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**What is the Optimal Portfolio Composition for Institutional Investors given different
Commercial Real Estate Indices?**

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Abstract

Despite being essential investment tools for investors, the topic of choosing between commercial real estate (CRE) indices in theory and practice has been severely under-discovered in academic research. This study compares the nature and analyzes the return data of five CRE indices to recommend to practitioners which index to apply in their academic studies and real-life portfolios. The results show that the CoStar Commercial Repeat-Sale Index incorporates information the most efficiently and represents a broad range of properties in the CRE market. Furthermore, within the optimal portfolios, an allocation towards direct real estate indices of around 57% or 66%, depending on the portfolio type, is recommended.

Keywords

Commercial Real Estate Indices; Index comparison; Portfolio analysis; Institutional investors

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1. Introduction

Until 1978, when the National Council of Real Estate Investment Fiduciaries (NCREIF) NPI was introduced as the first real estate index, real estate returns were not measured (NCREIF 2023a). Since then, real estate indices for commercial real estate (CRE) have become increasingly relevant. They are particularly beneficial for institutional investors and investment managers when making asset allocation decisions regarding how much real estate to add to a portfolio compared to stocks and bonds, as well as how much direct vs indirect real estate to include (Garay 2016). Besides that, they can serve as benchmarks for performance attribution and support theoretical real estate market analyses (Garay 2016; Fisher, Geltner, and Webb 1994). Hence, it is crucial for institutional investors to choose the most suitable and reliable index when performing any of these operations. Nevertheless, there is not one widely accepted real estate index but several with different construction methods and differing results (Sun, Yang, and Zhao 2012). Even though numerous studies explore different index construction methodologies and techniques, the topic of index appropriateness and coverage is still not sufficiently discovered. Sun, Yang, and Zhao (2012) were the first to address this perspective by studying the nature of different indices in order to understand their relevance to particular participants in the CRE industry. Nevertheless, the existing literature on this topic and the data used in the study are severely outdated, considering that some of the tested indices no longer exist. Further, despite comparing the suitability of the CRE indices for theoretical applications, their study is missing a real-life application of comparing which index is most appropriate for actual investment portfolios. Consequently, it is crucial to test whether the results found in earlier studies still hold in today's economic environment, especially in such uncertain times, such as the COVID-19 pandemic and substantial interest rate changes. Hence, the purpose of this thesis is to challenge the results found by Sun, Yang, and Zhao (2012) and extend their analysis by

adding another index to the evaluation and exploring which index best reacts to changing interest rates, as these significantly influence the valuation of real estate assets and can ultimately influence their optimal allocation within a portfolio. Finally, I compare the indices' effectiveness when setting up investment portfolios in practice. This is done by exploring the research question: "**What is the optimal portfolio composition for institutional investors given different commercial real estate indices?**" Thereby, the focus will be on comparing which index is the most appropriate CRE index to apply in theory and practice.

The following will be structured as follows: firstly, existing literature is reviewed on index construction methods and weighting techniques. After that, background information on the indices covered in this thesis is provided. Subsequently, the methodical approach is explained, followed by the empirical results. Following on from this, the interpretation of the results is explained in the form of theoretical and practical implications, as well as the limitations of this study. Finally, the most important results and takeaways are summarized.

2. Literature Review

2.1 Appraisal-Based vs. Transaction-Based Real Estate Indices

The two main values converted into real estate indices are appraisals and transaction prices (Garay 2016). Appraisals are estimates made by humans, often appraisers, regarding the value of properties and are often used in markets with infrequent or limited transactions and, therefore, scarce transaction data (Fisher, Geltner, and Webb 1994). Consequently, appraisal-based real estate indices are based on these human appraisals rather than on transaction prices. These indices have the advantage of being easier to construct due to their great data accessibility and simplicity (MacGregor, Schulz, and Green 2018). Nonetheless, appraisals, therefore, are subjective estimates rather than objective evaluations. Therefore, research has shown that they deviate vastly from the subsequent sale prices (Sun, Yang, and Zhao 2012). Consequently, appraisal-based indices tend to be smoothed, as the appraised values are less volatile than the

actual sale prices because of an underestimation of real estate risk. This smoothness is because appraisers frequently include past appraisals of the same properties in their evaluation and combine these values with recent comparable sale values to arrive at the final reported value (Fisher, Geltner, and Webb 1994). Therefore, an issue with appraisals is that they tend to be anchored to previous appraisals and disaggregate new information about properties. As a result, appraisal-based indices often depict a delayed reflection of the market and lag the underlying market value changes (Sun, Yang, and Zhao 2012; Fisher, Geltner, and Webb 1994).

The focus of transaction-based real estate indices is on the description of actual transaction prices of properties (Fisher, Geltner, and Webb 1994). More specifically, transaction prices are an empirical observation made solely after a property has been sold. Consequently, an advantage of transaction-based real estate indices is that they express the real-time prices of properties and are not based on subjective estimations (Fisher, Geltner, and Webb 1994). Hence, they are neither smoothed nor lagged. Nonetheless, also transaction-based real estate indices have significant downsides. The key issue of transaction-based real estate indices is to keep a constant quality, meaning that for the index to be reliable, lots of transactions are needed, with the chosen properties and, consequently, the index itself being representative of the whole market (Chau et al. 2021). One complication relates to the fact that no two properties are identical, and commercial properties are traded with low frequency due to their large sales prices. Hence, there is a chance that the sample of sales in one period might be skewed due to only using a subsample for the estimation (Chau et al. 2021). The result is that the transaction prices are inefficient, and the subsample used is not representative of the entire property market, resulting in a sample selection bias (Chau et al. 2021). Another complication is that the characteristics or quality of the properties in the sample can change from period to period due to reasons such as restructuring or refurbishing of the properties (Fisher, Geltner, and Webb 1994). These changes significantly impact the transaction prices and ultimately negatively affect the interpretation and

measurement of the observed price differences across time (Chau et al. 2021). Nonetheless, the lack of adequate data has been the most significant obstacle of transaction-based real estate indices (Downs and Slade 1999). The data needed to create the index stems from not publicly available information, which makes the index construction much more difficult (Downs and Slade 1999). More specifically, in states without public disclosure, the professionals must rely on informal networks to obtain the transaction data, making its reliability questionable. Consequently, important information, such as whether a transaction has occurred, is often missing (Chau et al. 2021). Even if there is data on the transaction and an index could be created, there is often missing information on significant price-influencing attributes, ultimately damaging the accuracy of the index. None of the two index construction methods has proven to be the ultimately superior one yet, and both are still widely applied in practice and academics nowadays (Sun, Yang, and Zhao 2012; Fisher, Geltner, and Webb 1994).

2.2 Value- vs Equal-Weighting Scheme

To determine the value of the individual assets in an index, they can be weighted according to different schemes. One of these techniques is the value-weighting method, which is the predominant method applied in stock markets (Sun, Yang, and Zhao 2012). In this method, the number of shares outstanding is an important determinant of the value of a stock in an index, as its value is determined by multiplying the number of shares outstanding by the stock's price (Hayes 2022). Hence, the assets with a higher market capitalization receive a greater weight in the index. Accordingly, index components with a higher market capitalization will have a greater impact on the overall index performance (Hayes 2022). The primary rationale for why this method is so widespread in the stock market is that the ownership of equity in a company is dividable, so that the value-weighted stock index accurately reflects the actual wealth of an average investor in the stock market (Sun, Yang, and Zhao 2012). Moreover, in equity markets, the stock of large organizations tends to be the most liquid, while that of smaller businesses is

more volatile. Consequently, the equity market is best represented by an index, which is mainly influenced by large-cap stocks, as they provide the most stable and accurate representation.

Unlike other investment types, real estate properties are indivisible, and it is difficult for ordinary CRE investors to participate in numerous high-value transactions simultaneously (Sun, Yang, and Zhao 2012). Therefore, the value-weighting method is not the predominant technique applied in the CRE market. Instead, many real estate indices are equally weighted, meaning that all assets have an equal impact on the index performance (Hayes 2022). Furthermore, smaller-value properties are favored in this method compared to the value-weighting scheme by giving them the same level of importance as larger-value properties (CFI Team 2023). Since the majority of transactions in the CRE market are of low value, an equally weighted index will be affected mainly by low-value properties (Sun, Yang, and Zhao 2012). Accordingly, the equal-weighting scheme provides a more accurate representation of the CRE market.

2.3 CRE Indices Overview

As this thesis aims to challenge the results found in the paper by Sun, Yang, and Zhao (2012), mostly the same CRE indices will be covered, namely the NAREIT, NCREIF NPI, NCREIF TBI, and CCRSI. No data was available on Moody's CPPI index, so instead, their analysis is extended by adding the GS CPPI index.

The National Association of Real Estate Investment Trusts (Nareit) is a trade organization and worldwide representative for Real Estate Investment Trusts (REITs) focusing on the U.S. (Sun, Yang, and Zhao 2012; NAREIT 2023a). The members of Nareit are real estate companies that operate as REITs, as well as publicly traded real estate businesses and individuals that provide services to REITs (NAREIT 2023a). The respective index of Nareit is the FTSE Nareit U.S. Real Estate Index (NAREIT 2023a). For the purpose of this analysis, the Nareit Equity Index (NAREIT), which tracks the performance of equity REITs in the U.S., will be used.

Since this index covers all publicly traded real estate companies in the U.S., it is a well-diversified index (Sun, Yang, and Zhao 2012). Nevertheless, recent market analyses report that most CRE properties in the U.S. are privately owned and that most private investors need to rely on debt to finance their CRE investments (Kuhl 2023). Hence, the NAREIT does not cover the majority of CRE investors, and its coverage is rather narrow (Sun, Yang, and Zhao 2012). Besides that, the NAREIT equity index is levered, which means that it amplifies market condition changes in the CRE sector. Additionally, REITs are traded daily, just like stocks. Consequently, they are exposed to stock market factors, such as higher liquidity and volatility. These factors combined could lead to excess volatility (Sun, Yang, and Zhao 2012). Despite that, the NAREIT is value-weighted, which seems reasonable as the assets it tracks are traded like stocks. Based on the stock market factors the NAREIT carries, the expected empirical results are that the NAREIT index has a higher volatility than the other CRE indices and exhibits the highest correlation with a stock index such as the S&P500. Moreover, because of its narrow coverage, the NAREIT is anticipated not to be representative of the entire CRE sector.

NCREIF is a non-profit organization and data service provider founded to support the tax-exempt institutional real estate investment sector to collect and provide CRE performance and benchmarking information (Sun, Yang, and Zhao 2012; NCREIF 2023d). Its members include mainly pension funds but also professionals such as real estate appraisers and investment managers (Fisher n.d.). NCREIF published both the NCREIF Property Index (NCREIF NPI), an appraisal-based index, and the NCREIF Transaction-Based Index (NCREIF TBI), which is based on transaction data (Sun, Yang, and Zhao 2012). Since 2020, the NCREIF TBI has not been published anymore since the number of transactions occurring has become too insignificant to produce a reliable index (NCREIF 2023c). Nevertheless, the NCREIF TBI remains part of this analysis as it might be a valuable index for academic research on the CRE market. Properties are included in the two indices when a data-contributing member owns them, and they are

excluded when they are sold to non-members (Sun, Yang, and Zhao 2012). Hence, both indices characterize privately held CRE properties. Additionally, all returns from both indices are reported on an unleveraged basis, which aids in avoiding excess volatility (NCREIF 2023b; NCREIF 2023c). Despite representing privately held CRE properties, both indices only have a low market coverage with a total market value of around \$900 billion, compared to the total market value of U.S. CRE of around \$20 trillion (NCREIF 2023b; NAREIT n.d.). Moreover, the NCREIF NPI is weighted according to the value-weighting scheme, which is not intuitive considering the assets it tracks are real estate properties (NCREIF 2023b). In contrast, the NCREIF TBI is equal-weighted, which is more intuitive for a real estate index (NCREIF 2023c). Based on this information, likely empirical results are that both indices show some counterintuitive results, as pension funds, as the primary users, might be interested in very particular properties that are not representative of the entire sector. Furthermore, the NCREIF NPI is expected to have a low volatility because of the fact that it is appraisal-based and, therefore, likely smoothed. The NCREIF TBI is expected to have a higher volatility than the NCREIF NPI because it is based on transactions and not appraisals. Nevertheless, because both indices are based on the same properties, they are expected to be highly correlated.

The CoStar Commercial Repeat-Sale Index (CCRSI) is published by the CoStar Group and is an unleveraged, transaction-based real estate index (CoStar 2023b). Moreover, the index exists in both an equal-weighted and value-weighted version, but for this analysis, the equal-weighted version will be used as it is a more reasonable weighting method for real estate indices. Unlike other indices, such as NCREIF, which only consists of large, prime properties, the CCRSI includes CRE transactions of all deal sizes (CoStar 2023b). The result is an advantageous ample market coverage. Since the majority of transactions in the CRE market is of low value and the CCRSI is equal-weighted, it is predominantly driven by low-value properties (Sun, Yang, and Zhao 2012; CoStar 2023c). Because of this characteristic, it is expected that the CCRSI provides

an adequate representation of current market conditions. Furthermore, because the CCRSI is unleveraged, its returns are expected to be less volatile than those of the NAREIT. Additionally, since this index is transaction-based, it should be more volatile than the NCREIF NPI but somewhat less volatile than the NCREIF TBI because of the broader coverage of the CCRSI.

Lastly, the Green Street Commercial Property Price Index (GS CPPI) is an appraisal-based index focusing on high-value CRE transactions (Green Street 2023). It is unleveraged and covers the prices at which CRE transactions are presently contracted or negotiated (Green Street 2023). As established before, only a minor part of all CRE transactions is of high value, as the majority constitutes low-value transactions (CoStar 2023c). Hence, the coverage of the GS CPPI is very narrow. Furthermore, the GS CPPI is a value-weighted index, which is not the predominant method for real estate indices (Green Street 2023). Since this means that it is most sensitive to high-value property price variations, instead of measuring the performance of average properties, this index is likely not that representative of the entire market sector. Hence, an expected empirical result is that this index will display some counterintuitive results. Furthermore, due to its similarity to the NCREIF NPI, a high correlation between the two indices is highly likely. Additionally, its volatility is expected to be lower than that of the transaction-based indices and similar to that of the NCREIF NPI because of its appraisal-based nature.

Table 1. Summary of the indices analyzed in this thesis

<i>Index Name</i>	<i>Input Data</i>	<i>Leverage</i>	<i>Weighting method</i>	<i>Property transaction size</i>	<i>Market Coverage</i>
NAREIT	Equity REIT Prices	Leveraged	Value-weighted	Not applicable	Low
NCREIF NPI	Appraisals	Unleveraged	Value-weighted	High-value	Low
NCREIF TBI	Transaction prices	Unleveraged	Equal-weighted	High-value	Low
CCRSI	Transaction prices	Unleveraged	Equal-weighted	High- & low-value	High
GS CPPI	Appraisals	Unleveraged	Value-weighted	High-value	Low

Source: Data partially from Sun, Yang, and Zhao (2012)

Table 1 summarizes the key characteristics of the different CRE indices, showing that there is a combination of appraisal- and transaction-based indices, with the majority being

unleveraged. Furthermore, both weighting methods are almost equally present. Besides that, most CRE indices analyzed focus on high-value transactions and have a low market coverage.

3. Research Methodology

To explore the research question “What is the optimal portfolio composition for institutional investors given different CRE indices?” a quantitative research approach is most appropriate and straightforward. Accordingly, return data was downloaded on a monthly basis for the NAREIT, CCRSI, and the GS CPPI and quarterly for the NCREIF NPI and NCREIF TBI (NAREIT 2023b; CoStar 2023a; Green Street 2023; Bloomberg 2023). The time period covered ranges from the first quarter of 2000 until the second quarter of 2023, as data preceding this time are not as accurate for transaction-based real estate indices (Sun, Yang, and Zhao 2012). One exception is the NCREIF TBI, whose publication was terminated in 2020. All downloaded indices are composite indices, meaning the return data is at the national level without any subdivisions into different CRE property types. Besides that, monthly return data for the Case-Shiller (CS) and quarterly data for the Federal Housing Finance Agency (FHFA) house price indices, which measure the return of non-commercial real estate in the U.S., were downloaded for the same period (FRED 2023b; FHFA 2023). This is because house prices and CRE are highly positively correlated, so they can be used to check for counterintuitive results among the CRE indices (Sun, Yang, and Zhao 2012). Besides that, data for the S&P500, the U.S. federal funds interest rate, and for the ICE BofA U.S. Corporate index, tracking the performance of publicly traded bonds in the U.S, were downloaded quarterly (Bloomberg 2023; FRED 2023c; FRED 2023a). To make the return data comparable, all indices were adjusted to be quarterly, and the returns and standard deviations were annualized. The S&P500 and the bond index were needed for the portfolio analysis to answer the research question of establishing the optimal weights of the CRE indices in a combined portfolio of the three types of indices. For this, the

average expected returns and standard deviations were calculated for each still-existing CRE index for the period from 2000 to 2023. Because of significant interest rate fluctuations during that time and to avoid negative Sharpe ratios, I calculated the average return for each CRE index by adding today's risk-free rate to the average risk premiums for each index. Further, I assumed that an institutional investor holds real estate next to traditional stocks and bonds. Thus, I proxied this with the S&P500 index and the ICE BofA U.S. Corporate Index. Hence, the covariances were calculated in a matrix between the CRE indices, the S&P500, and the bond index. Then, the expected portfolio return was established as the product of the weight of each index in the portfolio and its respective average past return. The portfolio variance was calculated as the product of the transposed weight vector and the covariance matrix times the weight vector. The risk-free rate was taken as today's 3-month U.S. treasury bill rate. The Solver was then used to solve for the optimal weights of each index in the portfolios by minimizing the variance for the minimum-variance portfolio and by maximizing the Sharpe ratio for the tangency portfolio.

4. Empirical Analysis Results

This section describes the results of the statistical analyses, and their implications will be discussed in Section 5.

4.1 Means & Standard Deviations

To answer how institutional investors should choose among the different CRE indices, comparing their mean returns and volatilities is essential, as these significantly affect their weights in the portfolio analysis conducted later on. Accordingly, tables 3-8 in Appendix A report the annualized summary statistics of the indices introduced previously. Crisis and non-crisis subperiods are used because Sun, Yang, and Zhao (2012) discovered differences in results to verify whether these persist. As expected, the NAREIT has the highest volatility of all CRE indices in all periods tested because of its leverage and exposure to high stock market volatility.

In contrast, the NCREIF NPI has the lowest volatility in almost all periods tested because of its appraisal-based nature and smoothness. However, in contrast to previous research, this result does not hold in both the financial and the COVID crisis periods, in which the CCRSI's volatility is lower. Similarly, the GS CPPI's volatility is only slightly higher than that of the NPI but significantly lower than that of the other CRE indices, apart from the crisis periods. Further, the NCREIF TBI's volatility is higher than the NPI's as it depicts the second-highest volatility of all CRE indices tested in all subperiods. This result was also expected due to its transaction-based nature and narrow coverage. Besides that, the CCRSI's standard deviation is surprisingly low in all periods tested, which could be due to its broad coverage. As also shown by Sun, Yang, and Zhao (2012), the CS & FHFA suggest negative mean returns for the housing market during the financial crisis period, in line with the troubles of the housing and CRE markets during the housing crisis. Even though the CRE indices should capture this, the NCREIF NPI, TBI, NAREIT, and GS CPPI suggest counterintuitive positive mean returns. Similar counterintuitive results can be found during the COVID crisis when the CS and FHFA indices suggest positive mean returns, and the GS CPPI suggests negative mean returns, very close to zero.

4.2 Correlations

To further understand the differences in nature of the CRE indices, it is crucial not just to analyze their mean returns and volatilities but also how they move together and how they move with other housing and stock indices, such as the S&P500. Tables 9-14 in Appendix B report the results of this correlation analysis. As expected, the NAREIT exhibits relatively low and often even negative correlations with the other CRE and housing indices, especially in the pre- and post-financial crisis periods. Even during the COVID pandemic, when its correlations become slightly more positive, they remain at very low levels. In contrast, the correlations between the NAREIT and the S&P500 index are very high over the entire sample period, reaching their maximum values during the financial and COVID crisis periods. In fact, the

correlations between the S&P500 and the NAREIT are higher than any of the other correlations of the S&P500 and any other correlation between the other CRE indices. Besides that, even though results from previous research can be confirmed in that the NCREIF NPI and TBI depict a high correlation when considering the entire sample period until 2020, the pre-financial crisis and financial crisis period, this result does not hold anymore during the post-financial crisis period (Sun, Yang, and Zhao 2012). The initial high correlation can be explained because of their equal coverage, whereas later on, the number of properties in the NCREIF NPI increased more compared to the number of transactions, making the NCREIF TBI increasingly unreliable and leading to its discontinuation (NCREIF 2023c). Other than that, the NCREIF NPI and TBI depict somewhat low correlations with the CCRSI, especially in non-crisis times, whereas they increase during crisis periods. Further, as anticipated, the NCREIF NPI and GS CPPI depict very high correlations in all periods, which could be because both are appraisal-based. In contrast, the correlation between the NCREIF TBI and the GS CPPI is comparatively low and only increases during the financial crisis, in which almost all correlations increase. Other than that, the correlations between the GS CPPI and the other CRE and housing indices seem somewhat similar to those of the NCREIF NPI with the other CRE and housing indices. More specifically, they are overall low in non-crisis periods but increasing in both crisis periods. Hence, they tend to behave relatively similarly.

4.3 Plot Analysis

Additionally, it is essential to visually analyze the differences of the CRE indices by analyzing a graph that displays their returns (See Figure 1 in Appendix C). This analysis further confirms the expected results. First, it shows the excessive volatility of the NAREIT index (pink line), with extreme up and down movements. Further, it displays the counterintuitive results of the NCREIF NPI (dark red line) indicated in the previous analysis. For example, when the financial crisis started in the second quarter of 2007, the NCREIF NPI still showed a return

increase of around 1%, while all other indices displayed a decline between 4% and 14%. Also, from the beginning of 2009 onwards, it shows a strict upward trend of roughly 11%, which is not captured by the other CRE indices, apart from the GS CPPI. Additionally, the graph confirms the smoothness of the NCREIF NPI compared to the other CRE indices, as the dark red line displays much fewer up and down movements and peaks. For example, from 2011 onwards, the NCREIF NPI followed a very smooth and stable return decrease of around 5% for almost eleven years. Further, what stands out is that even though the line of the GS CPPI (grey) is not as smooth as that of the NCREIF NPI, it follows more or less a parallel pattern and is, overall, still smoother than the other indices. Besides that, the counterintuitive results of the GS CPPI found earlier can be confirmed. For example, from June 2021 onwards, the GS CPPI suggests a strictly positive return increase of around 8%, which is not captured by the other CRE and housing indices, except for the NCREIF NPI. Besides that, it is noticeable that, especially in non-crisis periods, the CCRSI (dark green line) behaves differently compared to the NCREIF NPI and GS CPPI, with more extreme and often opposing movements.

4.4 The Effect of Interest Rate Changes on Commercial Real Estate

Commercial real estate returns and, consequently, the valuation of CRE assets are significantly influenced by a broad variety of factors. One of these influencing factors are interest rates (Naranjo and Ling 1997). As interest rates rise, commercial property values and, consequently, their returns usually decrease (Major 2023; Hoesli and Malle 2021; Peng and Thibodeau 2019). One reason for this is that CRE properties are typically valued using an income approach by discounting their cash flows at a capitalization rate (Hoesli and Malle 2021). This rate incorporates a risk-free interest rate and a risk premium to compensate for the investment risk of investing in real estate. When interest rates are increased, the future cash flows are discounted at a higher rate, ultimately decreasing the value of the properties (Hoesli and Malle 2021). Apart from this, increased interest rates also lead to higher financing costs. Indeed, the

cost of borrowing increases as a result of rising interest rates (Major 2023). Hence, with rising mortgage costs, it becomes more difficult and less profitable for new investors to invest in CRE properties. Simultaneously, existing bank loans that are adjusted frequently to changes in interest rates become more costly and make the existing investments in CRE less profitable. These results also hold for decreasing interest rates, just in the opposite direction, with cheaper borrowing costs and increasing property values and returns (Peng and Thibodeau 2019). Hence, if the CRE indices incorrectly react to changes in interest rates, they would inadequately capture this risk and incorrectly forecast the level of returns. Consequently, they would be misvalued, which would ultimately skew their optimal portfolio allocation. Hence, it is crucial to verify that the CRE indices tested in this study correctly react to changing interest rates to ensure that the portfolio allocations found later on are based on reliable indices and that the results can be trusted. Overall, strong academic support exists for an inverse or negative relationship between interest rates and CRE prices (Major 2023; Hoesli and Malle 2021; Peng and Thibodeau 2019).

Tables 15-20 in Appendix D show the results of the respective correlation analysis. When considering the entire sample period, the GS CPPI is the only CRE index displaying a negative correlation with interest rates. However, none of the indices depicts a negative correlation when excluding COVID from the sample. Hence, it is crucial to look at different subperiods. In the pre-financial crisis period, the GS CPPI and CCRSI best capture the effect of interest rate changes on CRE returns, whereas, during the financial crisis, only the NAREIT displays a negative correlation. After that, all indices have improved in capturing the effect of interest rates. In the post-financial crisis and pre-COVID period, all indices but the NAREIT, and during COVID, all indices correctly display the correlation. Hence, overall, the GS CPPI and CCRSI capture the effect of interest rates on CRE returns the best. Apart from splitting the subperiods into crisis and non-crisis periods, it makes sense to split into increasing and decreasing interest periods to check for any alarming reactions (See Tables 21-26 in Appendix E). First, for

decreasing interest rate periods since 2007, almost all indices show intuitive negative correlations, except for the NCREIF NPI in the early years after the financial crisis. An explanation for this is that appraisal-based indices often underplay relevant information because they are smoothed and lagged. In contrast, in times of increasing interest rates, there are mixed results. Since 2015, only the NCREIF NPI, GS CPPI, and CCRSI display intuitive negative correlations, whereas the NAREIT, NCREIF TBI, and, since 2022, the GS CPPI all depict positive correlations with interest rates. In general, there has been an improvement of all indices regarding their reaction to interest rate changes, and especially for decreasing rates, all indices seem to capture the changes in interest rates very well. In fact, no index is consistently underperforming when reacting to interest rate changes, indicating that no index consistently underestimates interest rate risk. Figure 2 in Appendix F further visualizes these findings. When looking at the interest rate increase between 2016 and 2019, it is clearly visible that the CCRSI (dark red line), GS CPPI (green line), and NCREIF NPI (dark blue line) are the best at capturing this increase by showing declining returns. Further, the CCRSI displays movements that are almost opposite to those of the interest rates, highlighting its strength in reacting to interest rate movements. However, it is observable that, especially in times of increasing interest rates, the NCREIF TBI (light blue line) continues to report increasing CRE returns, opposite to the other indices, which is counterintuitive.

4.5 The Optimal Portfolio Allocations for Institutional Investors given different CRE Indices

As analyzed in section 4.1, the different CRE indices report varying mean returns and volatilities. These differences will affect the optimal portfolio compositions of institutional investors. More specifically, when establishing a portfolio out of a stock, a bond, and a real estate index, the weight allocated to real estate will differ depending on the risk-return tradeoff of each index. Hence, in a mean-variance portfolio, which minimizes the portfolio's variance, the highest share is allocated to those CRE indices with a low volatility. In contrast, in a tangency portfolio,

which maximizes the Sharpe ratio, the highest weight is allocated to those CRE indices with the highest individual Sharpe ratio. Table 2 reports the results of this portfolio analysis, showing the exact weights that should be allocated to each CRE index in the two portfolio variations.

Table 2. CRE Portfolio Allocations

	Minimum-Variance Portfolio				Tangency Portfolio			
	A	B	C	D	A	B	C	D
S&P500	13.58%	3.83%	5.26%	7.04%	0.00%	2.80%	10.57%	8.18%
ICE BofA US	84.82%	38.77%	57.34%	44.32%	78.17%	30.72%	62.34%	41.20%
NAREIT	1.60%	x	x	x	21.83%	x	x	x
NCREIF NPI	x	57.40%	x	x	x	66.48%	x	x
GS CPPI	x	x	37.40%	x	x	x	27.08%	x
CCRSI	x	x	x	48.64%	x	x	x	50.62%
Exp. Return	8.87%	10.53%	8.36%	8.97%	10.10%	10.82%	8.51%	8.99%
SD	5.55%	3.15%	4.53%	3.71%	6.38%	3.23%	4.64%	3.73%
Sharpe	0.32	0.83	0.34	0.49	0.32	0.85	0.34	0.49

When comparing the allocations to the mean-variance portfolios, it stands out that all portfolios show positive non-zero allocations for all CRE indices. Further, all portfolios provide similar annualized expected returns. However, compared to the other CRE indices, the allocation to the NAREIT is much smaller, which makes sense due to its high volatility. In contrast, the allocation to the NCREIF NPI is the highest due to its low volatility. This allocation to the NCREIF NPI ultimately provides the highest Sharpe ratio (0.83), given a minimum risk level. Further, it stands out that the NCREIF NPI is the only CRE index that would receive an allocation of more than 50% in a portfolio with the S&P500 and the ICE BofA U.S. bond index. The second highest allocation would be made to the CCRSI, with almost 50% and a corresponding Sharpe ratio of 0.49. Despite incurring a worse risk-return trade-off than for the NCREIF NPI, institutional investors could still receive better returns at lower risk levels than with investments into the NAREIT or GS CPPI.

Further, when analyzing the tangency portfolios, which maximize the Sharpe ratio, it stands out that the overall returns and Sharpe ratios are somewhat similar to those of the mean-

variance portfolios and only increased slightly. The NCREIF NPI portfolio still provides the highest Sharpe ratio, which makes sense since the NCREIF NPI has the highest individual Sharpe ratio of all the indices compared in this thesis. The allocation to the NCREIF NPI is even higher than in the mean-variance portfolio. In this case, the CCRSI still delivers the second-highest Sharpe ratio, and its allocation increased to slightly above 50%. Interestingly, the portfolio, including the NAREIT, now delivers the second-highest return, as the weight allocated to the NAREIT significantly increased. Nevertheless, due to its extremely high volatility, the Sharpe ratio remains very low. Overall, the NAREIT and GS CPPI still provide the lowest Sharpe ratios and, consequently, the worst risk-return tradeoffs for institutional investors.

5. Interpretation of the Results

5.1 Theoretical Implications

This thesis contributes to the existing academic literature about real estate indices in very distinct ways. So far, existing academic literature on which CRE index is the most appropriate to apply has been very limited and outdated. Therefore, this study extends this literature stream by testing previous results in a new time period and by expanding the indices analyzed. The NAREIT index and the NCREIF NPI and TBI indices are among the most well-known and widely applied indices in academic studies (Sun, Yang, and Zhao 2012). However, this analysis showed that the correlations of the NAREIT and the other CRE indices are very low, and in contrast to this, it depicts a high correlation with the S&P500. Hence, the information captured by this index deviates largely from that captured by the other CRE indices because it is an equity index that captures equity prices and, therefore, stock market sentiment. Due to this and its resulting narrow coverage, it is likely not representative of the entire CRE sector and, therefore, incorrectly depicts current CRE market conditions. Hence, the NAREIT should not be applied outside of its context of representing the equity prices of REITs when performing academic

studies on the CRE market. The NCREIF NPI has the advantage of being unleveraged. Nevertheless, it is an appraisal-based and value-weighted index, which is uncommon for property indices. The NCREIF TBI is one of the few indices tested with the advantages of being transaction-based, unleveraged, and equal-weighted despite only having a narrow coverage. The analysis showed that the correlation of the NCREIF NPI and NCREIF TBI is very high, especially in the early periods, indicating that the information they portray is very similar. However, the previous mean return and plot analyses have identified some counterintuitive results from both indices. This is likely due to their very specific and narrow coverage, representing mainly the particular interests of pension funds by focusing on high-value properties. These counterintuitive results indicate that these indices should not be applied for general purposes in academic studies as they are not adequate at representing average low-value CRE properties. Similar to the NCREIF NPI, the GS CPPI is an unleveraged, appraisal-based, and value-weighted index focusing on high-value properties, and their very high correlations confirmed the theoretical similarities between the two indices. Consequently, the information they capture is very similar. Besides that, the GS CPPI displays somewhat low correlations with the other CRE indices, indicating that their information coverage differs significantly. Furthermore, the correlations between the GS CPPI and the CS and FHFA move similarly to those of the NCREIF NPI with the housing indices over the entire period, only with minor differences in the financial crisis and post-financial crisis period. Based on its counterintuitive results and similarity to the NCREIF NPI, the GS CPPI does not represent the entire CRE sector either. An explanation for this stems from its focus on high-value properties in the portfolios of U.S. REITs (Green Street 2023). Since this constitutes only the minority of CRE transactions, the coverage of the GS CPPI is somewhat narrow, and therefore, the quantitative analyses likely showed that this index is not representative of the entire CRE sector. Hence, it should only be applied to investigate high-value properties in the U.S. In contrast, the low correlations with

other CRE indices tested showed that the information captured by the CCRSI is actually very different, especially in non-crisis periods. Also, the CCRSI is one of the few indices tested with the advantages of being transaction-based, unleveraged, and equal-weighted. Further, it is the only index that covers deals of both high and low value. Since it is equal-weighted and most CRE transactions are of low value, its focus is on low-value transactions (CoStar 2023c). Hence, it is the only index analyzed that actually represents average CRE properties in the market. Further, the mean return, correlation, and plot analyses solely provided intuitive results for this index, indicating an adequate information coverage of typical CRE properties and a good representation of the overall CRE market. Hence, instead of applying CRE indices focusing on niche areas of the CRE market in academic studies, the CCRSI constitutes a solid alternative to assess the overall market. Another contribution of this study relates to the interest rate analysis. It is crucial for institutional investors to know which CRE index is most optimal to apply in their theoretical risk management strategies to manage interest rate risk, depending on which CRE index reacts most accurately and for academics when conducting studies on the relationship of CRE and interest rate changes. The results showed that no CRE index consistently underperformed in its reactions to interest rate changes, indicating that all indices tested are suitable for these risk management strategies and academic studies. However, the CCRSI showed the most intuitive correlations of all CRE indices analyzed in all periods. Hence, for theoretical risk management strategies of both rising and falling interest rates and for market research on the CRE and interest rate relation, the CCRSI is the recommended index to apply. Additionally, the NCREIF NPI reacted intuitively to rising interest rates. Thus, institutional investors should exploit this index when setting up risk management strategies for rising interest rates. Finally, the GS CPPI is a suitable index for the risk management of decreasing interest rates or for market research on the effect of decreasing interest rates on CRE indices. Overall, this study extends existing academic literature by providing a more thorough understanding of

the CRE indices in terms of their coverage and most adequate theoretical applications. Instead of relying on the NAREIT and NCREIF NPI as the most commonly applied indices, academics and institutional investors should consider the results of this study to incorporate the particular CRE index with the most appropriate coverage and nature for their intended research objective.

5.2 Practical Implications

Apart from aiding academics and institutional investors in choosing the most appropriate CRE index for their theoretical academic research on CRE markets, this study also helps institutional investors and investment managers make practical investment decisions. In this case, characteristics such as the weighting method or coverage become less significant influence factors, whereas the risk and return variables become increasingly more influential. More specifically, this study analyzed the differences in mean returns and volatilities of the different CRE indices and consequently showed how these differences affect portfolio allocations in real life. Not only did this study analyze how much should be added to a direct real estate index, compared to stocks and bonds, but it also compared how much would be allocated to a REIT index. This was analyzed for both a minimum variance and a tangency portfolio. To ensure the results of these portfolio allocations are reliable, an interest rate analysis was conducted, showing that despite some indices being superior, all indices are overall adequate in their reaction to interest rate changes. Hence, no index consistently reacted incorrectly and underestimated the interest rate risk, which would have led to inadequate returns and inappropriate portfolio allocations. The results of the portfolio analysis showed that, in practice, institutional investors should allocate significantly less to REIT indices, such as the NAREIT studied here, than to direct real estate indices when creating a minimum-variance portfolio. This result can be explained based on the high stock market volatility of the NAREIT, which makes a portfolio including this index less optimal than the other portfolios that include CRE indices tracking direct real estate. In fact, investors should choose the NCREIF NPI instead when creating a

portfolio consisting of the S&P500, a bond index, and a real estate index, as this index leads to the highest return while minimizing the portfolio's risk. More specifically, institutional investors are advised to invest the majority of their funds (around 57.4%) into the NCREIF NPI, around 38.8% into bonds, and only a minor part (around 3.8%) into stocks. This will provide institutional investors with the most optimal return while minimizing risk. The practical implications are similar for investors with the aim of creating a tangency portfolio and receiving the highest risk-adjusted return (Sharpe ratio). Generally, institutional investors are also advised to select one of the CRE indices tracking direct real estate instead of REIT indices when setting up a portfolio, as this leads to higher Sharpe ratios. Even though choosing the NAREIT out of all CRE indices can lead to the second-highest return of all the portfolios, this return is accompanied by the highest risk of all portfolios, making it the least recommended option. In fact, institutional investors should again choose the NCREIF NPI when setting up a tangency portfolio consisting of stocks, bonds, and a CRE index, as this would give them the most optimal risk-return tradeoff. More specifically, this can be achieved by investing around 66.5% in the NCREIF NPI, 30.7% in bonds, and 2.8% in stocks. Alternatively, it is recommended to choose the CCRSI index, as this provides the second-highest Sharpe ratio. However, its risk-return tradeoff is significantly worse than the NCREIF NPI's. Overall, institutional investors are recommended to choose CRE indices tracking direct real estate over REIT indices when setting up real-life portfolios. More specifically, the NCREIF NPI is advised as the best CRE index when setting up minimum variance or tangency portfolios.

5.3 Limitations and Future Research

Despite the contributions of this study to theory and practice, there are several limitations. Firstly, data availability and access to CRE indices significantly limited the sample of indices that could be tested in this study. Because the return data of other significant CRE indices was not available, their results could not be challenged. Furthermore, the scope of this

study limited the depth in which the interest rate analysis could be conducted. Even though the intuitiveness of the direction was analyzed here, it is still open to test what a reasonable strength in reaction would be. Besides that, the generalizability of the portfolio analysis should be viewed with caution because the representativeness bias of extrapolating a small piece of information likely influenced the results. The inputs were based on the average values for each index for the time period 2000-2023. Of course, when taking different periods as calculation input, the average returns and volatilities of the indices would differ, and the consequent portfolio allocations and practical implications for investors would look different. However, due to the narrow scope of this study, these differences could not be analyzed.

Consequently, future research should repeat this analysis and extend it by including further significant CRE indices. This is crucial to give researchers a proper overview of which CRE index is most appropriate for their academic research to ultimately increase the reliability of results. Furthermore, future research should analyze not only the reaction direction of the CRE indices to interest rate changes but also whether the strength of the reactions seems reasonable. Additionally, the portfolio allocation for institutional investors should be repeated and based on different time periods to analyze variations in the recommendations. Finally, despite the majority of CRE transactions being of low value, the CCRSI is the only index that includes low-value transactions, even though just partially. It might be of particular interest to academics who want to explore CRE markets to develop an index solely constituting low-value properties and one solely comprising high-value properties to be able to display the full picture of the CRE market.

6. Conclusion

Undoubtedly, commercial real estate has become an increasingly relevant investment product for institutional investors. Especially the different construction methodologies and techniques of the underlying CRE indices have been widely explored in academic research.

However, the nature and coverage of the different indices and their relevance to different players in the industry have only received little attention, and existing academic studies can be considered outdated despite the undoubtful relevance of the topic. Hence, this study challenged and extended the existing literature by finding quantitative evidence on the differences in the nature of several highly significant CRE indices. The aim was thereby to provide advice on which index is the most appropriate to apply in theory and practice, with a focus on giving institutional investors advice on what the most optimal portfolio composition would be given different CRE indices. More specifically, this study quantitatively analyzed the NAREIT, NCREIF NPI and TBI, CCRSI, and GS CPPI. The results showed little commonality in the different indices' coverage and information content. Despite being one of the most commonly applied indices in academic studies, the NAREIT equity index captures stock market sentiment and does not adequately represent current conditions in the CRE market. Hence, it should not be applied out of context for general purposes in academic research. Further, this study confirmed previous results by showing that the information content of the NCREIF NPI and TBI is very similar and that their sample coverage is very narrow and specific due to several counterintuitive results. Hence, they should not be applied out of their initial purpose of representing the specific interests of pension funds. However, the NCREIF NPI performed well in its reaction to interest rate increases and can be regarded as a solid index to use in academic studies testing the relationship between CRE indices and interest rate increases. Besides that, this study extended previous research by showing that, similar to the NCREIF NPI, the information content of the GS CPPI differs drastically from that of the other CRE indices. Several counterintuitive results of this index proved its narrow and specific coverage, indicating that it does not provide a solid measure of average CRE properties. Hence, the GS CPPI should preferably be applied in studies focusing on high-value CRE properties or in studies focusing on the relationship with interest rate decreases. Finally, the information content of the CCRSI is actually very different from that

of the other CRE indices, and its results were solely intuitive. Hence, as it is the only index analyzed with a main focus on low-value transactions, which form the majority of properties in the CRE market, this index actually performs well in representing average CRE properties and current market conditions. Therefore, it is a solid input for academic studies examining the average CRE market and for interest movements in any direction. These findings have many important implications for participants in the CRE market. Applying the NAREIT or NCREIF NPI as default indices in academic studies is not appropriate, and the results of this study should be used as a basis to choose the most appropriate index depending on the research goal. Further, based on their differences in nature, the indices vary in their efficiency for setting up investment portfolios. More specifically, the NCREIF NPI is the preferred index for institutional investors when setting up minimum-variance or tangency portfolios with a real estate index, the S&P500, and a bond index. Moreover, institutional investors should choose CRE indices tracking direct real estate over REIT indices for their investment portfolios. However, due to the narrow scope of this study, there is still a need for further analysis of this topic. Hence, future research should further analyze the effectiveness of the indices for setting up portfolios by taking varying time periods as inputs and analyze the differences in results. Furthermore, even though this study analyzed the direction intuitiveness of the indices in their reactions to interest rates, it is essential to challenge these results and further look into the appropriate strength of reactions. Finally, this study focused solely on existing indices and found that the CCRSI depicts the most appropriate picture of average CRE properties. However, it still includes high-value properties in its database despite the majority of CRE transactions being of low value. Hence, it might be of particular interest for researchers to develop an index solely consisting of low-value transactions and one solely consisting of high-value transactions to be able to best characterize the complete picture of current CRE market conditions.

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Appendix A

Table 3. Summary statistics: Period 2000-2020

<i>Index name</i>	<i>NAREIT</i>	<i>NCREIF NPI</i>	<i>NCREIF TBI</i>	<i>CCRSI</i>	<i>GS CPPI</i>	<i>CS</i>	<i>FHFA</i>
Mean	0.11543	0.08491	0.09660	0.04940	0.04727	0.03895	0.03662
Standard Deviation	0.10727	0.04529	0.09580	0.05779	0.06588	0.03444	0.03491

Note: Mean & Standard Deviation are annualized values

Table 4. Summary statistics: Full period 2000-2023 (excluding NCREIF TBI)

<i>Index name</i>	<i>NAREIT</i>	<i>NCREIF NPI</i>	<i>CCRSI</i>	<i>GS CPPI</i>	<i>CS</i>	<i>FHFA</i>
Mean	0.11766	0.08143	0.05431	0.04045	0.04849	0.04799
Standard Deviation	0.21024	0.04766	0.05798	0.07292	0.03810	0.03873

Note: Mean & Standard Deviation are annualized values

Table 5. Summary statistics: Pre-financial crisis period 2000Q1-2006Q4

<i>Index name</i>	<i>NAREIT</i>	<i>NCREIF NPI</i>	<i>NCREIF TBI</i>	<i>CCRSI</i>	<i>GS CPPI</i>	<i>CS</i>	<i>FHFA</i>
Mean	0.21468	0.11753	0.13784	0.09650	0.07593	0.08860	0.07256
Standard Deviation	0.13452	0.02429	0.08930	0.04211	0.03642	0.02064	0.01855

Note: Mean & Standard Deviation are annualized values

Table 6. Summary statistics: Financial crisis period 2007Q1-2011Q1

<i>Index name</i>	<i>NAREIT</i>	<i>NCREIF NPI</i>	<i>NCREIF TBI</i>	<i>CCRSI</i>	<i>GS CPPI</i>	<i>CS</i>	<i>FHFA</i>
Mean	0.04655	0.01568	0.01056	-0.08908	0.00026	-0.06362	-0.05407
Standard Deviation	0.36129	0.08388	0.14128	0.06377	0.13154	0.02544	0.03057

Note: Mean & Standard Deviation are annualized values

Table 7. Summary statistics: Post-financial crisis & pre-covid period 2001Q2-2019Q4

<i>Index name</i>	<i>NAREIT</i>	<i>NCREIF NPI</i>	<i>NCREIF TBI</i>	<i>CCRSI</i>	<i>GS CPPI</i>	<i>CS</i>	<i>FHFA</i>
Mean	0.10399	0.09406	0.10640	0.07565	0.05009	0.04890	0.05083
Standard Deviation	0.13828	0.01357	0.06752	0.03746	0.02220	0.01730	0.02825

Note: Mean & Standard Deviation are annualized values

Table 8. Summary statistics: Covid crisis period 2021Q1-2023Q2 (excluding NCREIF TBI)

<i>Index name</i>	<i>NAREIT</i>	<i>NCREIF NPI</i>	<i>CCRSI</i>	<i>GS CPPI</i>	<i>CS</i>	<i>FHFA</i>
Mean	0.04414	0.05751	0.09071	-0.00583	0.10334	0.11566
Standard Deviation	0.24423	0.05923	0.05785	0.10421	0.04623	0.04255

Note: Mean & Standard Deviation are annualized values

Appendix B

Table 9. Correlations: Period 2000Q1-2020Q1

	<i>NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>CS</i>	<i>FHFA</i>	<i>TBI</i>	<i>S&P 500</i>
NPI	1.00							
NAREIT	0.26	1.00						
GS CPPI	0.66	0.54	1.00					
CCRSI	0.52	0.12	0.37	1.00				
CS	0.43	0.27	0.44	0.64	1.00			
FHFA	0.34	0.12	0.36	0.65	0.73	1.00		
TBI	0.53	0.02	0.37	0.31	0.28	0.36	1.00	
S&P500	0.19	0.68	0.40	0.02	0.15	0.02	-0.02	1.00

Table 10. Correlations: Full period 2000Q1-2023Q2 (excluding TBI)

	<i>NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>CS</i>	<i>FHFA</i>	<i>S&P500</i>
NPI	1.00						
NAREIT	0.22	1.00					
GS CPPI	0.67	0.46	1.00				
CCRSI	0.53	0.09	0.39	1.00			
CS	0.44	0.25	0.44	0.64	1.00		
FHFA	0.33	0.10	0.30	0.63	0.78	1.00	
S&P 500	0.07	0.70	0.27	-0.02	0.16	0.04	1.00

Table 11. Correlations: Pre-financial crisis period 2000Q1-2006Q4

	<i>NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>CS</i>	<i>FHFA</i>	<i>TBI</i>	<i>S&P 500</i>
NPI	1.00							
NAREIT	0.23	1.00						
GS CPPI	0.53	0.33	1.00					
CCRSI	0.04	-0.24	0.09	1.00				
CS	0.09	-0.04	0.25	0.58	1.00			
FHFA	0.06	-0.06	0.16	0.52	0.52	1.00		
TBI	0.48	0.26	0.14	0.14	0.01	0.35	1.00	
S&P500	0.19	0.56	0.17	-0.22	-0.06	-0.17	0.12	1.00

Table 12. Correlations: Financial crisis period 2007Q1-2011Q1

	<i>NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>CS</i>	<i>FHFA</i>	<i>TBI</i>	<i>S&P 500</i>
NPI	1.00							
NAREIT	0.25	1.00						
GS CPPI	0.66	0.65	1.00					
CCRSI	0.67	0.44	0.53	1.00				
CS	0.33	0.72	0.83	0.32	1.00			
FHFA	0.18	0.33	0.50	0.22	0.57	1.00		
TBI	0.62	0.04	0.48	0.31	0.32	0.18	1.00	
S&P500	0.29	0.83	0.68	0.48	0.65	0.35	0.04	1.00

Table 13. Correlations: Post-financial crisis & pre-covid period 2011Q2-2019Q4

	<i>NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>CS</i>	<i>FHFA</i>	<i>TBI</i>	<i>S&P 500</i>
NPI	1.00							
NAREIT	0.07	1.00						
GS CPPI	0.69	0.05	1.00					
CCRSI	-0.02	-0.25	0.15	1.00				
CS	-0.19	-0.10	0.02	0.06	1.00			
FHFA	-0.04	-0.17	0.28	0.46	0.28	1.00		
TBI	0.04	-0.46	0.08	0.16	0.05	0.36	1.00	
S&P500	-0.15	0.59	-0.09	-0.30	0.14	-0.16	-0.39	1.00

Table 14. Correlations: Covid crisis period 2020Q1-2023Q2 (excluding TBI)

	<i>NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>CS</i>	<i>FHFA</i>	<i>S&P500</i>
NPI	1.00						
NAREIT	0.03	1.00					
GS CPPI	0.69	0.21	1.00				
CCRSI	0.64	-0.22	0.56	1.00			
CS	0.73	0.31	0.68	0.58	1.00		
FHFA	0.59	0.09	0.43	0.58	0.83	1.00	
S&P 500	-0.24	0.93	-0.01	-0.41	0.10	-0.06	1.00

Appendix C

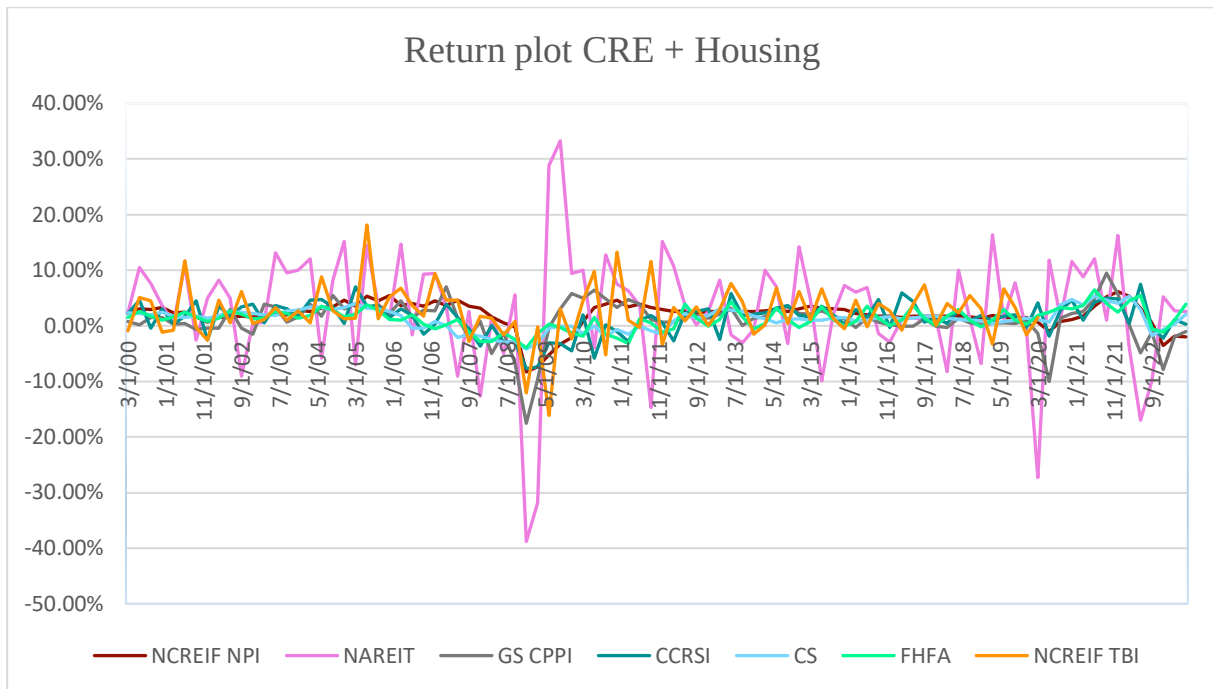


Figure 1: Return plot of the CRE and housing indices

Appendix D

Table 15. Correlations: Period 2000Q1-2020Q1

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>NCREIF TBI</i>	<i>Interest Rate</i>
Interest Rate	0.31	0.05	0.04	0.11	0.12	1.00

Table 16. Correlations: Entire Period 2000Q1-2023Q2 (excluding TBI)

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>Interest Rate</i>
Interest Rate	0.13	0.01	-0.05	0.03	1.00

Table 17. Correlations: Pre-financial crisis period 2000Q1-2006Q4

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>NCREIF TBI</i>	<i>Interest Rate</i>
Interest Rate	0.37	0.06	-0.08	-0.25	0.07	1.00

Table 18. Correlations: Financial crisis period 2007Q1-2011Q1

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>NCREIF TBI</i>	<i>Interest Rate</i>
Interest Rate	0.49	-0.16	0.05	0.53	0.15	1.00

Table 19. Correlations: Post-financial crisis & pre-covid period 2011Q2-2019Q4

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>NCREIF TBI</i>	<i>Interest Rate</i>
Interest Rate	-0.78	0.02	-0.51	-0.10	-0.02	1.00

Table 20. Correlations: Covid crisis period 2020Q1-2023Q2 (excluding TBI)

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>Interest Rate</i>
Interest Rate	-0.71	-0.11	-0.40	-0.45	1.00

Appendix E

Decreasing interest rates:

Table 21. Correlations: 2000Q1-2004Q2

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>NCREIF TBI</i>	<i>Interest Rate</i>
Interest Rate	0.50	0.06	-0.19	-0.16	-0.04	1.00

Table 22. Correlations: 2007Q3-2015Q3

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>NCREIF TBI</i>	<i>Interest Rate</i>
Interest Rate	0.09	-0.13	-0.25	-0.20	-0.13	1.00

Table 23. Correlations: 2019Q3-2022Q1

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>Interest Rate</i>
Interest Rate	-0.24	-0.20	-0.13	-0.25	1.00

Increasing interest rates:

Table 24. Correlations: 2004Q3-2007Q2

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>NCREIF TBI</i>	<i>Interest Rate</i>
Interest Rate	-0.02	-0.24	-0.25	-0.43	0.09	1.00

Table 25. Correlations: 2015Q4-2019Q2

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>NCREIF TBI</i>	<i>Interest Rate</i>
Interest Rate	-0.59	0.03	-0.09	-0.20	0.11	1.00

Table 26. Correlations: 2022Q2-2023Q2

	<i>NCREIF NPI</i>	<i>NAREIT</i>	<i>GS CPPI</i>	<i>CCRSI</i>	<i>Interest Rate</i>
Interest Rate	-0.90	0.95	0.22	-0.70	1.00

Appendix F

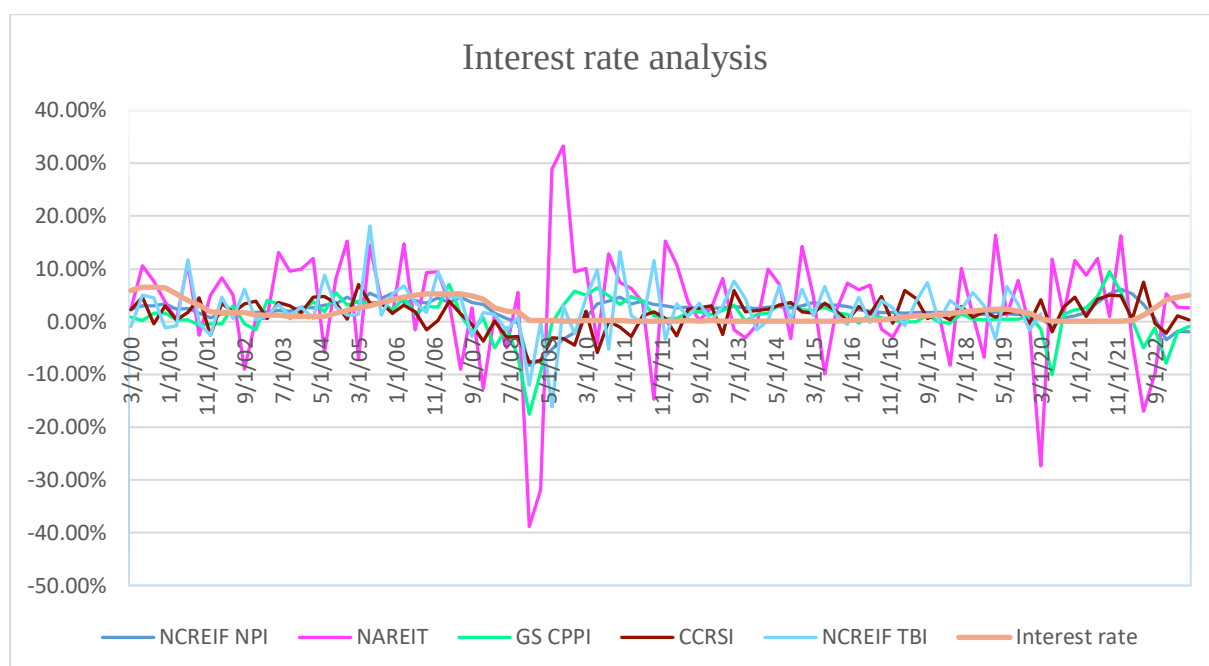


Figure 2: Return plot of the CRE Indices and Interest Rates