Modern Portfolio Theory Applied to Institutional Real Estate Investment

by

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SUBMITTED TO THE PROGRAM IN REAL ESTATE DEVELOPMENT IN CONJUNCTION WITH THE CENTER FOR REAL ESTATE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN REAL ESTATE DEVELOPMENT

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ABSTRACT

What is the optimal capital allocation to institutional-grade Real Estate that investment managers should pursue to achieve the highest risk-adjusted return? As Real Estate keeps evolving, institutionalizing, and becoming an asset class that is paramount to a well-balanced portfolio, the question of what product types and markets will provide the highest return, less volatility, and greatest diversification remains unclear. This research aims to find the optimal capital allocation in Real Estate that will generate the highest Sharpe Ratio.

This research will use endorsed Real Estate research platforms and conduct one-on-one interviews with institutional Real Estate investment managers to understand how to formulate an investment thesis and capital deployment strategy. Using a Mean-Variance analysis, this study will first illustrate what allocation to Real Estate will deliver the highest risk-adjusted return within a diversified portfolio. Afterward, this study will strive to create a simplified portfolio allocation tool for asset managers to use while formulating their investment decisions.

Thesis Supervisor: Tinchuck Ng
Title: Visiting Lecturer, Department of Urban Studies and Planning

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CHAPTER 1 – INTRODUCTION

1.1 Portfolio Optimization in Real Estate – Theory Review

According to Modern Portfolio Theory investors should diversify their portfolio to limit exposure to any single asset or risk, or in other words "should not put all their eggs in one basket." This concept is basic yet of paramount importance for portfolio optimization.

Diversification is not simply investing in several assets, rather investing in assets which pattern of return is different from each other therefore reducing portfolio volatility. This concept was first studied by Harry Max Markowitz in 1952 in his article "Portfolio Selection" and named Modern Portfolio Theory ("MPT"). He later won the Nobel Memorial Prize in Economic Sciences in 1990 for his work in portfolio management theory for individual wealth holders. MPT seeks to find the optimal portfolio of assets for a specific investor's preferences on risk and return. This is achieved by investing in different assets whose returns are not correlated, and under the assumption that investors are risk-averse, rational, and the market is efficient.

MPT is rarely used when asset managers are developing an investment thesis or structuring a portfolio of Real Estate investments. There are three main reasons for that (i) the mean variance approach of MPT requires accurate and long-term data that is not traditionally available within Real Estate (ii) the data processing required is too complicated and (iii) periodic rebalancing a portfolio of Real Estate investments results complicated due to elevated transaction costs. Due to these complications most allocation decisions are heavily influenced by asset managers' intuition and experience. This results in asset managers using quantitative techniques to analyze individual properties' returns yet lacking a portfolio diversification tool for a set Real Estate investments.[1,2]

1 Fu, Tingting

2 Liu,Yanija

1.2 Purpose and Motivation

Given that asset allocation within Real Estate[3] is based and highly influenced by empirical knowledge and so called "gut feeling" rather than data-driven analyses, this study aims to develop an alternative and simplified quantitative model that will serve as guide for asset managers to understand where their portfolio lies in terms of risk-adjusted returns. It is imperative that data-driven investment strategies are implemented by asset managers given the recent uptick in capital inflows into institutional Real Estate and the resulting competitiveness. The goal of this research is to find a framework that can be replicated by institutional Real Estate managers to build a Real Estate allocation strategy for longevity and risk-adjusted performance.

Today's volatile and uncertain market conditions paired with the high inflationary environment of the past year and forecasted for the near future, make it paramount defining a sound Real Estate investment strategy that will protect downside. All major indexes of public markets are down year-to-date, with the Dow Jones and S&P 500 11.4% and 15.57% as of May 16th, 2022, respectively. In total, more than $11 trillion in value have been erased from global stocks since the end of March. Many industry experts are forecasting further decreases in valuations given that the Price-to-Earnings ratio of the market is still at 20x when historically it has been at around 15x. In addition, less than 30% S&P companies have hit a one-year low compared to 82% during the financial crisis in 2008, according to Bloomberg. The inherent risk of investing in the United States today, make it imperative to find the best risk-adjusted Real Estate strategy for asset managers. Moreover, the recent decline in valuations in public markets combined with the rising interest rate environment may present asset managers the opportunity of investing in Real Estate at attractive valuations soon.

This study sees an opportunity to apply Mean Variance Optimization– a mathematical framework to arrange a portfolio of investments across different asset classes such that expected return is maximized for a given level of risk– to identify the optimal allocation to commercial Real Estate for asset managers to invest in and create a simplified portfolio allocation tool for asset managers to use.

3 For the purposes of this study "asset allocation" or "allocation" refers to the fraction or percentage of funds invested to a specific asset type in relation to an investor's total portfolio.

In detail, this study aims to answer the following question:

1. *What allocation to Real Estate will deliver the highest Sharpe ratio for asset managers?*

Answering this question will require deep understanding of the Mean Variance Optimization methodology to be applied, the data employed in the analysis, and the limitations of this study. In the following chapters, the methodology applied, and data sources and analysis techniques will be described in further detail after introducing pertinent information investment benefits and recent trends on institutional Real Estate investment.

CHAPTER 2 – INSTITUTIONAL REAL ESTATE INVESTMENT

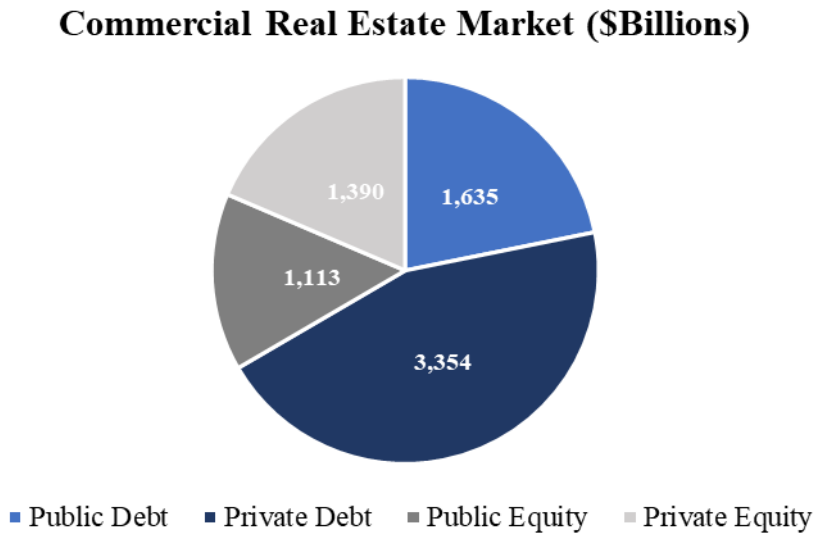
2.1 What is Commercial Real Estate Investment?

Some of the recurring questions faced by investors include- Why invest in commercial Real Estate? What are the benefits of investing in commercial Real Estate? This chapter aims to provide a broad overview of what is Real Estate, the size of this asset class, the different investment types within it, the vehicles for investment available to asset managers, and the benefits of investing in Real Estate.

Commercial Real Estate has been widely outlined as being composed by four quadrants:

Private Equity	**Public Equity**
Private Debt	**Public Debt**

These quadrants are estimated to have the following amounts invested as of December 31st, 2021:



**Source: Pension Real Estate Association*

Each of the above investment types is available to investors based on how much they are willing to invest and can have their own role within an investment portfolio; however, this study will focus on analyzing trends and the optimal allocation across investments within Private Equity Real Estate. Investments in property types including office, industrial, retail, hotels and multifamily are available to institutional investors via the following structures:

1. *Open End Funds:* Funds that hold investments in properties where investors can enter or exit at the fund's calculated Net Asset Value (NAV) each quarter.
2. *Close End Funds:* Funds with a limited fund life. Investors commit capital, capital is called, invested, and finally liquidated by the end of the fund life.
3. *Separate Account:* An investment vehicle is created and tailored for a particular institutional investor and managed by an expert manager. Capital within this investment vehicle is not pooled with other investors.
4. *Direct Investment:* An institutional investor has direct ownership in properties.
5. *Fund of Funds:* A fund which pools investors and invests in Real Estate funds.
6. *Co-Investment:* An existing investor in a fund invests alongside (ie. in the same investment vehicle) the fund manager in a specific asset.
7. *REITs:* Real Estate Investment Trusts are private or publicly traded Real Estate securities that are exempt from corporate tax on distributed earnings.

Within the above-mentioned investment vehicles there are three main strategies based on the risk and return profiles: core, value-add, and opportunistic.

1. *Core:* Typically use low leverage and aim for low risk/low return investments which mainly generate return from income. Institutional allocation in North America amounts to 66% of Real Estate investor allocations.
2. *Value-Add:* Typically use medium leverage and aim for medium risk/medium return investments that generate return from both income and asset value appreciation. Institutional allocation in North America amounts to 25% of Real Estate investor allocations.
3. *Opportunistic:* Typically use high leverage and aim for high risk/high return investments that generate return mostly from asset value appreciation. Institutional allocation in North America amounts to 9% of Real Estate investor allocations.[4]

2.2 Commercial Real Estate Investment Benefits

Commercial Real Estate Investment has different benefits on an investor's portfolio, but some of the most cited include:

1. *Good returns with low volatility:*

Annual Returns, 1978 to 2021:

	S&P 500	Barclays US Aggregate Bond Index	NCREIF Property Index
Average Return Per Year	14.17%	7.21%	9.38%
Volatility	16.17%	6.73%	7.40%
Sharpe Ratio	0.55	0.34	0.54

**Source: Pension Real Estate Association*

In the chart above the S&P 500 average returns are used as a proxy for public equities returns in the United States, the Barclays Us Aggregate Bond Index average returns is used as proxy for fixed income returns in the United States, and lastly the NCREIF Property– an index that represents returns to a direct, unlevered investment in a diversified portfolio of Commercial Real Estate– is used as a proxy for commercial Real Estate returns. As noted, commercial Real Estate returns fall between public equities and debt returns; however, they do have significantly lower volatility than that of public equities. This ultimately translates into an almost equal Sharpe ratio between public equities and commercial Real Estate. Moreover, Real Estate's maximum drawdown– the maximum loss from a peak to a trough of a portfolio– is almost half of that of public equities as seen on the chart below:

Maximum Drawdown, 1978 to 2021:

S&P 500	NCREIF Property Index
-45.60%	-23.90%
Q3 2007 - Q1 2009	Q2 2008 - Q4 2009

**Source: Pension Real Estate Association*

4 Pension Real Estate Association

2. *Income generation:*

As 66% of the Real Estate investor allocations is placed in Core investments and these generate most of their return via operating cash flow, it is pertinent that income generation is one of the main factors that attracts capital inflows into this asset class. The chart below helps illustrating how the yield of an investment in a diversified Commercial Real Estate portfolio compares to the yield of an investment in public equities or bonds:

Income Generation by Asset Class, As of Q4 2021

Income Return On NCREIF Property Index	Cashflow Return On NCREIF Property Index (1)	Dividend Yield S&P 500	Dividend Yield Barclays US Aggregate Bond Index
4.24%	2.79%	1.29%	1.75%

(1) Cashflow Return is Income Return net of Capital Expenditures

**Source: Pension Real Estate Association*

It is important to note that the effect of capital expenses, leverage and fees can decrease the observed yield of a Commercial Real Estate Investment and consequently reduce its spread over public equities or bonds yields.

3. *Diversification*

As noted in the chart below the correlation of annual returns in the NCREIF Property Index and a broad range of public equities and bonds is very low and in cases negative, making Commercial Real Estate a great portfolio diversifier.[5]

Annual Correlations

	Large Cap Equities (1)	Medium Cap Equities (1)	Small Cap Equities (1)	Treasuries (2)	Investment Grade Corporate Bonds (2)	High Yield Corporate Bonds (3)	Hedge Funds (4)
NCREIF Property Index	0.13	0.06	0.05	-0.06	-0.27	-0.37	0.15

(1) Annual correlation form 1979 to 2021
(2) Annual correlation form 1978 to 2021
(3) Annual correlation form 1984 to 2021
(4) Annual correlation form 1994 to 2021

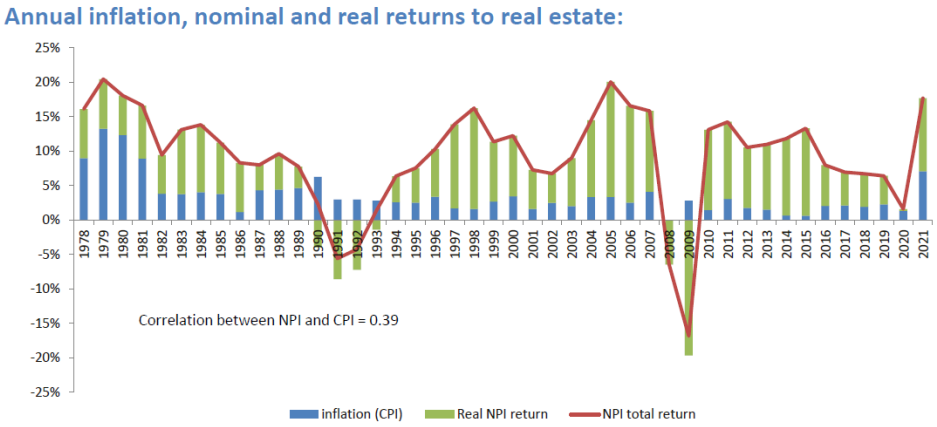
**Source: Pension Real Estate Association*

5 Pension Real Estate Association

The low correlation of Real Estate returns with returns of public equities and fixed income products plays a bigger role in private Real Estate investments, as REITs correlate with the stock market. It is important to note that correlation moves over time, and it could potentially rise when aggressive market movements occur.[6]

4. *Inflation Hedge:*

In the chart below it is noticed how nominal and real returns to Real Estate are highly correlated with annual inflation. However, both have outperformed inflation as measured by CPI 37 out of the last 43 years. Moreover, commercial Real Estate performance for five-year holding periods has outperformed inflation over those periods with 84 percent probability.[7]



**Source:* Why Real Estate? Updated to Q4 2021. Pension Real Estate Association

2.3 Definition of Institutional Investors

Although there is not a clear definition of what defines an institutional Real Estate investor, the SEC defines a qualified institutional buyer (QIB) as a class of investor that can be assumed to be sophisticated and manages a minimum investment of $100 million in securities on a discretionary basis. Real Capital Analytics (RCA)– one of the leading Real Estate research platforms– divides institutional Real Estate investors in its data base into the following categories:

1. Private Equity Funds
2. Pension Funds
3. Insurance Companies
4. Banks

5. Finance Companies– Non-bank financial institutions
6. Investment Managers or Advisors
7. Sovereign Wealth Funds
8. Open-End Funds

The charts below present the Top 10 Real Estate Investment Managers of 2021 and Fundraisers for direct investment of 2020 to help understand who the biggest institutional Real Estate investors are:

Top 10 Managers Based on North America Assets ($Millions)

Rank	Manager	Assets Under Management ($Millions)
1	Brookfield Asset Management	149,271
2	Hines	99,872
3	Nuveen Real Estate	97,692
4	MetLife Investment Management	87,334
5	Principal Real Estate Investors	77,677
6	Blackstone	68,478
7	J.P. Morgan Asset Management	64,851
8	Invesco Real Estate	62,757
9	NYL Investors	58,287
10	Clarion Partners	54,083

**Source: Institutional Real Estate, Inc.*

Top 10 Fundraisers for Direct Investment

Rank	Manager	Capital Raised ($Millions)
1	Blackstone	64,931
2	Brookfield Asset Management	29,014
3	Starwood Capital Group	16,861
4	GLP	16,435
5	Lone Star Funds	16,200
6	AEW	12,227
7	The Carlyle Group	10,860
8	Rockpoint Group	10,741
9	BentallGreenOak	9,713
10	Angelo Gordon	9,449

** Source: PERE.com*

6 Norges Bank Investment Management

7 Peyton, Martha

CHAPTER 3 – REAL ESTATE MARKET OVERVIEW

3.1 Pertinent Macroeconomic Trends Implications on Real Estate

While the US economy fully recovered in 2021 form the pandemic-induced recession of 2020, the pace of GDP growth in 2022 will slow and some experts even forecast a recession as inflation has reached multi-decade highs. Strong economic growth, labor shortages, and supply chains have all together put pressure on price increases and the Federal Reserve has taken aggressive action to control that.[8]

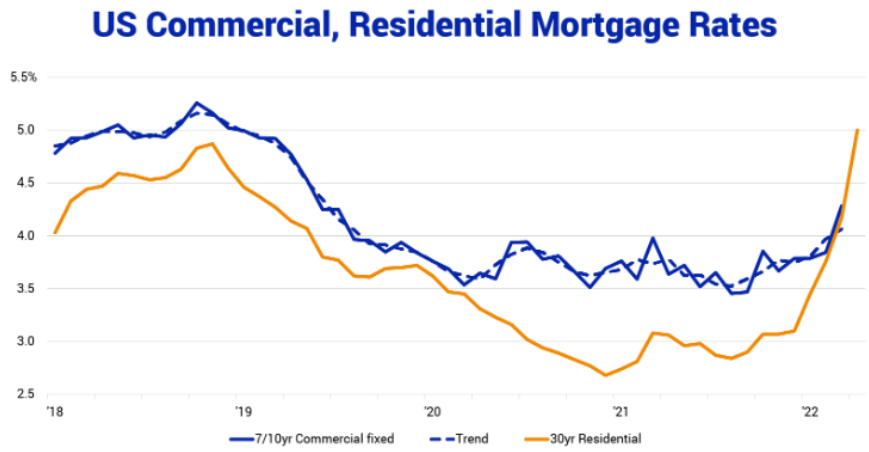
The Federal Reserve has increased the target federal funds rate 75 basis points year to date and has firmed up expectations for a series of half-point rate increases this spring and summer. Moreover, officials argue that if inflation does not show signs of diminishing soon rates will need to rise closer to 4% rather than 3% which most projected. The hope, however, is that inflation will fall as supply-chain disruptions and more workers return to the labor market.[9]

Inflation poses a challenge for the financing of commercial Real Estate. As the Federal Reserve has increased interest rates to control inflation, the cost to finance commercial Real Estate investments has increased. In 2021, US commercial mortgages averaged a 3.7% rate for 7/10-year fixed rate products. Into March of 2022, the same metric has already climbed to 4.3%. This could potentially pose a high refinancing risk for buyers that financed commercial Real Estate short-term and must refinance soon. If property income has not grown enough to compensate for the higher debt service that will be faced as loans mature, someone will have to take a loss; however, it is too soon to tell what the outcome will be.[10] The chart below helps illustrating the recent increase in US Commercial Mortgage Rates:

8 CBRE

9 Wall Street Journal

10 Real Capital Analytics



**Source: Real Capital Analytics*

3.2 Recent Trends in Institutional Real Estate Investing

Deal Volume

Deal volume in the US in 2021 surpassed previous record amounts and was up to levels that could normally be associated with total global deal volume. Stability across certain product types combined with high hopes for recovery and consequently higher property incomes fueled deal activity. However, there are still sectors and markets that have not showed signs of weakness. Multifamily had the largest deal volume, representing 42% of all deal activity, especially in smaller markets which represented 80% of all multifamily activity. One of the reasons for that is that remote work has driven investors to consider these smaller markets now. Industrial was the second most active property type, representing 21% of all deal activity. This was driven by investor optimism on income growth for this product type as supply chain adjusts to change in consumer needs.[11] The chart below provides a summary of transaction volume over 2021:

11 Real Capital Analytics

	2021	
	Volume ($ Billions)	Year over Year % Change
Office	139.2	57%
Retail	76.9	88%
Industrial	166.1	56%
Hotel	44.5	238%
Multifamily	335.3	128%
Seniors Housing & Care	17.8	70%
Development Site	28.9	21%
Total	808.7	88%
Portfolio	235.3	100%
Single Asset	573.4	83%

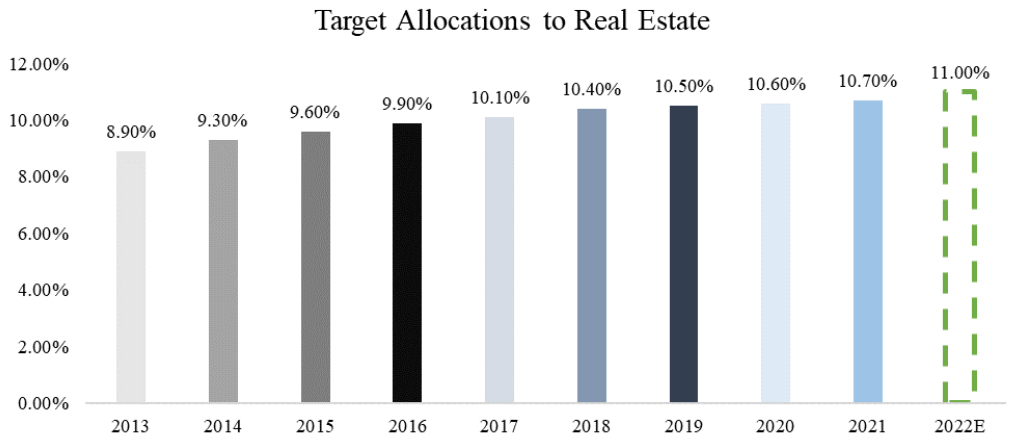
**Source: Real Capital Analytics*

While commercial property sales further grew at double digits into the first quarter of 2022, uncertainty about war, interest rates and inflation have decelerated price growth. Prices in the first quarter of 2022 climbed 17.4% year-over-year compared to 19.1% in the last quarter of 2021. However, it is not clear whether this deceleration in price growth is a result of the uncertainty that erupted at the beginning of 2022 or simply a return to the trend as double and triple digits growth rates are certainly not normal.[12]

Allocations

Institutional investment in commercial Real Estate has continued to grow over the past eight years to an average allocation of 10.7% at the end of 2021. From 2020 to 2021 allocations only grew 10 basis points; however, given the substantial nominal dollar size of allocations to commercial Real Estate, this 10 basis points implies a potential for an additional $80 to $120 billion of capital committed over the coming years. Looking forward into 2022 institutions expect to increase target allocations by 30 basis points by the end of the year, reaching an average allocation of 11.0%

12 Real Capital Analytics



**Source: Cornell University's Baker Program in Real Estate, Hodes Weill & Associates*

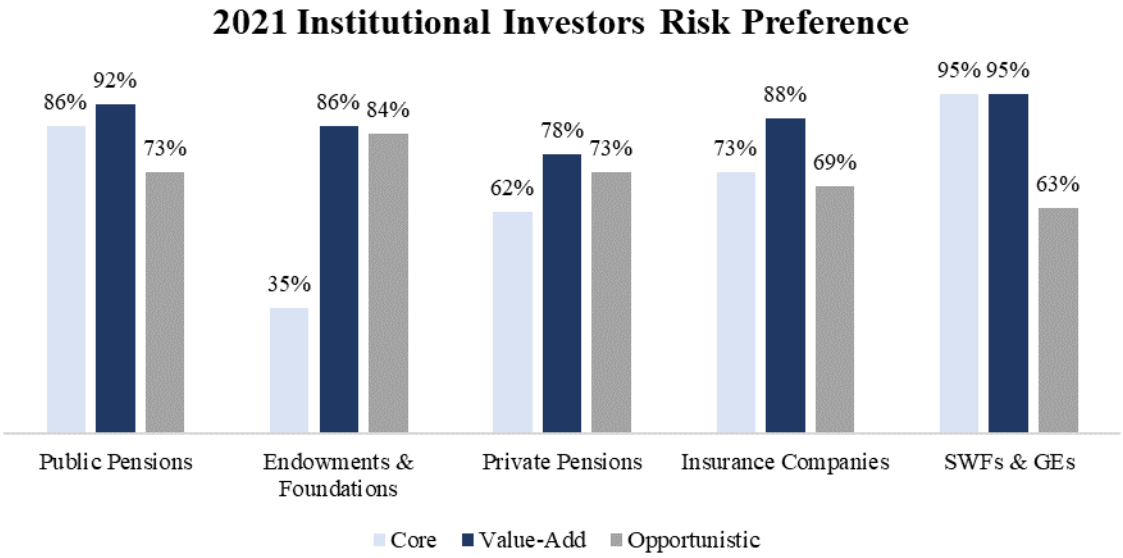
In addition to higher target allocations to commercial Real Estate, portfolios are under-invested to Real Estate by the largest margin in seven years. The percentage of funds invested in Real Estate decreased to 9.3% down in 2021 down from 10% in 2020. There are two main reasons for this under-investment (i) the capital deployment slowdown that COVID-19 triggered (ii) the denominator effect, as public equities are near all-time high valuations and AUMs have increased, Real Estate represents a smaller share of institutional portfolios. This level of under-invested along with high liquidity levels, and rising investor sentiment is accelerating capital inflows to Real Estate. Moreover, cross border capital flows continue to rise, and the US remains the preferred destination for international capital flows.

Risk Preferences

Investors are expecting that opportunistic buying opportunities will arise from the current dislocations in the market for product types like office, retail, and hotels. On the other hand, conviction remains high for industrial and multifamily sectors. Within multifamily, vacancy rates have hit all-time lows and rents have climbed at high levels despite increasing levels of construction. The two major concerns over the pandemic have been inflation and supply chain issues. Multifamily generally benefits from inflation given the short-term nature of its lease terms, and supply chain issues have further solidified the need for industrial and logistics product.

Appetite for higher return strategies continue to be the preference among institutional investors looking to take advantage of the emerging distress in the market. Nearly 92% of institutional investors reported that they are targeting value add and opportunistic strategies. Within these, value add remains the most popular strategy with 87% of institutional investors reporting that they are looking for value-add

investments, representing a 3% increase over 2020. SWFs and GEs remain the biggest players within core investments, this could be partially attributed to their preference for industrial and logistics product type and the high transaction volume within these over the last 18 months. Endowments & Foundations are most likely to invest in opportunistic strategies, while Public Pensions remain the biggest institutional investor within value-add strategies.[13] More detail on institutional investor's risk preference is shown in the chart below:



**Source: Cornell University's Baker Program in Real Estate, Hodes Weill & Associates*

Environmental, Social, and Corporate Governance

The COVID-19 pandemic has prompted a huge push for environmental and social responsibility, and this has resulted in an increased number of owners and tenants committing to net zero goals for 2030. Investors have accepted that climate risk is a financial risk and in conjunction with occupiers are starting to implement sustainability-focused strategies that protect their properties and enhance operational and financial performance. Retrofitting existing buildings will be a critical part of transitioning to a low-carbon economy; however, this remains more expensive and complicated than building new green buildings. To tackle this challenging issue and achieve net zero goals, knowledge sharing, and collaboration will be essential. Moreover, data driven solutions will be the one of the major catalysts of this process as they will enable for energy monitoring, transparent reporting, and knowledge sharing. Although many parties within

the Real Estate world have chosen to take initiative on their own, bolder action from federal and state governments will be needed to create appropriate incentives.[14]

3.3 Real Estate Market Outlook

Worries of a global economic recession have mounted as the US is expected to hike interest rates 10 to 12 times between 2022 and 2023, which would bring the federal funds rate somewhere between 2.5% and 3.5% by the end of 2023. More importantly, every recession has been preceded by hikes in interest rates. In addition, historical data shows that hikes in interest rates of 2.5% or higher above the previous cycle-average typically triggers a recession. This rising rate environment has put pressure on commercial Real Estate financing and although there is still substantial debt capital available for deals, uncertainty in the market remains.[15]

Despite the challenges mentioned above, the industrial market remains strong with near historically low vacancies and rent growths outpacing inflation. Multifamily has rebounded even in urban areas with concessions burning off and rents increasing at a rapid pace. Retail Real Estate has exhibited mixed results with high end performing well and middle to low continuing to struggle.[16] Like retail, office is showing mixed results, certain product is starting to see smaller increases in vacancy rates and asking rents ticking up, more clarity on this product type will be seen on subsequent quarters as the return to office continues. However, higher cap rates are emerging in Class B and C office where fundamentals are the weakest.[17]

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13 Hodes Weill & Associates
14 JLL
15 CBRE
16 JLL
17 CBRE

CHAPTER 4 – DATA ANALYSIS

4.1 Data Introduction and Sources

The data used for this study as it pertains to Real Estate was gathered from NCREIF and the proxy for Real Estate investment allocation used is the NCREIF-ODCE index. NCREIF is the National Council of Real Estate Investment Fiduciaries, and its main focus is collecting, validating, aggregating and disseminating commercial Real Estate performance data for investment and academic uses. NCREIF was founded in 1982 in Chicago, IL and is the leading provider of commercial Real Estate performance data; thereby, their data base was selected as the one and only source for collecting Real Estate data for this study.

The data collected from NCREIF for this study consists of performance returns from 2013 to 2021 within the Open-End Diversified Core Equity Index ("ODCE"). The NCREIF-ODCE Index is a capitalization-weighted, gross of fee, time-weighted return index with an inception date of December 31, 1977. The main policies to qualify for the ODCE Index are the following:

1. *Real Estate – at least 80% of the fund's gross assets are invested in private equity direct Real Estate. Private equity direct Real Estate are individual properties that are submitted to NCREIF and are individually valued representing the fund's effective ownership share of property gross market value.*
2. *Domain – at least 95% of the fund's aggregate properties gross market value at effective ownership share of all Real Estate are invested in US markets.*
3. *Property Types – at least 75% of the fund's aggregate gross market value of Real Estate at effective ownership share are invested in office, industrial, apartment, and retail property types. For purposes of this test, the fund is allowed to include the value of a loan investment if the underlying collateral is one of the four property types mentioned*
4. *Stabilized – at least 75% of the fund's gross assets are invested in private equity direct Real Estate properties that are 75% or more leased. The value of the Real Estate is determined using the property gross market values at the fund's effective ownership share.*
5. *Leverage – no more than 35% Tier 1 leverage as defined in the NCREIF PREA Reporting Standards, which uses the fund's outstanding principal balance of debt relative to the fund's gross assets. For certain accounting methods, such as the non-operating equity investment model, the fund's assets and liabilities must be appropriately grossed-up to account for off-balance sheet debt.*

6. *Diversification – no more than 60% (± for market forces) of the gross market value of Real Estate in one property type, and must be invested in three of the four main property types, with a minimum of 5% in each of the three types. No more than 65% (± for market forces) of Real Estate gross market value in one region. For purposes of diversification, the fund is allowed to include the value of a loan investment if the underlying collateral is one of the four main property types. Property types and regions are as defined by the NCREIF Property Index ("NPI").*[18]

The data pertaining returns across all other asset classes studied and included in the search for the optimal portfolio was gathered from a Bloomberg Terminal. These other asset classes studied include US Equities, Commodities, US REITs, Developed Markets Equity, International REITs, Developed Markets Equity, Treasury Inflation Protected Securities, Investment Grade Bonds, Short Term Treasuries, Municipal Bonds, Intermediate Term Corporate Bonds, Short Term Corporate Bonds, High Yield Corporate Bonds, International Treasuries, Private Equity, and Venture Capital. These asset classes were selected based on guidance from Nuveen and their 2022 Midyear Outlook on asset allocation, which is consistent with other asset managers' portfolio compositions. [19] To understand the performance of these other asset classes the following Exchange Traded Funds ("ETFs") were used as a proxy to calculate their returns and standard deviations:

1. VTI- Seeks to track the performance of the CRSP US Total Market Index.
2. PDBC- Seeks to achieve its investment objective by investing in commodity-linked futures and other financial instruments that provide economic exposure to a diverse group of the world's most heavily traded commodities.
3. VNQ- Invests in stocks issued by Real Estate investment trusts (REITs), companies that purchase office buildings, hotels, and other real property. REITs behave differently from Private Equity Real Estate due to their high correlation with the general stock market, therefore their inclusion as a separate asset class. [20]
4. VEA- Seeks to track the investment performance of the FTSE Developed All Cap ex US Index.
5. VNQI- Invests in stocks in the S&P Global ex-U.S. Property Index, representing Real Estate stocks in more than 30 countries.

18 NCRIEF
19 Nuveen
20 Pension Real Estate Association

6. VWO- Invests in stocks of companies located in emerging markets around the world, such as China, Brazil, Taiwan, and South Africa.
7. TIP- Seeks to track the investment results of an index composed of inflation-protected U.S. Treasury bonds.
8. AGG- Seeks to track the investment results of an index composed of the total U.S. investment-grade bond market.
9. SHY- Seeks to track the investment results of an index composed of U.S. Treasury bonds with remaining maturities between one and three years.
10. MUB- Seeks to track the investment results of an index composed of investment-grade U.S. municipal bonds.
11. VCIT- Seeks to provide a moderate and sustainable level of current income. Invests primarily in high-quality (investment-grade) corporate bonds.
12. VCSH- Seeks to provide current income with modest price fluctuation. Invests primarily in high-quality (investment-grade) corporate bonds.
13. HYG- Seeks to track the investment results of an index composed of U.S. dollar-denominated high yield corporate bonds.
14. IGOV- Seeks to track the investment results of an index composed on non-U.S. developed market government bonds.
15. SPLPEQTY- Seeks to provide tradable exposure to the leading publicly listed companies that are active in the private equity space.
16. TRVCI- Seeks to track the performance of seven sector indices that represent the US venture capital investments.

4.2 Objective Functions

The objective function of this study and the portfolio optimization model being built is understanding (i) where a portfolio of investments lie on a risk-adjusted basis and (ii) how to deliver the highest risk-adjusted return given a set of investments. Sharpe ratio is the proxy for risk-adjusted return and is calculated as the expected return of the portfolio minus the return on the riskless asset to the standard deviation:

$$Sharpe\ Ratio = \frac{R_p - R_f}{\sigma_p}$$

where:

R_p = return of portfolio

R_f = risk-free rate

σ_p = standard deviation of the portfolio's excess return

Moreover, to calculate the portfolio's Sharpe ratio it is necessary to understand and incorporate the correlations of different asset classes as this will have a direct effect on the standard deviation of the portfolio. Therefore, the variance of the portfolio is calculated as follows:

- **Portfolio variance** = $w_1^2\sigma_1^2 + w_2^2\sigma_2^2 + 2w_1w_2Cov_{1,2}$

Where:

- w_1 = the portfolio weight of the first asset
- w_2 = the portfolio weight of the second asset
- σ_1= the standard deviation of the first asset
- σ_2 = the standard deviation of the second asset
- $Cov_{1,2}$ = the covariance of the two assets, which can thus be expressed as $p_{(1,2)}\sigma_1\sigma_2$, where $p_{(1,2)}$ is the correlation coefficient between the two assets

4.3 Data Handling, Method Description, and Analysis

Using the above-mentioned data from NCREIF and Bloomberg respectively, yearly returns, average returns, standard deviation of returns and correlation of returns were calculated for each asset class to build a Mean Variance Optimization model. The method used to calculate these metrics was the following:

1. Yearly Returns: for Bloomberg data these were calculated based on closing prices for the first and last trading day of each year where data was available. For NCREIF-ODCE data these were calculated by adding the quarterly returns provided by NCREIF.
2. Average Returns: for both Bloomberg and NCREIF data this was calculated by taking a simple average of the yearly returns available for each index.

3. Standard Deviation of Returns: for both Bloomberg and NCREIF data this was calculated using the STDEV function in Microsoft Excel incorporating the yearly return data for each individual index.
4. Correlation of Returns: this was calculated using the Data Analysis Correlation function in Microsoft Excel incorporating yearly returns for each index.

It is important to note that NCREIF data had to be "unsmoothed" to calculate the metrics mentioned above. NCREIF-ODCE index calculates return each quarter as if each given property was acquired at the beginning of the quarter and sold at the end of the quarter at determinate appraisal plus the cash flow received for the quarter. Cash flow for this return is calculated as Net Operating Income ("NOI") less any capital expenses. The reason behind using appraised values rather than transaction prices is that Real Estate in general does not transact on a quarterly basis. However, this results in two main issues (i) not all properties are revalued each quarter and (ii) appraisals tend to lang transaction prices. This ultimately results in appraised values to be less than actual transaction prices in a rising market and vice versa. In other words, the data reported by the NCREIF-ODCE Index becomes less volatile than transaction data, therefore the need to "unsmooth" it.[21]

To "unsmooth" data, appraisal values are modelled as the moving average of the value indicated by current and previous comparable transactions therefore, we have:

$$V_t^* = \alpha V_t + \alpha(1-\alpha)V_{t-1} + \alpha(1-\alpha)\text{^}2V_{t-2}$$

Where:

V_t^* Is the optimal appraised value in period *t*

V_t Is the value from comps in period *t*

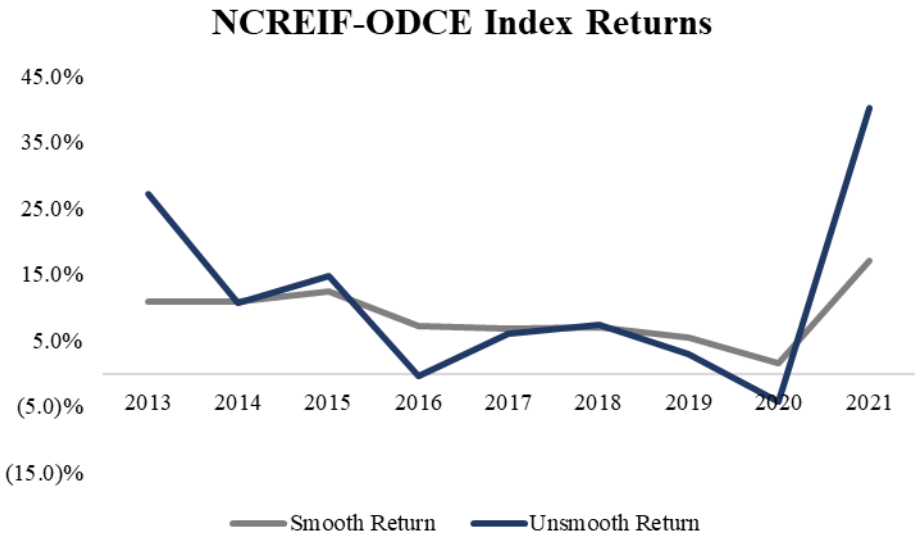
This reduces to:

$$V_t = V_t^*/\alpha - (1-\alpha)/\alpha V_{t-1}^*$$

Moreover, empirical evidence suggests that an α of 0.4 for NCREIF data when estimating annual returns simplifying the "unsmoothing" formula to:

$$V_t = V_t^*/0.4 - (1 - 0.4)/0.4V_{t-1}^*$$
$$V_t = 2.5V_t^* - 1.5V_{t-1}^*$$

Ultimately, this process adjusts for stale appraisals and lags in the appraisal process. [22] The chart below helps illustrating the smooth and unsmooth returns of the NCREIF-ODCE index data used in this study:



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21 Fisher, Jeffrey
22 Fisher, Jeffrey

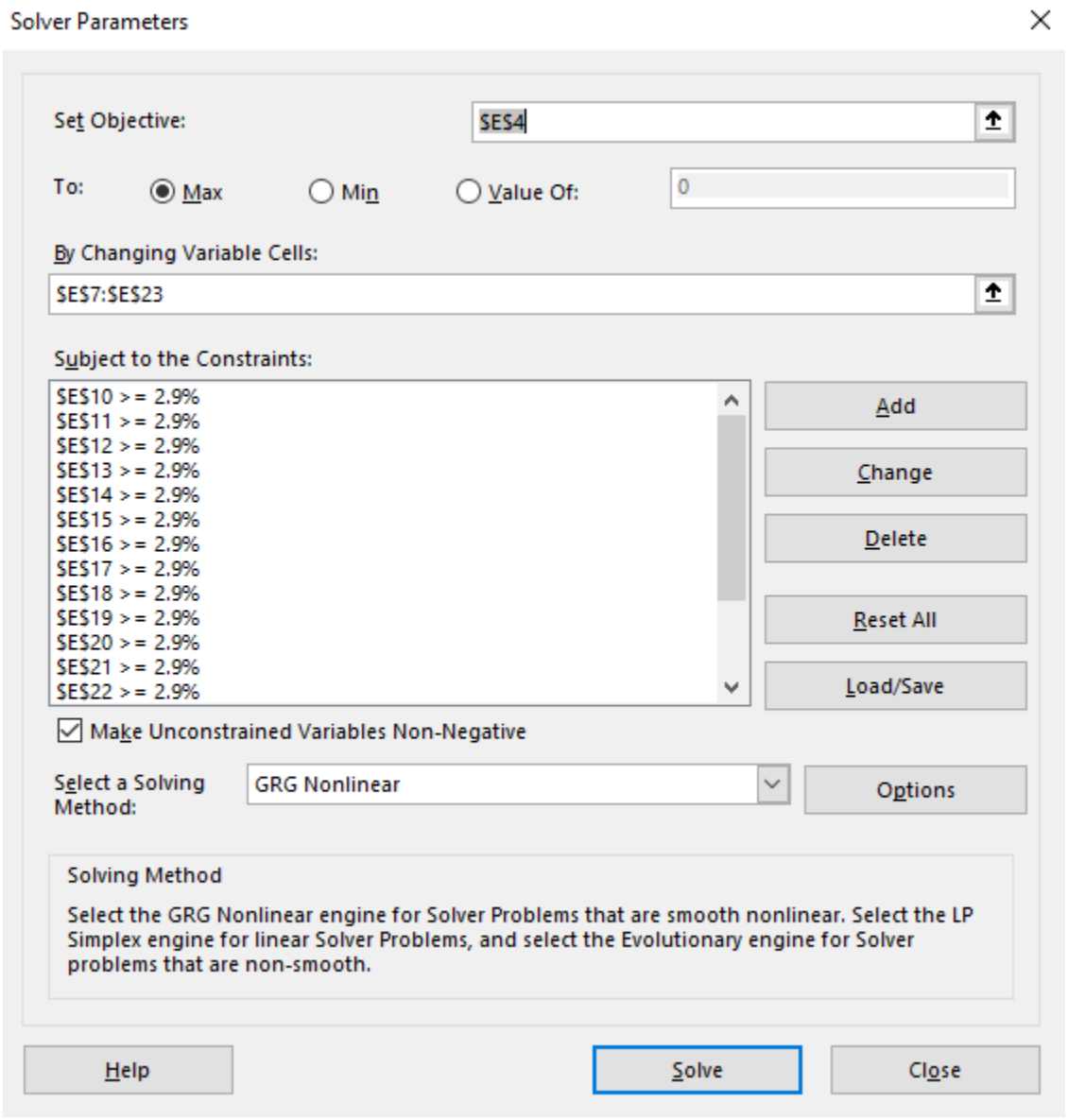
Using the NCREIF-ODCE "unsmooth" yearly returns calculated, and the yearly returns for the other indexes the following parameters were calculated to further understand the historic performance of each:

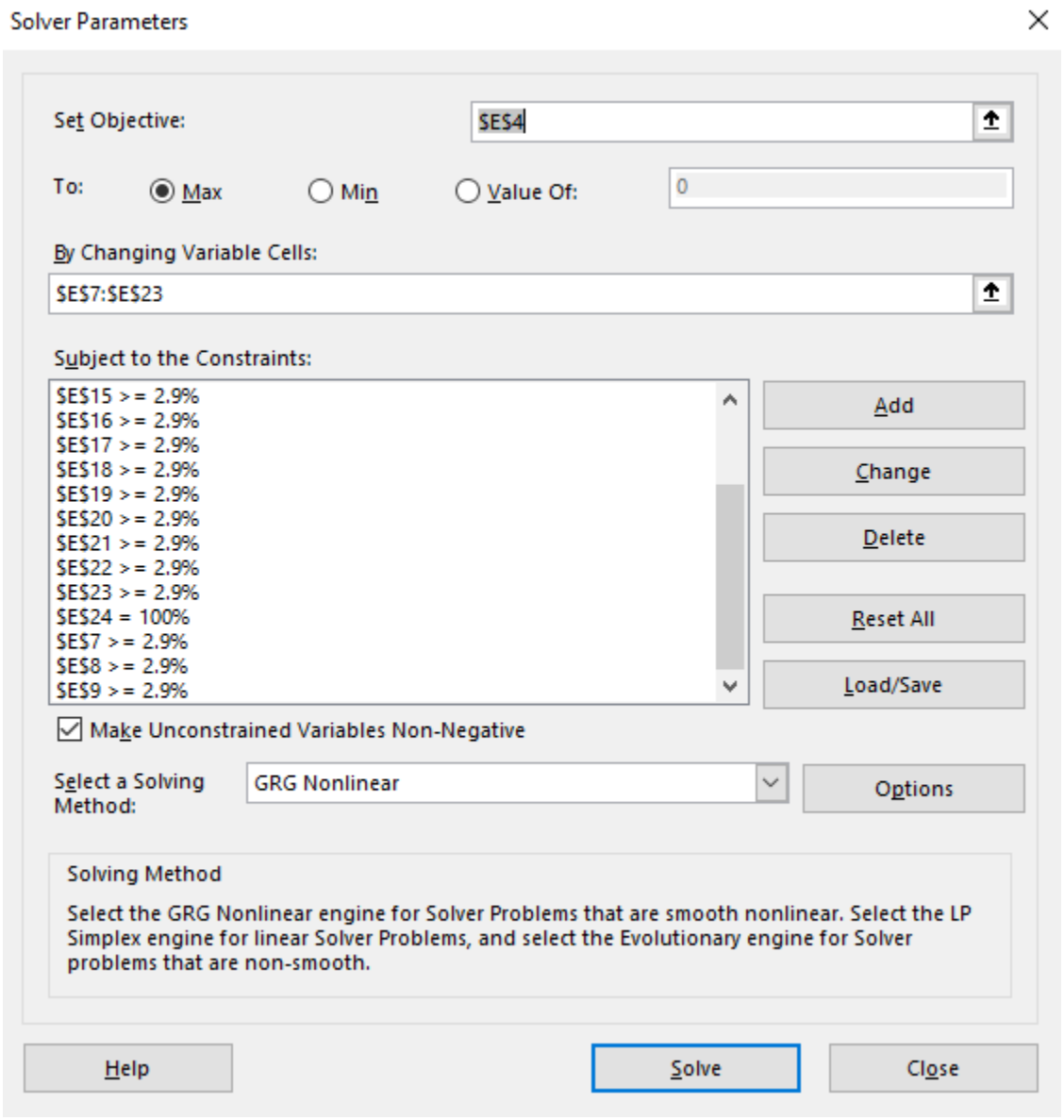
Index	Start Yr	End Yr	Min	Max	Avg Return	Std Dev	Variance
ODCE	2013	2021	(4.3)%	40.2%	11.6%	14.1%	2.0%
VTI	2002	2021	(37.6)%	28.1%	8.8%	16.8%	2.8%
PDBC	2015	2021	(26.2)%	11.9%	(4.7)%	13.5%	1.8%
VNQ	2005	2021	(40.5)%	41.2%	6.7%	20.6%	4.2%
VEA	2008	2021	(42.5)%	23.7%	1.7%	18.3%	3.3%
VNQI	2011	2021	(20.1)%	32.1%	1.3%	15.4%	2.4%
VWO	2006	2021	(54.7)%	65.1%	5.8%	27.3%	7.4%
TIP	2004	2021	(9.4)%	9.0%	1.4%	5.4%	0.3%
AGG	2004	2021	(4.1)%	5.4%	0.7%	2.8%	0.1%
SHY	2003	2021	(1.5)%	2.8%	0.2%	1.3%	0.0%
MUB	2008	2021	(7.2)%	8.7%	0.9%	4.2%	0.2%
VCIT	2010	2021	(6.1)%	10.1%	1.8%	5.2%	0.3%
VCSH	2010	2021	(2.4)%	3.9%	0.7%	2.0%	0.0%
HYG	2008	2021	(23.6)%	15.9%	(0.7)%	9.3%	0.9%
IGOV	2010	2021	(9.7)%	12.7%	0.0%	6.6%	0.4%
SPLPEQTY	2004	2021	(66.4)%	46.5%	8.2%	27.6%	7.6%
TRVCI	2002	2021	(49.0)%	62.9%	19.8%	29.3%	8.6%

Last, to calculate the Correlation Matrix necessary for the Mean Variance Optimization model, the Data Analysis Correlation function in Microsoft Excel was used to generate the following:

	ODCE	*VTI*	*PDBC*	*VNQ*	*VEA*	*VNQI*	*VWO*	*TIP*	*AGG*	*SHY*	*MUB*	*VCIT*	*VCSH*	*HYG*	*IGOV*	*SPLPEQTY*	*TRVCI*
ODCE	1.00																
VTI	0.39	1.00															
PDBC	-0.37	0.13	1.00														
VNQ	0.37	0.67	0.12	1.00													
VEA	0.18	0.77	0.20	0.57	1.00												
VNQI	-0.02	0.27	0.32	0.22	0.50	1.00											
VWO	-0.14	0.60	0.28	0.52	0.78	0.36	1.00										
TIP	-0.29	0.34	0.19	0.29	0.31	0.05	0.51	1.00									
AGG	-0.47	0.00	0.34	-0.02	-0.11	0.08	0.07	0.67	1.00								
SHY	-0.23	-0.25	0.07	-0.50	-0.41	-0.10	-0.25	0.18	0.59	1.00							
MUB	-0.22	0.12	0.03	0.29	0.07	0.02	0.22	0.68	0.63	-0.01	1.00						
VCIT	-0.45	0.22	0.41	0.25	0.18	0.37	0.26	0.69	0.89	0.36	0.62	1.00					
VCSH	-0.43	0.27	0.36	0.15	0.29	0.44	0.27	0.53	0.73	0.41	0.30	0.90	1.00				
HYG	-0.14	0.63	0.46	0.62	0.80	0.26	0.83	0.54	0.04	-0.42	0.23	0.31	0.32	1.00			
IGOV	-0.53	0.12	0.35	-0.22	0.32	0.41	0.34	0.31	0.51	0.23	0.22	0.53	0.55	0.20	1.00		
SPLPEQT	0.33	0.82	0.19	0.80	0.88	0.39	0.70	0.25	-0.20	-0.56	0.00	0.12	0.21	0.78	0.05	1.00	
TRVCI	0.30	0.86	-0.10	0.34	0.60	0.21	0.50	0.36	0.18	0.03	0.24	0.25	0.28	0.36	0.30	0.52	1.00

Once (i) average returns, (ii) standard deviation of returns, (iii) correlations of returns are finalized the Mean Variance Optimization model is ready for use. To solve for the "tangency portfolio", that is the portfolio with the highest Sharpe Ratio, within the set of investments analyzed in this study the Solver function in Microsoft Excel was used. However, the following parameters were inputted into the solver function to ensure that (i) 100% of the funds available to investors are invested, (ii) no investment is shorted, and (iii) at least 50% of the funds invested are evenly allocated across the seventeen asset classes studied- therefore the minimum allocation of 2.9% across each individual asset class:





A detailed Excel financial model is available on reserve at MIT Libraries.

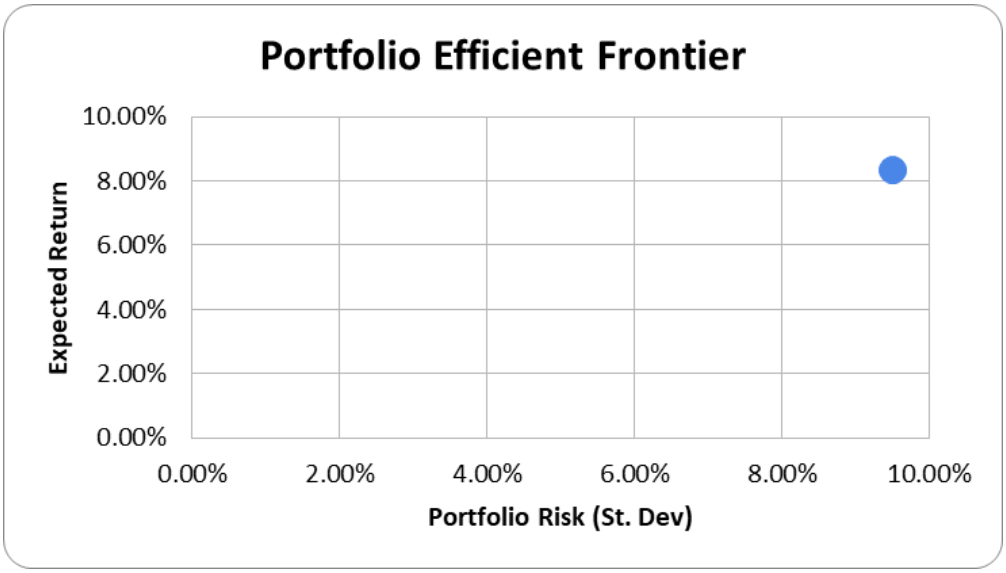
CHAPTER 5 – RESULTS AND CONCLUSIONS

5.1 Tangency Portfolio Across All Asset Classes and ODCE Portfolio

Using the above-mentioned data, methodology and parameters the "tangency portfolio" or portfolio with the highest Sharpe Ratio was solved for and the results were the following:

	Portfolio St.Dev	Portfolio Return	Sharpe Ratio
Tangency Portfolio	**9.50%**	**8.32%**	**0.80**

	Return	Risk	Weight
ODCE	11.61%	14.10%	46.71%
VTI	8.78%	16.80%	2.90%
PDBC	-4.74%	13.49%	2.90%
VNQ	6.73%	20.60%	2.90%
VEA	1.73%	18.26%	2.90%
VNQI	1.32%	15.40%	2.90%
VWO	5.77%	27.29%	2.90%
TIP	1.42%	5.39%	2.90%
AGG	0.67%	2.82%	2.90%
SHY	0.23%	1.26%	2.90%
MUB	0.91%	4.20%	2.90%
VCIT	1.82%	5.20%	2.90%
VCSH	0.68%	2.00%	2.90%
HYG	-0.66%	9.34%	2.90%
IGOV	0.03%	6.63%	2.90%
SPLPEQTY	8.20%	27.59%	2.90%
TRVCI	19.82%	29.34%	9.79%
			100%



To achieve the highest Sharpe Ratio, the model built, and solver function found the above presented weights or allocations for each asset class. It is important to note that the model found an outsized 46.71% allocation to the NCREIF-ODCE index- the proxy for Real Estate investment in this study- which highlights the paramount importance of Real Estate investment within a diversified portfolio. This outsized allocation was mostly achieved due to the high Sharpe Ratio of the NCREFI-ODCE index itself and the low correlation with all other asset classes. However, the low correlation with all other asset classes could be attributed to the fact that the NCREIF-ODCE index is the only non-publicly traded vehicle within the portfolio studied. It is important to note that the allocation achieved in this study also differ from the typical allocation of 60% equities/40% fixed income products or 70% equities/30% fixed income products that most asset managers follow. That is because to the introduction of the NCREIF-ODCE index into the mix of asset classes to invest in and how that interacts and correlates with others.

5.2 Conclusions and Study Limitations

The tangency portfolio found throughout this study helps illustrating the great benefit of adding Real Estate to an investor's or asset manager's portfolio. Moreover, the model built could serve as a simplified portfolio allocation tool for asset managers to use. However, the tangency portfolio found should not be replicated as there are many limitations across the model due to its simplification, and data due to its lack of availability. MPT-based portfolio strategy depends heavily on the accuracy of inputs and the lack of transaction-driven return data for the NCREIF-ODCE index may yield suboptimal allocations. Other limitations of this study that should be addressed in future iterations include:

- The appraisal unsmoothing process used to amplify the volatility across the NCREIF-ODCE index may result in bias based on the alpha coefficient used,
- The property types within the NCRIEF-ODCE index and acceptable to institutional investors are constantly evolving and data as of today is limited, therefore those property types were excluded from this study,
- Direct Real Estate investments are exposed to several property-level and capital market idiosyncratic risks including environmental, structural, tenant credit, replacement cost, leverage, and liquidity, and it might result impossible mitigating those risks even after investing in a large portfolio of properties. Therefore, institutional managers investing in Real Estate through ODCE funds may be exposed to these risks,
- Elevated transaction costs of Real Estate make portfolio rebalancing cost-prohibitive,

- And the ETFs that were used to determine the optimal allocation across all non-Real Estate asset classes' performance could vary from the underlying investments they aim to track.

CHAPTER 6 – WORKS CITED

"2021 Institutional Real Estate Allocations Monitor." *HodesWeill & Associates*, Oct. 2021, www.hodesweill.com/single-post/2021-institutional-real-estate-allocations-monitor.

Costello, Jim. "Capital Trends - US Big Picture." *Real Capital Analytics*, 2022, app.rcanalytics.com.
---. "Capital Trends - US Big Picture 2021." *Real Capital Analytics*, 2022, app.rcanalytics.com.
---. "Where Next for US Commercial Mortgage Rates?" *Real Capital Analytics*, May 2022, app.rcanalytics.com.

"Decarbonizing the Built Environment." *JLL*, June 2021, www.us.jll.com/en/trends-and-insights/research/decarbonizing-the-built-environment.

"Despite Strengthening Headwinds, Global Economy May Still Avoid Recession." *CBRE*, May 2022, www.cbre.com/insights/viewpoints/despite-strengthening-headwinds-global-economy-may-still-avoid-recession.

"The Diversification Potential of Real Estate." *Norges Bank Investment Management*, Jan. 2015, www.nbim.no/contentassets/6f7dc4d09cd94c10b76906442e6e1549/nbim_discussionnotes_1-15.pdf.

"Fed's Powell to Take WSJ Questions on Inflation and Economic Outlook." *Wall Street Journal*, May 2022, www.wsj.com/articles/feds-powell-to-take-wsj-questions-on-inflation-and-economic-outlook-11652779802.

Fisher, Jeffrey. "US Commercial Real Estate Indices: The NCREIF Property Index." *Bank for International Settlements*, 2005, www.bis.org/publ/bppdf/bispap21zc.pdf.
Fu, Tingting. "Exploring a New Technique to Determine the Optimal Real Estate Portfolio Allocation." *Massachusetts Institute of Technology Center for Real Estate*, 2014. *DSpace*, hdl.handle.net/1721.1/87611.

Liu, Yanjia. "Incorporating Property Characteristics and Capital Market Conditions in Optimizing Commercial Real Estate Portfolios." *Massachusetts Institute of Technology Center for Real Estate*, 2014. *DSpace*, hdl.handle.net/1721.1/92600.

"NCREIF Data, Index and Products Guide." *NCREIF*, 2021, www.ncreif.org/data-products/property.

Peyton, Martha. "Is Commercial Real Estate an Inflation Hedge?" *The Counselors of Real Estate*, Nov. 2011, cre.org/wp-content/uploads/2017/04/Commercial_RE_Inflation_36_3.pdf.

Severino, Ryan. "Q1 2022 U.S. Economic Insights." *JLL*, May 2022, www.us.jll.com/en/trends-and-insights/research/slowing-not-stopping#:~:text=The%20U.S.%20economy%20got%20off,the%20underlying%20details%20remained%20positive.

"U.S. Real Estate Market Outlook 2022." *CBRE*, Dec. 2021, www.cbre.com/insights/books/us-real-estate-market-outlook-2022.

"Viewpoints from the Global Investment Committee." Nuveen, June 2022, www.nuveen.com/en-us/insights/investment-outlook/2022-midyear-outlook.

"Why Real Estate?" *Pension Real Estate Association*, Dec. 2021, www.prea.org/research/whyrealestate

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