER, M. 2009. The inflation hedging properties of real estate: A comparison between direct investments and equity returns. ERES Conference 2009.

FAMA, E. F. & SCHWERT, G. W. 1977. Asset returns and inflation. Journal of Financial Economics, 5, 115-146.

GANESAN, S. & CHIANG, Y. 1998. The inflation-hedging characteristics of real and financial assets in Hong Kong. Journal of Real Estate Portfolio Management, 4, 55-67.

GIANNOTTI, C. & MATTAROCCI, G. 2013. Risk measurement choice in selecting REITs: Evidence from the US market. Journal of Real Estate Portfolio Management, 19, 137-153.

GLASCOCK, J. L., LU, C. & SO, R. W. 2002. REIT returns and inflation: Perverse or reverse causality effects? Journal of Real Estate Finance and Economics, 24, 301-317.

GYOURKO, J. & LINNEMAN, P. 1988. Owner-occupied homes, income-producing properties, and REITs as inflation hedges: Empirical findings. Journal of Real Estate Finance and Economics, 1, 347-372.

HARTZELL, D., HEKMAN, J. S. & MILES, M. E. 1987. Real estate returns and inflation. Real Estate Economics, 15, 617-637.

HOESLI, M. 1994. Real estate as a hedge against inflation: Learning from the Swiss case. Journal of Property Valuation and Investment, 12, 51-59.

HOESLI, M. & HAMELINK, F. 1997. An examination of the role of Geneva and Zurich housing in Swiss institutional portfolios. Journal of Property Valuation and Investment, 15, 374-391.

HOESLI, M., MACGREGOR, B. D., MATYSIAK, G. & NANTHAKUMARAN, N. 1997. The short-term inflation-hedging characteristics of UK real estate. Journal of Real Estate Finance and Economics, 15, 27-57.

HOESLI, M., LIZIERI, C. & MACGREGOR, B. 2008. The inflation hedging characteristics of US and UK investments: a multi-factor error correction approach. Journal of Real Estate Finance and Economics, 36, 183-206.

HUTSON, E. & STEVENSON, S. 2008. Asymmetry in REIT returns. Journal of Real Estate Portfolio Management, 14, 105-124.

LEIBOWITZ, M. & R. HENRIKSSON, R. 1989. Portfolio optimization with shortfall constraints: A confidence-limit approach to managing downside risk. Financial Analysts Journal, 45, 34-41.

LEIBOWITZ, M. & KOGELMAN, S. 1991. Asset allocation under shortfall constraints. Journal of Portfolio Management, 17, 18-23.

LIMMACK, R. J. & WARD, C. W. R. 1988. Property returns and inflation. Land Development Studies, 5, 47-55.

LIU, C. H., HARTZELL, D. J. & HOESLI, M. E. 1997. International evidence on real estate securities as an inflation hedge. Real Estate Economics, 25, 193-221.

LIZIERI, C. MANSLEY, N. & WANG, Z. 2022. Real estate in a mixed-asset portfolio: The impact of market uncertainty and uncertainty aversion. EPRA Report.

LUCAS, A. & KLAASSEN, P. 1998. Extreme returns, downside risk and optimal asset allocation. Journal of Portfolio Management, 25, 71-79.

LUCEY, B. M., SHARMA, S. S. & VIGNE, S. A. 2017. Gold and inflation(s)–A time-varying relationship. Economic Modelling, 67, 88-101.

NATIONAL, T.-F. & LOW, S.-H. 2000. The inflation-hedging characteristics of real estate and financial assets in Singapore. Journal of Real Estate Portfolio Management, 6, 373-385.

PARK, J. Y., MULLINEAUX, D. J. & CHEW, I.-K. 1990. Are REITs inflation hedges? The Journal of Real Estate Finance and Economics, 3, 91-103.

RUHMANN, S. & WOOLSTON, C. 2011. US Private core real estate investing. NEPC.

SMITH, G. & GOULD, D. 2007. Measuring and controlling shortfall risk in retirement. Journal of Investing, 16, 82-95.

TITMAN, S. & WARGA, A. 1989. Stock returns as predictors of interest rates and inflation. Journal of Financial and Quantitative Analysis, 24, 47-58.

WURSTBAUER, D. & SCHÄFERS, W. 2015. Inflation hedging and protection characteristics of infrastructure and real estate assets. Journal of Property Investment and Finance, 33, 19-44.

YOBACCIO, E., RUBENS, J. & KETCHAM, D. 1995. The inflation hedging properties of risk assets. The case of REITs. Journal of Real Estate Research, 10, 279-296.

Appendix

Appendix 1: Inflation Correlations

	US_I	US_EI_arima	US_UI_arima
US_I	1.000		
US_EI_arima	0.362	1.000	
US_UI_arima	0.874	-0.136	1.000
	UK_I	**UK_EI_arima**	**UK_UI_arima**
UK_I	1.000		
UK_EI_arima	0.455	1.000	
UK_UI_arima	0.873	-0.038	1.000
	EU_I	**EU_EI_arima**	**EU_UI_arima**
EU_I	1.000		
EU_EI_arima	0.389	1.000	
EU_UI_arima	0.919	-0.006	1.000
	JP_I	**JP_EI_arima**	**JPN_UI_arima**
JP_I	1.000		
JP_EI_arima	0.178	1.000	
JPN_UI_arima	0.982	-0.013	1.000
	AU_I	**AU_EI_arima**	**AU_UI_arima**
AU_I	1.000		
AU_EI_arima	0.737	1.000	
AU_UI_arima	0.669	-0.009	1.000

Appendix 2: Results of Kwiatowski-Phillips-Schmidt-Shin (KPSS) Test

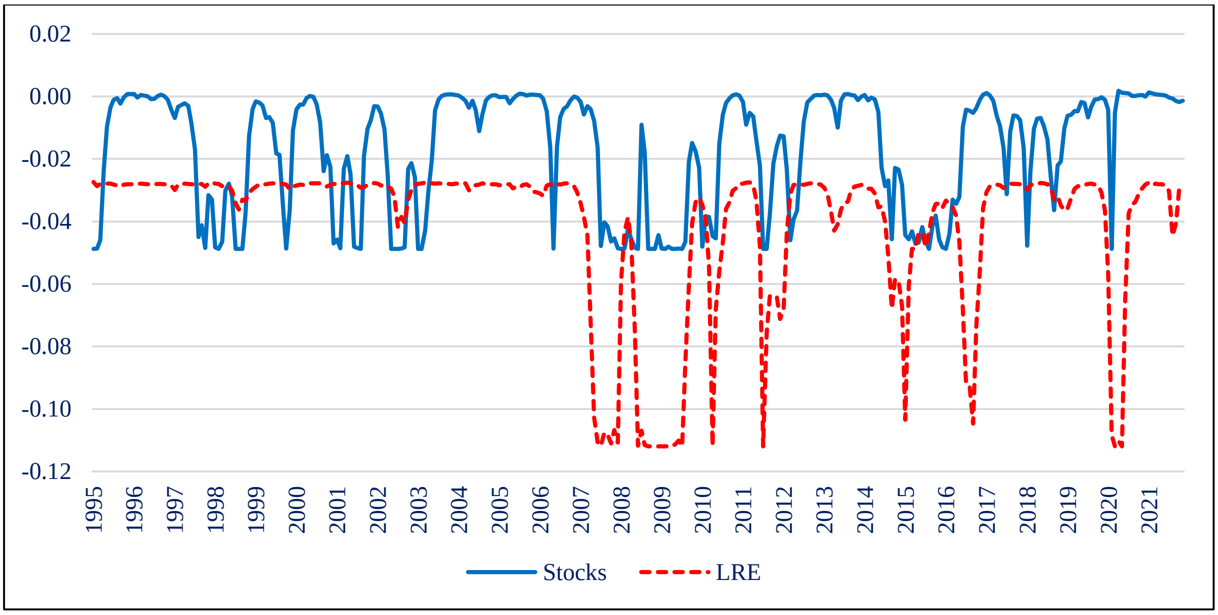
		Level	Difference	I(d)		Level	Difference	I(d)
lnLRE	**US**	6.105***	0.079	1	**EU**	6.203***	0.077	1
lnStocks		5.808***	0.099	1		4.286***	0.072	1
lnOil		4.500***	0.054	1		4.500***	0.054	1
lnGold		5.633***	0.286	1		5.633***	0.286	1
lnSilver		5.408***	0.089	1		5.408***	0.089	1
lnAgriculture		3.040***	0.066	1		3.040***	0.066	1
lnGDP		6.409***	0.167	1		6.268***	0.419	1
Interest Rate		4.712***	0.141	1		4.616***	0.176	1
EI		6.498***	0.616	1		6.479***	0.647	1
UI		6.375***	0.083	1		2.557***	0.696	1
lnLRE	**UK**	5.284***	0.044	1	**JPN**	4.544***	0.178	1
lnStocks		6.293***	0.031	1		0.849***	0.264	1
lnOil		4.500***	0.054	1		4.500***	0.054	1
lnGold		5.633***	0.286	1		5.633***	0.286	1
lnSilver		5.408***	0.089	1		5.408***	0.089	1

lnAgriculture		3.040***	0.066	1	3.040***	0.066	1
lnGDP		6.426***	0.243	1	1.496***	0.329	1
Interest Rate		4.904***	0.484	1	2.836***	0.364	1
EI		6.418***	0.263	1	6.418***	0.501	1
UI		5.388***	0.102	1	6.508***	0.662	1
lnLRE	AUS	4.563***	0.130	1			
lnStocks		5.295***	0.053	1			
lnOil		4.500***	0.054	1			
lnGold		5.633***	0.286	1			
lnSilver		5.408***	0.089	1			
lnAgriculture		3.040***	0.066	1			
lnGDP		6.525***	0.163	1			
Interest Rate		4.587***	0.473	1			
EI		6.516***	0.492	1			
UI		6.354***	0.060	1			

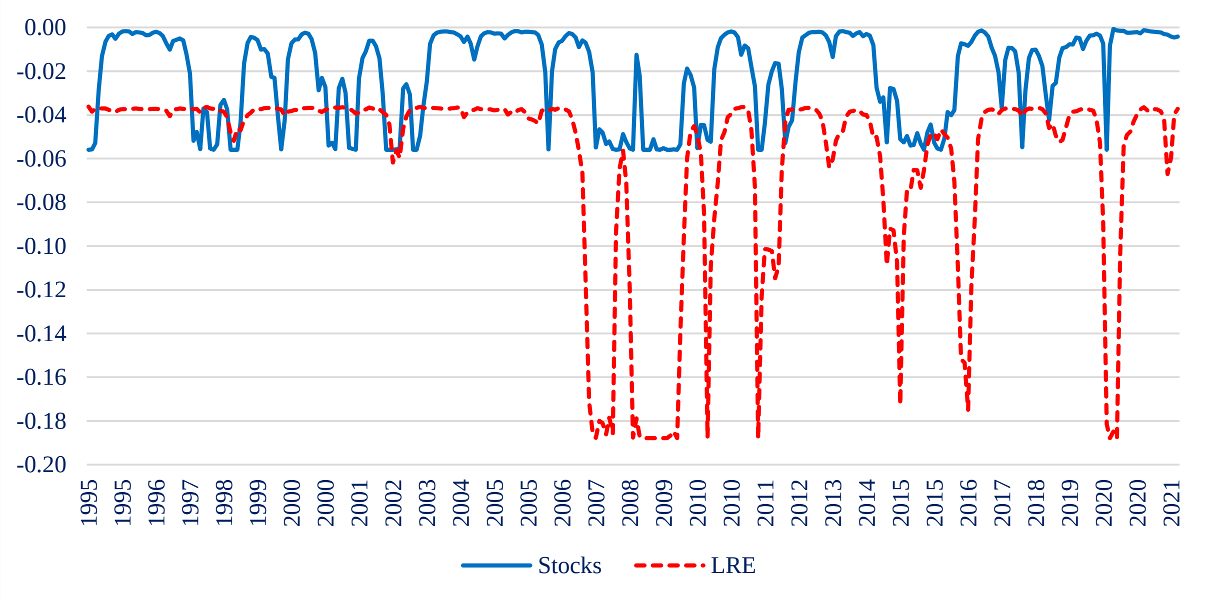
Notes: US stands for United States of America, EU stands for Eurozone, UK for United Kingdom, JPN for Japan, and AU for Australia. LRE denotes the FTSE/EPRA/NAREIT real estate stock total return index. Stocks denotes for each country the corresponding total return of the stock market index. Oil denotes the oil price in US Dollars. Gold denotes the gold price in US Dollars. GDP stands for GDP of each country. Interest rate are the 3-month treasury bill rates. EI index and UI index stand for an index of expected and unexpected inflation, respectively. SP denotes the starting point of the time series and Obs. displays the number of observations. I(1) is given for all variables in all countries

Appendix 3: Time-Varying Coefficients of LRE and Stocks

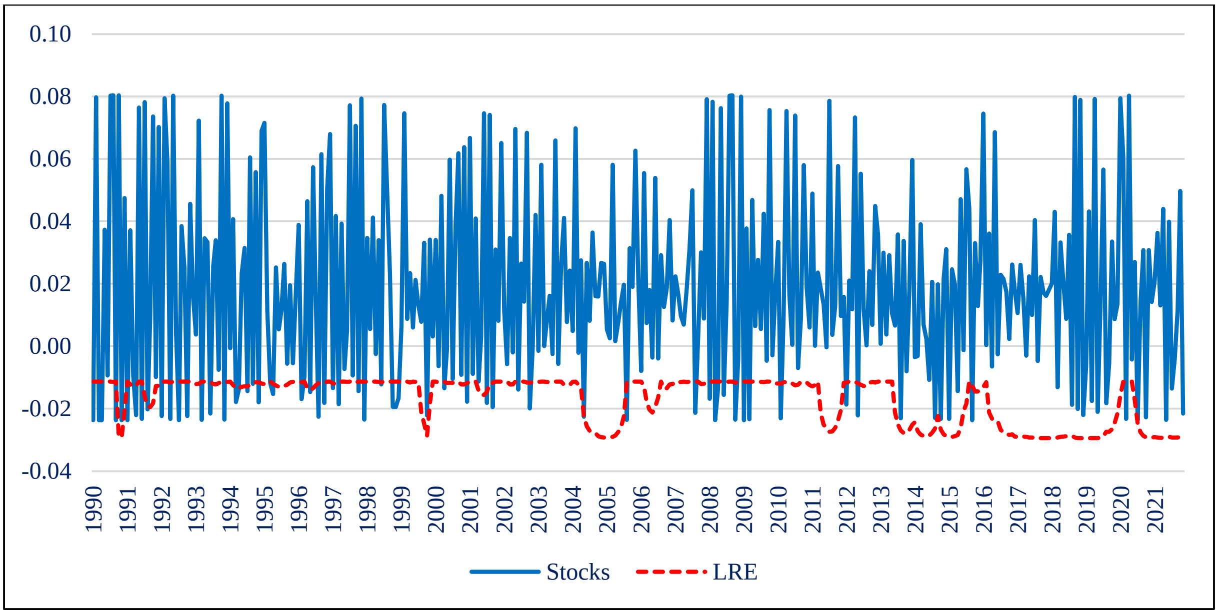
a. EU Time-Varying Coefficient of EI



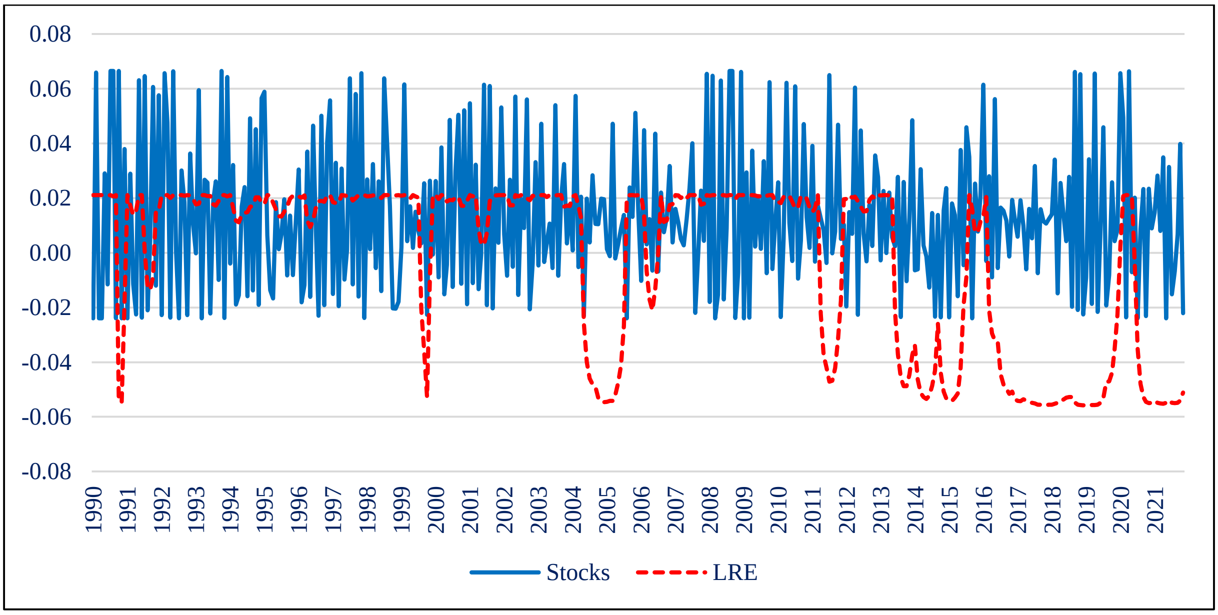
b. EU Time-Varying Coefficient of UI



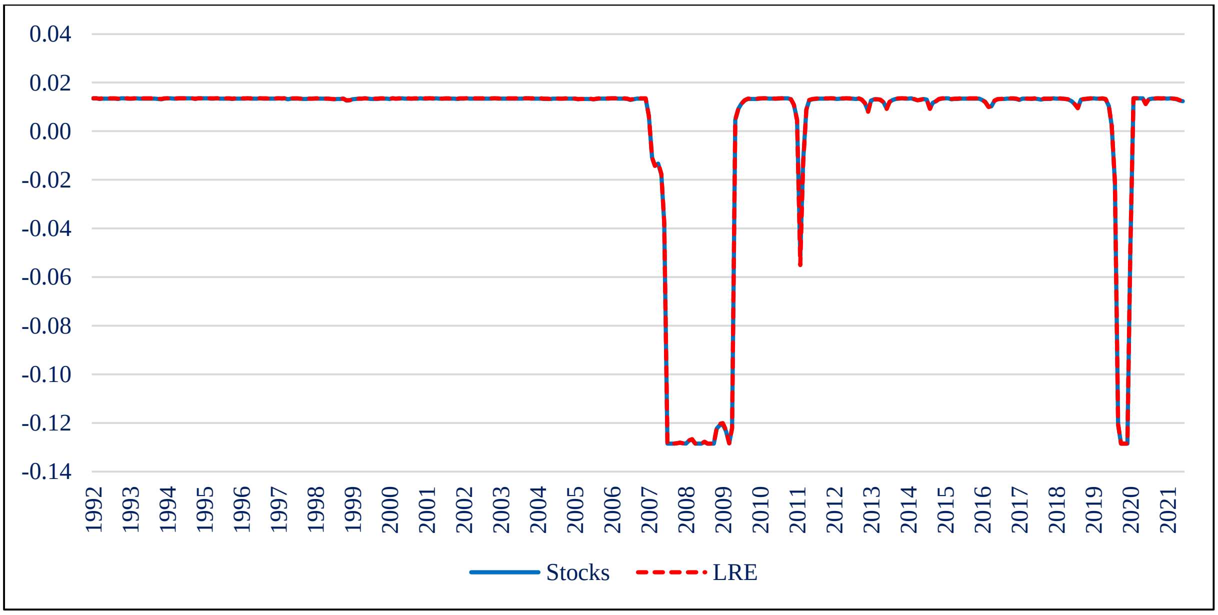
c. Japan Time-Varying Coefficient of EI



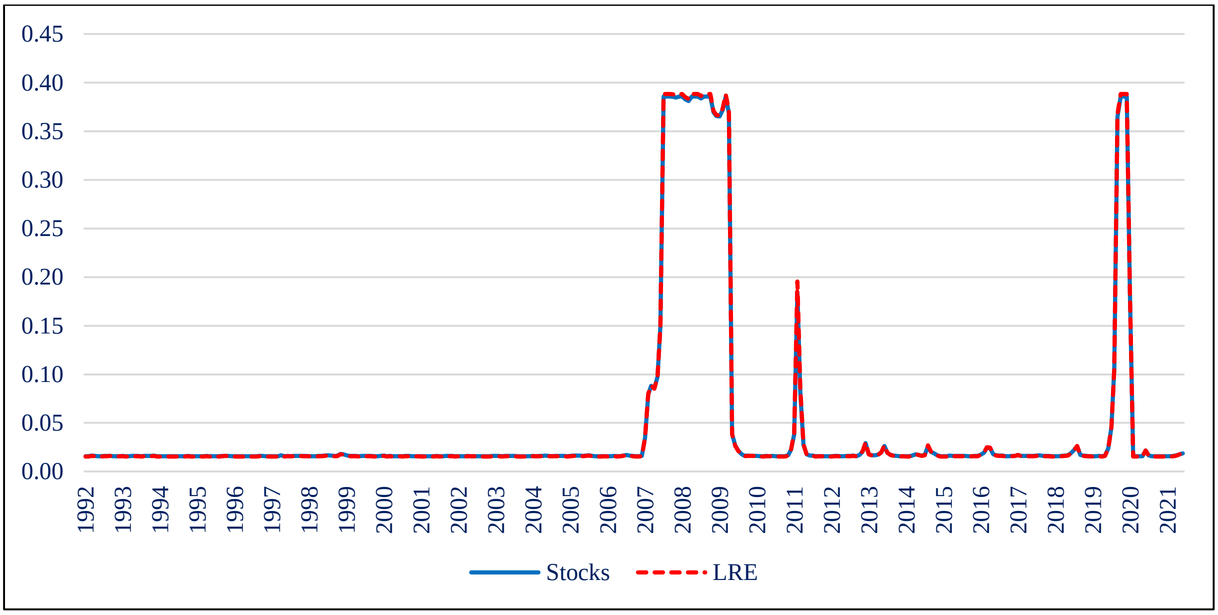
d. Japan Time-Varying Coefficient of UI



e. Australia Time-Varying Coefficient of EI



f. Australia Time-Varying Coefficient of UI



Appendix 4: Summary Statistics of Sectoral Total Return Index

		Mean	Std.	Max.	Min.	SP	Obs.
Residential	US	2325.390	1160.377	5919.390	509.340	01/2006	192
	UK	830.694	375.077	1603.020	146.460	01/2006	192
	EU	1057.898	615.742	2449.340	154.700	01/2006	192
Industrial	US	1206.935	719.940	4006.330	212.760	01/2006	192
	UK	721.093	408.844	2077.380	145.460	01/2006	192
	EU	2113.422	1935.370	8850.960	299.870	01/2006	192
Office	US	1501.264	414.111	2256.370	455.490	01/2006	192
	UK	1555.325	665.464	3042.550	349.140	01/2006	192
	EU	1284.762	317.858	2205.510	708.630	01/2006	192
Retail	US	1369.256	410.552	2227.160	354.230	01/2006	192
	UK	678.217	315.634	1421.740	49.390	01/2006	192
	EU	1509.551	432.892	2332.620	603.640	01/2006	192
Health	US	2593.477	967.741	4455.860	908.410	01/2006	192
	UK	1300.639	503.539	2521.780	583.520	01/2006	192
	EU	1159.253	443.807	2280.450	472.080	02/2007	179

Appendix 5: Results of Kwiatowski-Phillips-Schmidt-Shin (KPSS) Test for Sector Total Returns

		Level	Difference	I(d)			Level	Difference	I(d)
lnLREs_residential	US	1.163***	0.045	1	**lnLREs_industrial**	US	0.912***	0.134	1
	UK	0.822***	0.092	1		UK	0.649**	0.226	1
	EU	1.061***	0.176	1		EU	1.392***	0.255	1
lnLREs_office	US	1.100***	0.020	1	**lnLREs_retail**	US	0.821***	0.030	1
	UK	1.226***	0.043	1		UK	0.625**	0.105	1
	EU	1.044***	0.049	1		EU	0.218**	0.070	1
lnLREs_health	US	1.507***	0.022	1					
	UK	1.380***	0.094	1					
	EU	1.147***	0.008	1					

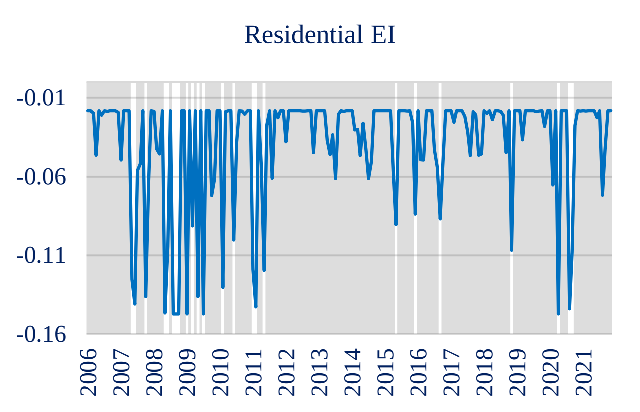
Appendix 6: Long-Term Equilibrium Relationships (β-vectors) by Sectors

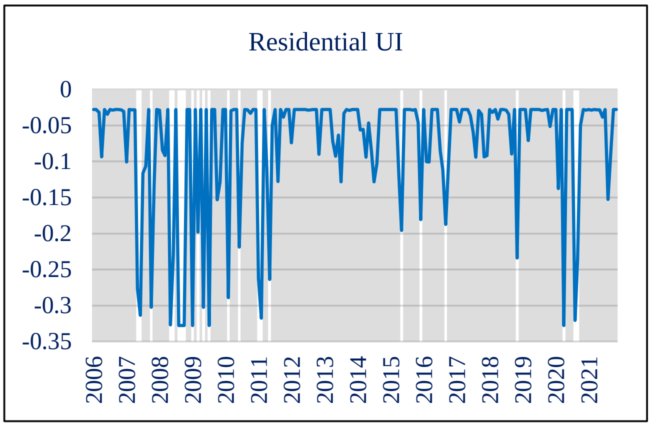
EUROZONE	Rank	EI_{t-1}	UI_{t-1}
Residential	1	-0.194***	-0.431***
		(0.026)	(0.063)
Industrial	1	-0.223***	-0.367***
		(0.027)	(0.064)
Office	1	0.147***	0.340***
		(0.024)	(0.056)
Retail	0		
Health Care	1	0.366***	0.860***
		(0.073)	(0.172)

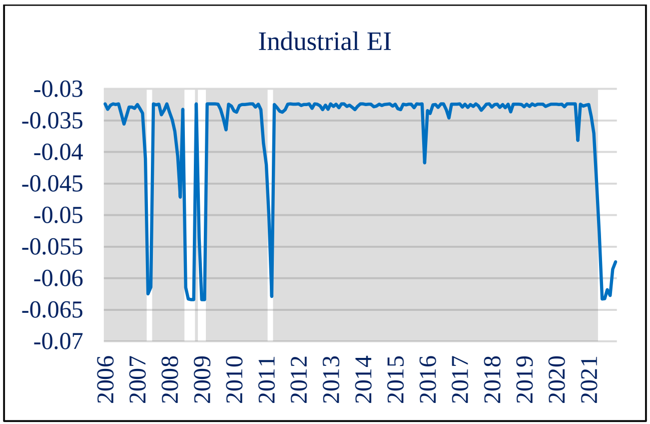
US	Rank	EI_{t-1}	UI_{t-1}
Residential	1	0.112***	0.061
		(0.016)	(0.079)
Industrial	1	0.010	0.216**
		(0.023)	(0.109)
Office	2	0.136***	0.519***
		(0.021)	(0.101)
Retail	1	0.217***	-0.084
		(0.036)	(0.172)
Health Care	2	0.079	-0.849*
		(0.092)	(0.449)

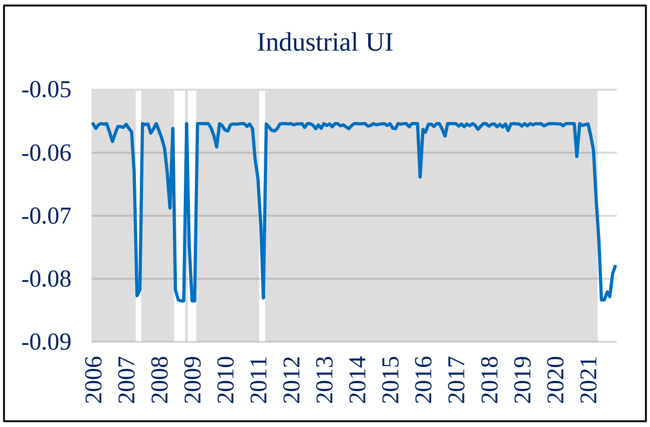
UK	Rank	EI_{t-1}	UI_{t-1}
Residential	3	-0.035***	0.489***
		(0.013)	(0.179)
Industrial	3	-0.045	-0.517
		(0.029)	(0.346)
Office	4	0.049***	1.161***
		(0.015)	(0.266)
Retail	3	0.073***	-0.224
		(0.018)	(0.251)
Health Care	3	0.015*	0.505***
		(0.008)	(0.118)

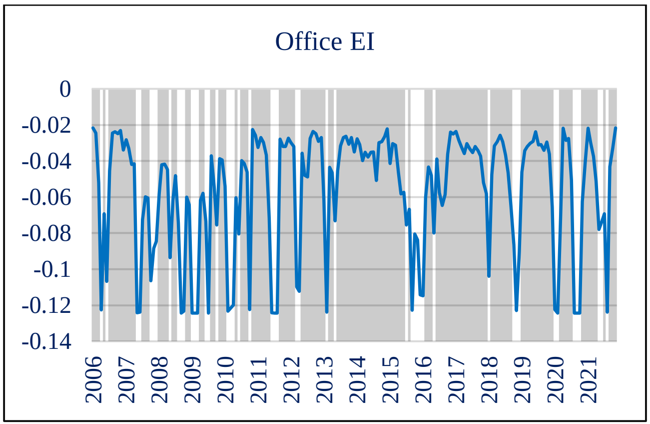
Appendix 7: Time-Varying Coefficients of EI and UI by Sector [EU]

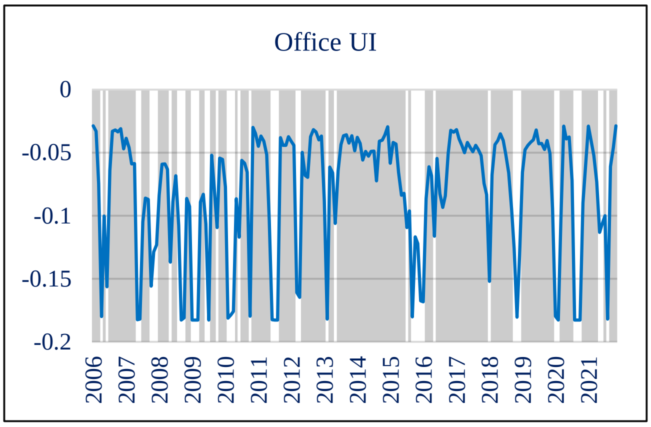


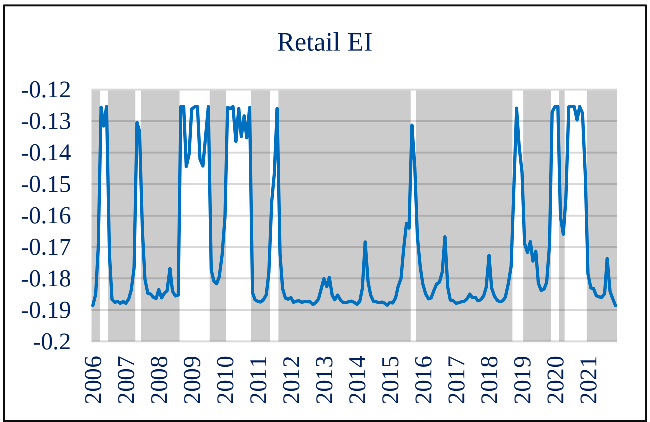


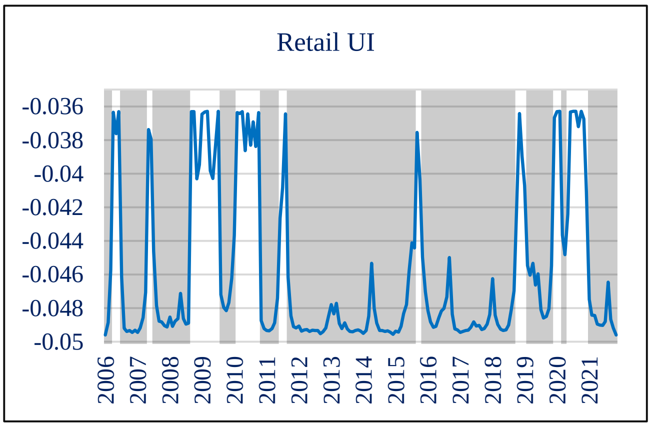




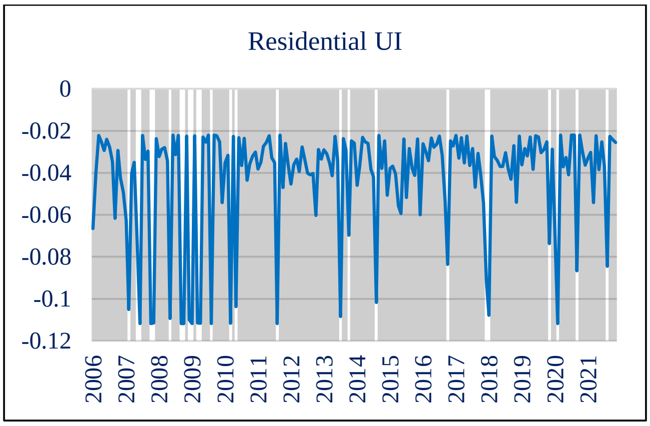


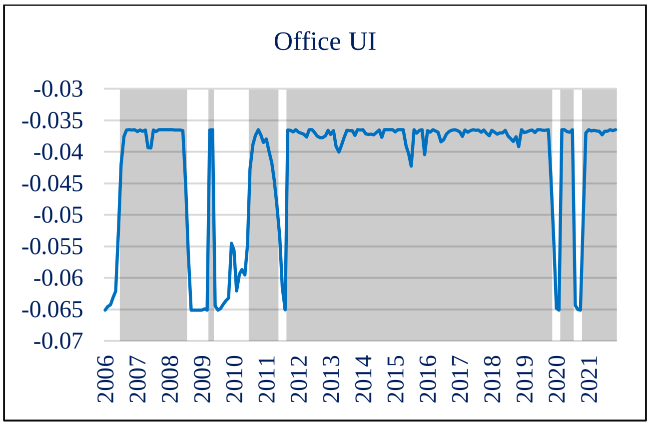


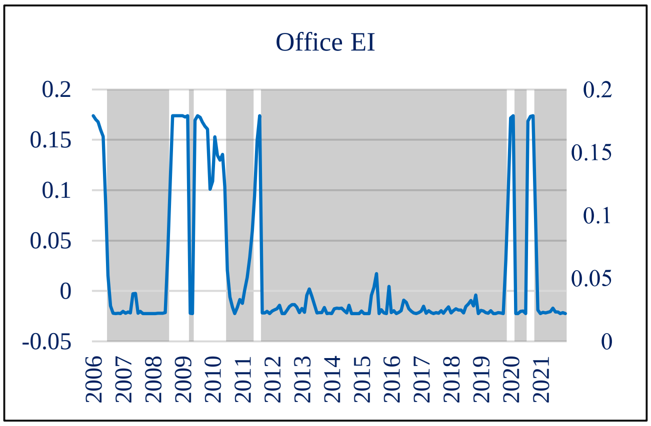


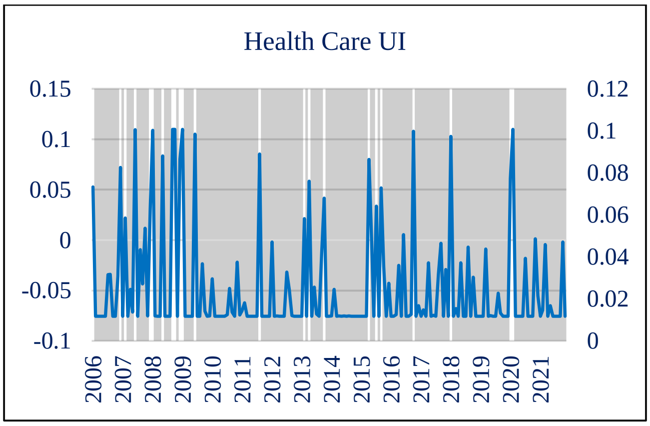


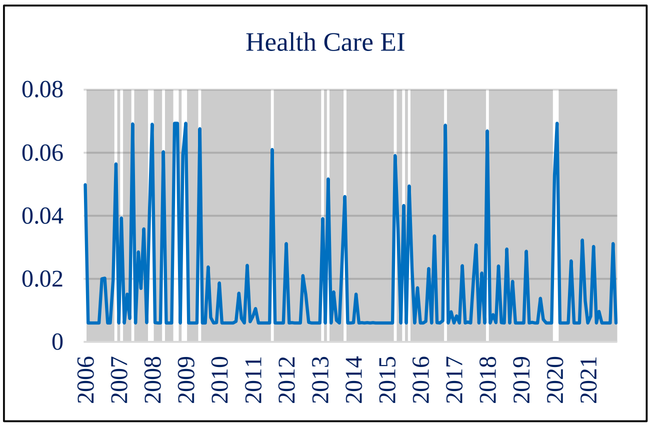
Appendix 8: Time-Varying Coefficients of EI and UI by Sector [US]



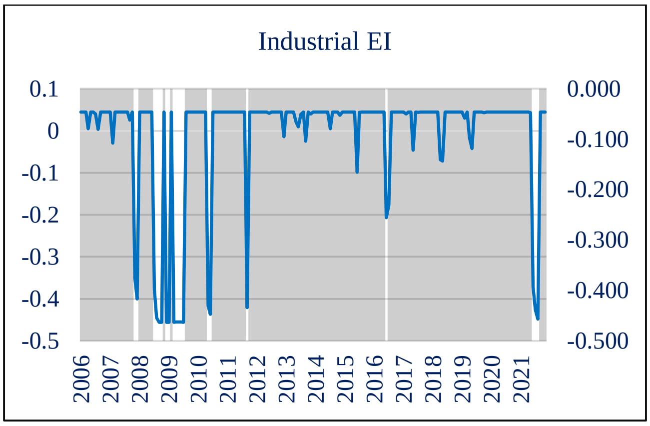


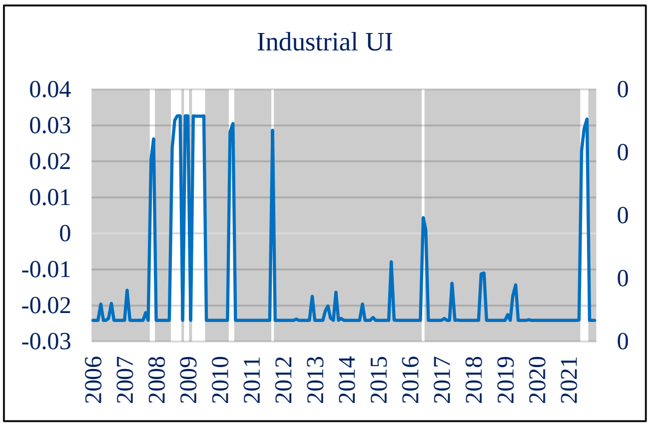


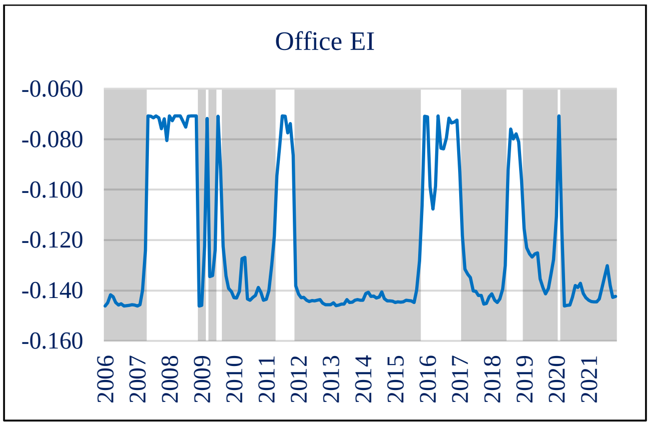


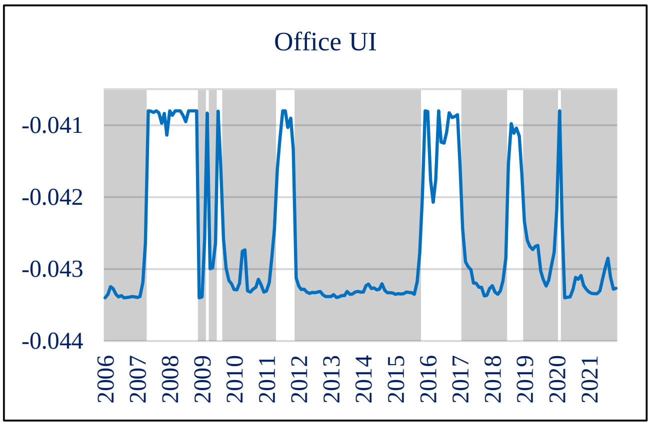


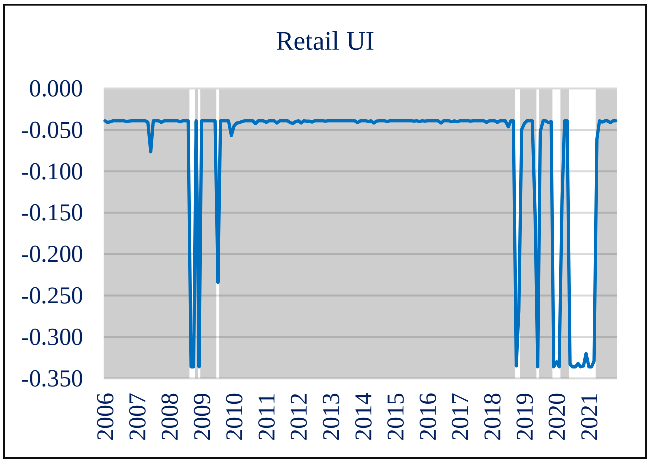
Appendix 9: Time-Varying Coefficients of EI and UI by Sector [UK]











Appendix 10: Average Summary Statistics of Portfolios with Various Real Target Returns and Investment Horizons for the Eurozone over the Entire Sample Period

Target Real Return	Weights of LRE	Shortfall Probability	Mean	SD	Sharpe Ratio
Rebalanced every 2 years					
r = 0%	56.93%	2.41%	2.25%	14.60%	23.57%
r = 1%	56.76%	3.87%	2.66%	21.31%	28.34%
r = 2%	34.49%	4.12%	3.44%	23.57%	29.58%
r = 3%	31.21%	4.59%	4.27%	23.61%	31.00%
Rebalanced every 5 years					
r = 3%	40.90%	5.16%	1.90%	23.18%	9.82%
Rebalanced every 10 years					
r = 3%	46.89%	4.49%	3.15%	27.90%	13.07%
Rebalanced every 30 years					
r = 3%	17.67%	6.94%	3.00%	105.31%	2.85%

Note: The weights of LRE, the shortfall probability, the mean of portfolio returns, the standard deviation of portfolio returns (SD), and the Sharpe ratios of portfolios are the average values over the entire sample period