REITs in a Mixed-Asset Portfolio

An empirical study

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Abstract

Diversification is a significant element of asset allocation. An alternative investment of great interest for many investors is real estate. The paper will explore the hypotheses whether real estate investment trust (REITs) warrants inclusion in an investment portfolio. The hypotheses will be explained qualitatively and quantitatively by exploring material evidence of the benefits of real estate in mixed asset portfolios in terms of inflation hedging, diversification, volatility dynamics etc. Variability among real estate and other asset classes such as equity and bonds will be explored through a classic Fama French factor model as well as more recent machine learning methods. Finally, a portfolio simulation analysis of a passive portfolio after the introduction of REITs over a 10 year period (2012-present) will be carried out to analyze the returns and volatility of a hypothetical mixed portfolio.

Contents

1 Introduction

Real Estate and, in particular, Real Estate Investment Trusts (REITs) are becoming an important investment vehicle for both institutional and retail investors wanting to diversify their portfolios. In fact, REITs capitalization in the US alone is approaching $1.25 trillion as opposed to about 100 billion USD by the turn of the century [Statista, 2021]. Immense growth globally has also been observed in recent years with some 865 REITs listed in more than 40 countries [Mattson-Teig, 2022].

The importance of REITs in an investment portfolio is evidenced by the large ownership held by institutions such as pension funds and insurance companies [Devos et al., 2013], as well as rapid foreign government adaption not only in the US but also in Europe [Mazurczak, 2011] and Asia [Ooi et al., 2006]. The increased inclusion of real estate, through REITs, in a mixed asset portfolio has created a need to systematically analyze its risk and return characteristics since the extent to which such securities should be included in a portfolio is determined by the estimates of risk and expected return.

There have been previous study which examined the risk and return consequences of the allocation of public real estate securities (REITs) in the mixed-asset portfolio. REITs are generally seen as having a similar role to real estate and acts as a portfolio diversifier or a risk reducer, and an effective hedging instrument against inflation [Coskun et al., 2017a]. [Chen et al., 2005b] illustrated the benefits of REITs from the perspective of asset allocation and diversification. Further results showed that REITs portfolio does provide some diversification benefits and return enhancements [Lee and Ting, 2009, Lee and Stevenson, 2004]. However, these benefits are contested. Diversification benefits of REITs change substantially over time [Huang and Zhong, 2010]. Besides, results also revealed that the REIT portfolios do behave differently relative to different asset classes [Newell et al., 2013, Lee, 2010] with benefits diminishing under certain periods [Marzuki and Newell, 2019]. [Chiang et al., 2013] suggests that REITs are not as defensive as they are in times of stable markets and may not be a good shelter during financial chaos.

This study aims to further increase the understanding of REITs from a quantitative perspective and long horizon, where we augment previous insights with Machine learning and statistical analysis. An empirical investigation is conducted focused on assessing the significance, risk-return characteristics and portfolio diversification benefits of REITs in a mixed-asset portfolio considering a 10-year time-period between 2012-2022. Analysis to identify financial and macroeconomic factors which influence REITs returns are investigated. Ultimately, we will examine the predictive performance of Fama French on REITs and a model trained with the same macroeconomic factors. After which the forecast performances of the models are compared.

The experiments are guided by the following research question:

Is the inclusion of real estate investment trust (REITs) in an investment portfolio warranted?

This study aims to provide implications for portfolio management and asset allocation by presenting empirically validated, data driven and practical investment decision-making mechanism regarding the potential strategic role of REITs in a portfolio. The following are the main contributions of the thesis:

(1) qualitatively and quantitatively review material evidence of the benefits of REITs in a mixed asset portfolio in terms of inflation hedging, diversification, volatility dynamics;

(2) examine real estate securities for return characteristics through the classic Fama-French factor model as well as more recent machine learning method; and

(3) portfolio simulation to test whether the addition of REITs in a mixed asset portfolio provides positive excess risk-adjusted return.

This thesis is organized as following: Chapter 2 begins by introducing the Real Estate Investment Trust (REITs) followed by a review of existing research on the various characteristics of REITs. Chapter 3 reports the case study methodology including data collection, experimental details and implementation consideration. Chapter 4 details empirical analysis and discusses their implications. Chapter 5 concludes the thesis and provides suggestion for future research.

2 Literature Review

Real Estate Investment Trusts (REITs) are securitized financial assets established by the US congress in 1960 to allow individual investors to invest in large-scale, income-producing real estates. The aim is to provide a way for individual investors to partly own valuable real estate asset without having to invest fully in such a capital-intensive endeavor. Investors can purchase a unit of a real estate asset portfolio through REITs in the same way one purchase shares of a publicly listed company through a stock, mutual funds, or exchange traded funds (ETF). A REIT investor receives a portion of the revenue generated by real estate investment through dividends.

In most countries, REITs has become the industrial standard for indirect real estate investment [Stevenson, 2013]. REITs were created primarily to facilitate a transparent, professionally managed, commoditized, and fiscally efficient property markets. Currently, approximately 145 million Americans live in the 43% of American households that own REIT stocks, directly or indirectly through mutual funds, ETFs, or target date funds [National Association of Real Estate Investment Trusts, 2019].

The introduction of REITs is also pivotal in providing a supportive environment for infrastructure growth. It help revitalise communities by pulling small capital together for infrastructure investment. In addition, REITs have a proven track record of attracting international capital [Deloitte, 2022]. For real estate developers, funding a real estate investment through REIT can often unlock new sources of funding and liquidity.

To qualify as a REIT, a company is legally mandated to invest 75 percent in real estate-related assets and to generate majority of its income from real estate investments such as rents and interest. REITs focus on long-term property income as opposed to turnaround from reselling of properties. REITs must hold its properties for at least two years for the production of rental income and has limitations with respect to the number of properties it can dispose during a year. REITs must also distribute 90 percent of its annual taxable income to shareholders annually in the form of dividends [IRS, 2021].

In return, REITs are eligible for special tax treatment such as deducting from its corporate taxable income all of the dividends that it pays out. In comparison, corporations, including conventional property companies, pay dividends out of after-tax income which leads to double taxation for investors. The dividends of REITs also tend to be relatively stable given the nature of the underlying real estate asset primarily receiving contractual rents paid by tenants. These makes REITs an attractive investment vehicle to many income-focused investors looking for high dividend yield and steady cash flow.

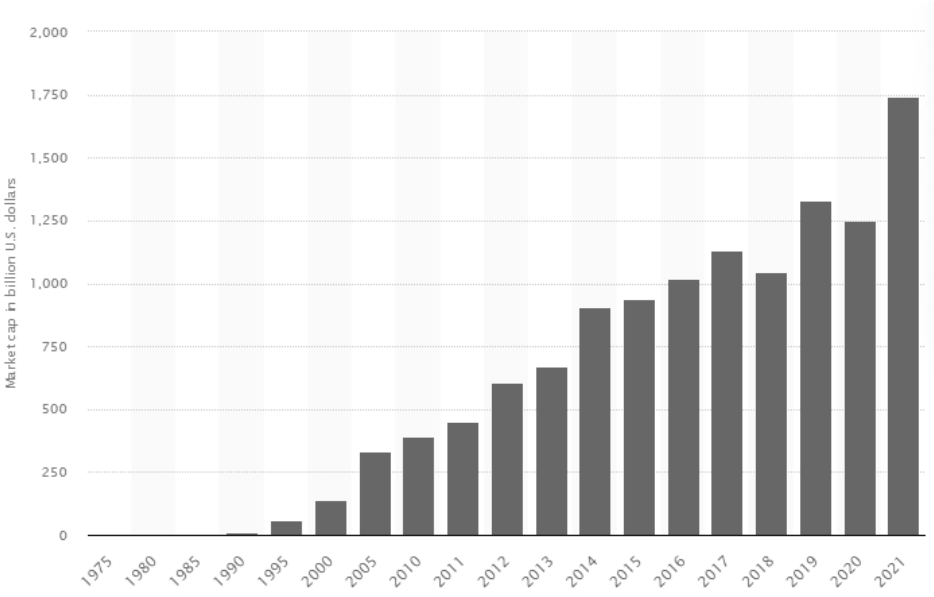


Figure 1. US REITs market capitalization from 1975 to 2021

Due to its inherent legislative and taxation benefits, a company must meet a variety of additional requirements in order to become a REIT and continue to operate under that regime. Whilst the regulation surrounding REITs does differ globally, there are broad similarities to the US approach [IRS, 2021]. As a matter of fact, more than 35 countries have adopted the US-based REIT approach including all G7 countries [Deloitte, 2019]. IRS stipulates the following prohibitions on REIT:

- Be an entity that would be taxable as corporation;
- Be managed by a board of directors or trustees;
- Have shares that are fully transferable;
- Have a minimum of 100 shareholders after its first year as a REIT;
- Have no more than 50 percent of its shares held by five or fewer individuals;
- Invest at least 75 percent of its total assets in real estate assets and cash;
- Derive at least 75 percent of its gross income from real estate related sources, including rents from real property and interest on mortgages financing real property;

The first REIT to be listed was Continental Mortgage Investors in 1965 at New York Stock Exchange. Other countries followed suit not too far behind with the first REIT legislation passed in Europe in 1969, Canada in 1993 and Asia in 2001. Immense growth globally has been observed in recent years in both the number of market participants as well as market capitalisation with some 865 REITs listed in more than 40 countries [Mattson-Teig, 2022]. In Europe, there is in excess of 150 REITs in operation across the 27 member states with market value of more than 129 billion USD [European Public Real Estate Association, 2022a].

In the emerging market, the MSCI Emerging Markets Core REIT Index covers 28 REITs with a 28 billion USD market cap. The leading countries in terms of their weights are South Africa (52%), Mexico (33%), Malaysia (8.3%), China (3.8%) and Turkey (1.8%) [National Association of Real Estate Investment Trusts, 2022]. Worldiwde, REITs has a combined equity market capitalization of approximately 2.5 trillion USD. In the US alone, REITs capitalization is approaching 1.75 trillion USD as opposed to about 100 billion USD by the turn of the century [Statista Reseach Deparment, 2007]. Figure 1 presents the significant growth in market capitalisation of the US REIT market from its conception in the 1970s to the present.

Properties in a REIT portfolio may include apartment complexes, data centers, healthcare facilities, hotels, infrastructure (fiber cables, cell towers, and energy pipelines), office buildings, retail centers, self-storage, timberland, and warehouses. REITs may hold different types of properties in their portfolios, such as a REIT that consists of both office and retail properties, but in general, REITs specialize in a specific real estate sector. Hence, it is common to hear terms such as retail REITs, office REITs, residential REITs, healthcare REITs, and industrial REITs. Office REITs may concentrate on office buildings and skyscrapers, health care REITs may concentrate on hospitals and retirement homes, hospitality REITs may concentrate on hotels and resorts, residential REITs may concentrate on single-family homes and student housing, and retail REITs may concentrate on storefronts and restaurants.

According to the sub-industry classification, the major REIT types in the MSCI Emerging Markets Core REIT index were as follows: diversified (62.2%), retail (24.54%), industrial (9.95%), hotel and resort (2.14%) and office (1.17%) [Morgan Stanley Capital International, 2022]. In Europe, these numbers are led by residential (35.5%), diversified (27.8%), office (10.9%), industrial (10.2%), and retail (5,9%) [European Public Real Estate Association, 2022b]. The top 10 constituents of the US REITs market as of 2022 and their corresponding property type specialization are listed in Table 1.

REIT	Market Cap	Dividend Yield	Property Type
Prologis (NYSE: PLD)	$116.4B	2.03%	Industrial
American Tower (NYSE: AMT)	$109.8B	2.38%	Communications
Crown Castle (NYSE: CCI	$76.8B	3.35%	Communications
Public Storage (NYSE: PSA)	$65.9B	2.14%	Self-storage
Equinix (NYSE: EQIX)	$64.4B	1.74%	Data centers
Simon Property Group (NYSE: SPG)	$48.9B	5.07%	Malls
Welltower (NYSE: WELL)	$43.0B	2.58%	Healthcare
Digital Realty (NYSE: DLR)	$40.1B	3.55%	Data centers
Realty Income (NYSE: O)	$40.1B	4.44%	Commercial
AvalonBay Communities (NYSE: AVB)	$34.6B	2.62%	Residential

Figure 2. Top 10 largest REITs 2022

The different REITs classification provides investors with diversification possibilities not available with traditional real estate. Real estate investment requires a sizable financial commitment, often limiting buyers to a specific type of property. Investing in REITs solves this issue by allowing investors to diversify by holding a portfolio of different property types, such as condos, retail space, healthcare facilities, or telecommunication infrastructure.

The growing significance of REITs has attracted research interest on the benefits of including REITs in the mixed-asset portfolio. Several empirical studies have covered major REIT markets, both in the form of region-wide REIT market studies such as in European Union [Niskanen and Falkenbach, 2010] and Asia [Ooi et al., 2006] as well as at an individual country level such as UK REITs [Newell and Marzuki, 2016], Turkish REITs [Coskun et al., 2017a], Malaysian REITs [Lee and Ting, 2009] and South Africa [Olaleye, 2011].

Existing research findings indicate that portfolio risk reduction is possible with holding of REITs. Using monthly return data compiled over a five-year period, [Kuhle, 1987] examined the effects of diversification on the reduction of total portfolio risk when REITs is added to the mixed-asset. A full Markowitz analysis [Economic Discussions, 2010] is employed to examine the risk and return potential and results indicate improvement of portfolio risk reduction. When overall performance measures are calculated, he observes a reduction of total portfolio risk in REITs and mixed-asset portfolios.

In the same year, [Grissom et al., 1987] also show that significant diversification benefits can be obtained by using REITs along with common stocks to create a well-diversified portfolios. A more recent study, [Chen et al., 2005a] claims that REITs appear to be non-redundant financial assets, which helps to enhance the completeness of a financial portfolio. Using U.S. REIT performance data over 1980-2002, an improvement in the mean variance portfolio frontier is observed.

Further studies on the linkage between REITs and other assets classes suggest the possibility of REITs being used as a risk diversifier. [Chaudhry et al., 2010] analyzed linkages between REITs and other assets empirically. Using methodologies that account for idiosyncrasies in the data, evidence of linkages between REITs and several of these assets is studied. For instance, the absense of a long-run linkage relationship between REITs and energy-related assets is found. This finding provide investors with cross hedging opportunities and diversification possibilities. [Fisher and Sirmans, 2012] suggest that REITs are able to provide diversification benefits to portfolios that contain small-cap stocks since they are subjected to different risk factors.

By examining ex-post performance using a dynamic asset allocation exercise with ex-ante information, [Chandrashekaran, 1999] suggest there are ex-ante benefits of diversification of REITs, showing portfolios that involve substantial allocation to REITs achieve mean-variance tradeoffs close to those attained by fixed-weight unconditional mean-variance efficient portfolios. A similar study by [Ng et al., 2017] evaluated REITs diversification performance between the period 2007 to 2015. The results indicate that all selected REITs outperform the index, and are less risky than the market given the beta values are less than one.

Looking at Figure 3, on average, the total risk of the REITs that is due to unsystematic risk is very much higher than that of systematic risk, i.e. 4.60 and 0.22 respectively. 94.3% of the total risk of REITs comes from unsystematic risk component which suggests that REITs risks are not shared with the wider market. The diversibility values which range from 0.87028 to 0.99901, with an average of 0.94289, further support that there are notable opportunities for diversification by including REITs in a mixed asset portfolio. More recent studies on emerging markets also suggest that REITs can be used as a risk diversifier. [Coskun et al., 2017b] found T-REITs (Turkish REITs) provide higher risk diversification benefits than traditional stocks (ie. bank equities).

Previous literature also examined if real estate assets can be incorporated and used as tools for inflation hedging for a mixed-asset portfolio. While the direct investment in real estate assets is often seen as a hedging tool against inflation, both positive and negative linkages between the aggregate price level and real estate financial asset prices have

No	REITs	Beta β_i	R-squared	Total risk σ_i^2	Systematic risk $\beta_i^2 \cdot \sigma_m^2$	Unsystematic risk σ_e^2	Diversifiability measure $\frac{\sigma_e^2}{\sigma_i^2}$
1	Amanah Harta Tanah PNB	0.062	0.009	2.885	0.025	2.860	0.991
2	Al-'Aqar Healthcare REIT	0.030	0.001	5.994	0.006	5.988	0.999
3	AmFirst Real Estate Investment Trust	0.236	0.125	2.914	0.364	2.551	0.875
4	AmanahRaya Real Estate Investment Trust	0.106	0.010	7.299	0.073	7.226	0.990
5	Atrium Real Estate Investment Trust	0.205	0.086	3.179	0.273	2.906	0.914
6	Axis Real Estate Investment Trust	0.212	0.045	6.425	0.292	6.133	0.955
7	CapitaLand Malaysia Mall Trust	0.186	0.035	6.503	0.225	6.278	0.965
8	Hektar Real Estate Investment Trust	0.088	0.007	7.252	0.051	7.201	0.993
9	IGB Real Estate Investment Trust	0.182	0.067	3.242	0.216	3.026	0.933
10	KLCC Real Estate Investment Trust	0.206	0.033	8.296	0.277	8.019	0.967
11	MRCB-Quill REIT	0.217	0.130	2.356	0.306	2.050	0.870
12	Sunway Real Estate Investment Trust	0.242	0.091	4.213	0.382	3.831	0.909
13	Pavilion Real Estate Investment Trust	0.225	0.055	6.030	0.330	5.701	0.945
14	Tower Real Estate Investment Trust	0.260	0.127	3.489	0.442	3.048	0.873
15	UOA Real Estate Investment	0.171	0.040	4.694	0.189	4.505	0.960
16	YTL Hospitality REIT	0.142	0.054	2.420	0.131	2.289	0.946
	Average	0.173	0.057	4.824	0.224	4.601	0.943

Figure 3. Selected REITs Risk features

been found and explained in studies during past decades. [Hardin III et al., 2010] argue that the relationship between REIT return and the inflation rate is mainly determined by two factors: inflation illusion and hedging effect. While the hedging effect shows a positive correlation between REIT return and inflation rate, the inflation illusion provides evidence for the opposite relationship. By developing a theoretical framework, the authors showcased that the relationship between REIT return and inflation rate depends on the relative intensity of the two factors. The relationship between returns on REITs and anticipated inflation has also been studied in emerging markets. In Africa, [Dabara et al., 2021] empirically suggested that REIT has poor hedging-characteristics across all inflation exposures (actual, expected, and unexpected).

Despite the controversial findings, far more studies suggest the long-term inflation hedging and partial inflation hedging abilities of REITs. For example, [Chatrath and Liang, 1998] suggest that even though there is no evidence that REIT returns are positively related to temporary or permanent components of inflation measures, there is evidence that REITs provide a long-run inflation hedge trough isolation of cointegrating vectors between alternate REIT indices and the CPI. [Lizieri et al., 2008] have a more nuance take. Their findings suggests that the long-run REIT returns are positively linked to anticipated inflation, but not to inflation shock. The analyses are undertaken using the error correction approach. In the long run, once real and monetary variables are included, REIT returns both in the UK and US are positively linked to inflation, a characteristics that differ from those of stocks.

Considerable literature examined if REITs can be incorporated and used as tools for inflation hedging, as effective risk diversifiers, or as duration balancers in an efficient portfolio. While the investment in REIT assets is often seen as a hedging and diversification tool, both positive and negative association has been observed. This study aims to further increase the understanding of REITs from a quantitative perspective and long horizon, where we augment previous insights with machine learning and statistical analysis.

3 Data and Methodology

In this chapter we describe the data we used, its sources and practical details of implementation.

3.1 Data

The main source of data is REIT indices and REIT stocks. We consider the REIT index *Dow Jones Equity All REIT* listed in site as our main instruments of analysis. We query the data between 2012-01 - 2022-07 on a daily basis on open-close-high-low.

The Dow Jones All REIT Index is designed to include all REITs in the U.S. Stock Market that meet the minimum float market capitalization (FMC) of USD 200 million and liquidity threshold median of at least USD 5 million daily value traded. The index is reviewed daily based on each company's capped market capitalization weight, and subject to the following constraints applied at each re-balancing [S&P Dow Jones Indices, 2022]:

- No single company's weight can exceed 10%.
- The aggregate weight of all companies weighing more than 4.5% cannot exceed 22.5%.

Figure 6 highlights the stable growth in market capitalisation of the Dow Jones All REIT Index in the last 10 years. The same period is utilized for the analysis which covers a full business or property cycle [Born and Pyhrr, 1994], thus adequate to empirically assess the long-term performance of REITs. Returns prior to this date was not included in the performance analysis due to the lack of comparable time series data bought partly by the underdeveloped index construction characterized by relatively few constituents and frequent spin-offs.

NUMBER OF CONSTITUENTS	134
CONSTITUENT MARKET [USD MILLION]	
MEAN TOTAL MARKET CAP	9,999.26
LARGEST TOTAL MARKET CAP	118,056.27
SMALLEST TOTAL MARKET CAP	316.52
MEDIAN TOTAL MARKET CAP	3,263.81
WEIGHT LARGEST CONSTITUENT [%]	9
WEIGHT TOP 10 CONSTITUENTS [%]	43.7

Figure 4. Dow Jones All REIT Index Characteristics

CONSTITUENT	SYMBOL	SECTOR*
American Tower Corp A	AMT	Real Estate
ProLogis Inc	PLD	Real Estate
Crown Castle Inc.	CCI	Real Estate
Equinix Inc	EQIX	Real Estate
Public Storage	PSA	Real Estate
Realty Income Corp	O	Real Estate
Digital Realty Trust	DLR	Real Estate
SBA Communications Corp	SBAC	Real Estate
Welltower Inc	WELL	Real Estate
Simon Property Group A	SPG	Real Estate

Figure 5. DJ All REIT Index Top 10 Constituents

Table 3.1 lists fundamental index characteristics and Table 3.2 list the top 10 REIT constituents by index weight.

The study aims to provide implications for portfolio management and asset allocation by presenting empirically validated, data driven and practical investment decision-making mechanism regarding the potential strategic role of REITs in a mixed-asset portfolio. Consequently, selected asset type are also studied such as gold, US treasury, S&P500 index, NASDAQ 100 Technology index, S&P Commodity index, and US interest rate.

Gold is selected for analysis owing to the common belief that, as opposed to real estate, it is a flexible liquid asset and one of the safest investment [Financial Times, 2019]. It represents a store of value that investors believe will insulate them against inflation and provides diversification [Ghosh et al., 2001].

The 10-year US treasury yield is selected as an indicator of broader investor confidence. Because Treasury bills, notes, and bonds is backed by the U.S. government, they are also viewed as one of the safest investments offering diversification and hedging benefits [U.S. Department of the Treasury, 2021].

The S&P 500 index consisting of 500 large companies in USA may be used as a proxy for the entire US stock market as it covers about 80% of that market [Standard and Poor's, 2021]. Despite the historic annualized average return of around 11.88% since its 1957 inception, there are still risks when investing in such a broadly diversified index because the returns have historically been volatile [Maverick, 2022]. Therefore, the study aim to explore whether it is desirable to combine an investment in the S&P 500 index with a different asset type such as REITs.

The NASDAQ 100 Technology Index is selected to represent the technology equities which has risen in popularity among investors looking for a high-growth stock with huge

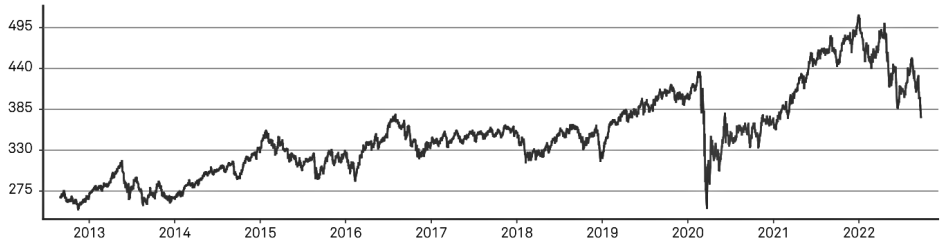


Figure 6. DJ All REIT Index Historical Performance

potential. The index tracks the largest publicly traded equity securities of US companies in the technology sector based on market cap [NASDAQ, 2022].

The S&P Commodity index is selected to represent the commodity asset class. Commodities are unique asset class with returns which are primarily independent of stock and bond returns. Thus, it is viewed that adding commodity exposure to a portfolio of stocks and bonds help in diversification, potentially lowering the risk of the overall portfolio and boosting returns [Ruano and Barros, 2022].

Finally, the US Interest Rate is selected to analyze the effect of interest rate fluctuations to the different asset classes mentioned above. Investors, portfolio managers and policy makers alike should be cognizant of the dynamic nature of the relationship between interest rates and asset markets bearing in mind the varying impact of interest rate in various assets [Yalla, 2020]. Studies are conflicting on REITs sensitivity to interest rate. [He et al., 2003] report significant sensitivity of REITs to changes in interest rates, while [Liang et al., 1995] found insignificant sensitivity.

The study aims to breakdown various component of a mixed-asset portfolio with a focus on examining the benefit of adding real estate securities for inflation hedging, diversification, and volatility improvement purposes.

The selected core asset type are extracted from 1992-01 - 2022-07 on a daily basis on open-close-high-low. The data are extracted from the *investing.com* through the Python API, investpy. For interest rates and US treasury bonds, we used *Federal Reserve Economic Data* (FRED). The data was queried on a daily basis, going as back to 1992.

3.2 Methodology

In this chapter we describe the main methodology used to answer our queries:

1. How REITs correlate with equities, interest rates, US treasury bonds and other asset classes in the long term?

2. How does Fama-French predict REITs? Can we improve prediction performance by either data augmentation or a more flexible machine learning model?

3. Are there any benefits in incorporating a REIT index together with the S&P 500 in terms of volatility, returns or Sharp ratio improvement?

We explore these questions in the three subsections that follows.

3.2.1 Correlation Analysis

To calculate the correlation between instruments, the sample Pearson correlation coefficient was utilized which is given by

$$r_{xy} = \frac{\sum_{i=1}^{n} (x_i - \bar{x}) \left(y_i - \bar{y}\right)}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^{n} \left(y_i - \bar{y}\right)^2}} \tag{1}$$

where n denotes sample size, $\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$, $\bar{y} = \frac{1}{n} \sum_{i=1}^{n} y_i$ and $x_i \sim X$ and $y_i \sim Y$. Here X and Y are random variables. For our application, we would interpret each instrument to be a random variable, where a sample would correspond to a daily closing price.

As an example, consider daily closing prices x_t^{gold} at day t of gold, which is represented by the random variable X^{gold}. We assume that x_t^{gold} is drawn independently and identically distributed from X^{gold} and hence we would be able to calculate the Pearson correlation between any two instruments (ie. gold and reit) having the same time indexing t.

3.2.2 Factor Analysis

Mean Model The analysis will briefly look at the elementary forecasting estimate of the mean based on the historical data focusing on the statistical significant of what is called the "central tendency" of a data set. The formula for computing the mean of a sample of data is given by

$$X = \frac{\sum_{i=1}^{n} X_i}{n} \tag{2}$$

We will briefly look into the estimated mean as a forecast for the next value of X_t that will be observed.

Fama French Model Various approaches and models for valuing securities and calculating expected returns on capital investments have been created, and several factors have been proven to significantly affect security returns. [Fama and French, 1993] developed the three-factor model comprising of market risk premium (e.g., security return less the risk-free rate of return), market size (e.g., market capitalization) and market value (e.g., book to market value).

The Fama-French factors take into consideration the impact of relative market capitalization (SMB) and book-to-market (HML) ratio on portfolio's performance. The market capitalization are relatively denoted as small (S) or big (B), while three quartiles such as low (L), medium (M) and high (H) represents the market value. SMB is the amount by which the return of a portfolio of small stocks is in excess of the return on a portfolio of large stocks, and HML is the amount by which return of a portfolio of stocks with a high book-to-market ratio is in excess of the return on a portfolio of stocks with a low book-to-market ratio [Fama and French, 1993].

The study will test the Fama-French 3 factor model in the context of REIT securities for the period of 2002-2022 on a daily basis using the Dow Jones Equity All REIT and S&P 500 as market proxy. The equation of the three factors model of Fama and French is:

$$R_i - R_f = a_i + b_i \left(R_m - R_f\right) + s_i \mathrm{R}_{SMB} + h_i \mathrm{R}_{HML} + e_i \tag{3}$$

with the following covariates:

- t denotes the time.
- i denotes the instrument
- R_i denotes the return of the instrument (ie. gold or reit).
- R_F denotes the risk free rate offered by an investment with zero risk. Practically, every investment asset carries some level of risk, so the risk-free rate is a theoretical concept. In the study, R_F is considered to be the interest rate of government treasury bill.
- R_M denotes the market return. Market return is a sum over or aggregate portfolio of all individual investors after cancelling out lending and borrowing. In other words, it equals the entire wealth of the state economy [Bodie and Marcus, 2008]. The methodology of Fama and French for $(R_m - R_f)$ is the weighted average return of all the stocks in the sample.
- SMB refers to *Small Minus Big (market capitalization)*. The factor accounts for a famous return anomalies called the size effect which states that small cap stocks have higher risk adjusted return than the stocks of the big cap stocks [Banz, 1981]. The methodology of Fama and French for SMB is explained by the difference between the return portfolios of small and big of stocks.
- HML refers to *High Minus Low (book-to-market ratio)*. This factor accounts for another famous return anomaly in financial markets called the book-to-market effect. It emphasizes that the larger the book-to-market ratio is, the better the prospects of the company in terms of risk adjusted return [Banz, 1981]. The methodology of Fama and French, for HML is explained by the difference between the return on the portfolios of high and low-book-to-market stocks.

The model also considers the following parameters which are inferred from fitting the model:

- a_i represents the average non-systematic risk component of the portfolio, i.e. it is attributable to firm-specific risks. Since the average is independent of the number of securities, n, the variance becomes negligible for large n. This means that as we increase the securities the constructed portfolio, the part of the portfolio risk attributable to firm-specific events becomes gradually smaller, as the risk resulting from firm-specific events is diversified away. However, systematic risk remains unchanged, regardless of the number of securities added into the portfolio.
- b_i represents the sensitivity to the market. It is a measure of the tendency of the return of a security to move in parallel with the return of the stock market as a

whole. A b_i higher than 1.0 can be interpreted as more volatile than the market, while stocks with betas less than 1 will have less momentum relative to the market. Investors generally use b_i to gauge how much risk a stock is adding to a portfolio.

- s_i represents instruments sensitivity to the SMB covariate. Intuitively, it corresponds as the effect of the current return difference between small and big stocks.
- h_i represents instruments sensitivity to the HML covariate. Intuitively, it corresponds as the effect of the book-to-market effect.

Daily data of HML and SMB are obtained at Ken French's personal website[1]. The coefficients a_i, b_i, s_i, h_i are estimated using linear regression and the e_i represents the residual.

Machine learning Model One can in principle predict $R_{i,t} - R_{F,t}$ using any model. We compare Fama-French against *LightGBM* [Ke et al., 2017], a machine learning model considered the gold standard for prediction problems. LightGBM is an implementation of *gradient boosting* [Friedman, 2001], which considers the task of finding a function $\hat{F}(x)$ such that $\hat{F} = \arg\min_F \mathbb{E}_{x,y}[L(y, F(x))]$ for observations $\{x_i, y_i\}_{i=1}^n$. One then assumes that $\hat{F}(x)$ has the form

$$\hat{F}(x) = \sum_{m=1}^{M} \gamma_m h_m(x) + \text{ const.} \tag{4}$$

where $h_m(x)$ denotes *weak-learners* i.e. (linear regressors, decision trees) [Bishop, 2006], γ_m the weight and M the number of learners. One would then iteratively find $\hat{F}$ by recursively fitting the residuals M times.

$$F_m(x) = F_{m-1}(x) - \gamma \sum_{i=1}^{n} \nabla_{F_{m-1}} L\left(y_i, F_{m-1}\left(x_i\right)\right) \tag{5}$$

To evaluate prediction power, we split the dataset into training (80%), validation (10%) and testing (10%). In particular, we use the last 10% of the data as testing, rather than a random partition. This way, we test the model's ability to generalize to future data.

[1] https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

We evaluate the performance of the model by considering the R^2 score, which is defined

$$R^2 = 1 - \frac{\sum_t (\hat{y}_t - y_t)^2}{\sum_t (y_t - \bar{y})^2} \tag{6}$$

where $\hat{y}_t$ denotes a prediction of y_t from a model.

3.2.3 Portfolio Simulation

The aim of this research is three fold: firstly, to verify the earlier studies on how REITs risk and return characteristics compare to that of other asset types, secondly, to apply Fama French and machine learning to explore pricing of REITS through factor analysis, and finally, to examine the impact of adding REITs to mixed equities portfolios over a relatively long and using a more up-to-date sample, i.e. the period of 2012–2022.

We built a quantitative simulation model for the purpose of generating a portfolio consisting of S&P 500 index equities and DJ All REIT index under different weight combination to satisfy the investor-defined confidence level in REITs as part of their passive investing strategy. The data for this evaluation was collected daily from 2012 to 2022 with closing price specification. The simulation of historical data was carried out to calculate the expected return and the expected volatility matrix. Furthermore, the Sharpe ratio in the portfolio model, which is also known as the return to risk ratio, is evaluated.

To begin with the simulation, the first step is to create a function with the portfolio allocation for the specified weights, as follows:

$$m(\alpha) = x_{\text{S\&P500}}(1 - \alpha) + \alpha x_{\text{REIT index}} \tag{7}$$

where $\alpha \in [0, 1]$ denotes the weight of REIT index in the portfolio. We consider a grid of α and calculate the return, rolling the sharp ratio and rolling volatility of the portfolio over time, to evaluate whether including a REIT index improves returns or risk over time. We calculate the Sharp ratio as

$$\text{Sharp ratio} = \frac{\text{Return}}{\text{Volatility}} \tag{8}$$

4 Results and Discussion

In this section we present the main findings and analyze how they relate to the research questions.

4.1 Correlation Analysis

We have analyzed the return behavior of REITs and other asset types using monthly data for the 10 year period of 2002-2022. Figure 7 presents a simple unconditional Pearson correlation matrix for the REIT market returns, gold, bonds, S&P 500 index, tech equity index, commodity returns, and US interest rates. The aggregated view of the coefficients shows a generally negatively correlated REIT market with bonds, commodity, and gold. Results also suggests that REITs seems to have a similar behavior to the S&P 500 index, and to a weaker extend co-movement with the Tech equity index. Interestingly, weakly positive correlation with interest rates is observed.

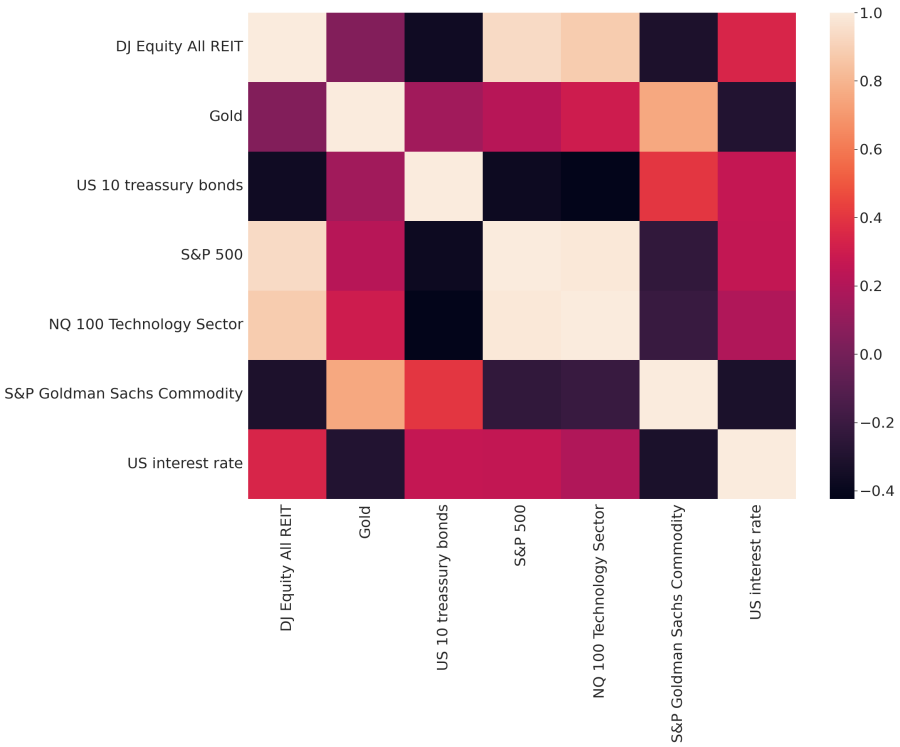


Figure 7. Correlation between different instruments

The results broadly align with previous research and intuition that REITs is a good passive investment for diversification. REITs is weakly correlated with gold, an investment vehicle that investors generally view as an insulator against inflation. Since inflation occurs when the supply of money increases relative to supply of hard assets, and both REITs and gold are hard assets that cannot be readily increased in supply, investors looking for diversification have the agency to include these inflation hedges which are also weakly correlated thus mutually diversifying. It must be noted that based on the 10 year period analyzed, gold offers an objectively better inflation protection than REITs. However, at high interest environment, a common response to combating inflation, REITs perform better than gold. Gold is highly sensitive to rising interest rates, as these increase the opportunity cost of holding the non-yielding asset [Reuters, 2022]. REITs, on the other hand, are better positioned to withstand elevated interest rate considering their dividend growth prospects and cash flow growth estimates.

Notice that both bonds and REITs are sensitive to interest rate changes by the Federal Reserve. Bond prices are strongly driven by interest rates. Bond prices decrease as interest rates rise and increase when interest rates fall. This is because most bonds have a fixed interest rate that increases in attractiveness when prevailing interest rates decline, increasing bond demand and bond price. Alternately, if market interest rates rise, existing bonds lose value because their coupon payments are now lower than the current market rates. Hence, in general, rising interest rates may negatively affect the value of a bond portfolio and vice versa. Interestingly, opposing conventional wisdom and consistent with the above findings, rising interest rates does not necessarily impact REITs return negatively as it does for bonds. After looking at correlation patterns and 10 year historical data, it appears that returns from REITs, for the most part, shows a positive correlation with increasing interest rates. That is, higher interest rates tend to occur alongside higher REIT return, but it is a weak tendency. A possible explanation is looking at the two key components of the property return depicted by formula:

$$\textit{Total Return} = \textit{Capital Return} + \textit{Income Return}$$

REIT investing allows for sharing in value appreciation and rental income from property investment. The income component of property return is driven by the rental income generated by the property while the capital return represents the actual percentage change in the value of the property.

Since 2000, interest rates and property appreciation have had a weak but positive relationship [Goodman and Neal]. That is, higher interest rates tend to occur alongside higher property appreciation. This is because higher interest rates have historically been associated with periods of stronger economic growth both leading to high home price appreciation. Following this, the first component of the total property return is positively impacted by rising interest rate. Additionally, REITs pay out regular dividends from the income return of the rental leases. Whilst a rise in interest rates does not have a direct impact on rents, high interest rates tend to coincide with or occur in response to higher inflation which generally pushes up rents [Fahy, 2022].

On top of this, rents have a general tendency to increase during massive interest hikes due to the need of landlords to recover the higher cost from their tenants. Rising interest rate also pushes up the rent from the demand side of the market equation as the higher cost of borrowing makes it unattainable for certain customer segments to purchase a property, thus increasing rental demands. For the most part, REIT returns and interest rates have a positive correlation owning to expansion in rents and income during periods of economic growth.

The positive correlation between REITs and S&P 500 and tech index is remarkable, and such points to potentially integrated markets. REITs are publicly traded like stocks which makes them liquid unlike actual physical real estate investments, and present them with characteristics that of a traded stock. When the indexes go up, REITs have a tendency to go up as well, and vice versa. Traditional stock prices are theoretically driven by corporate profits, whereas REITs are primarily based on income collected from property rents. The fact that traditional stock and REIT prices are driven by separate factors should diminish the correlation between the two asset types. The weakly positive correlation can be explained by the unexpected stock market and sometimes unwarranted price movements. REITs are nonetheless equity investments and are not immune from wider market price movements.

4.2 Factor Analysis

This research explores the asset pricing estimation performances of an historical mean model, Fama-French three factor model and a widely used machine learning prediction approach *LightGBM* described in Section 3.2.2.

The mean model forecast and the confidence interval look fairly reasonable, although they rest on strong assumptions, namely that the asset values are independently and identically normally distributed. Factors that determine the prices of and returns of financial

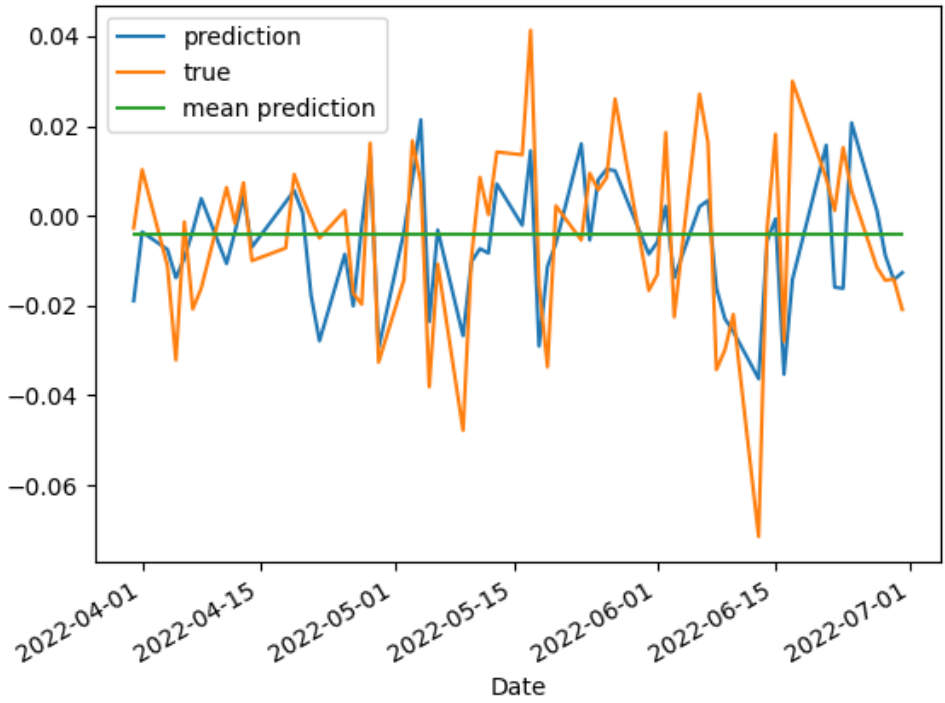
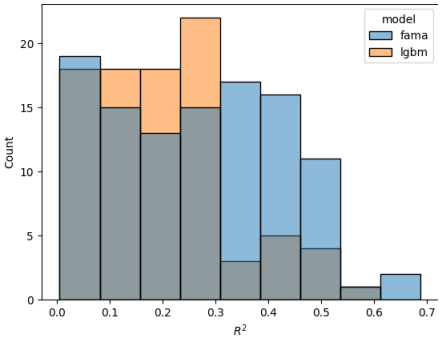


Figure 8. Mean prediction vs Fama-French for a selecREIT

or real assets such as REITs are much more sophisticated. The mean model is overly simplistic as it always expect the average. Another disadvantage is that it is disproportionately affected by outliers. However, mean model is the starting point for more sophisticated regression models such as the Fama French. Fama French, although not immune to outliers in the data, has more explanatory power than a mean model.

In Figure 8, we compare the mean prediction against the Fama-French model on held out test data for a selected REIT equity with ticker JBGS. Notice how the mean model always expect the average.

This research explores in detail the performance of Fama-French relative to *LightGBM*. Specifically, it uses a gradient boosting approach of the orginal Fama French three factor namely the size of firms, book-to-market values, and excess return on the market to obtain predictions of portfolio returns. On data from 100+ REIT portfolio returns in the United States over the 10 year period from January 2012 to July 2022, we compare R^2 results on test data comparing the Fama-French 3 factor model against *LightGBM*



((a)) R^2 for standard models

Figure 9

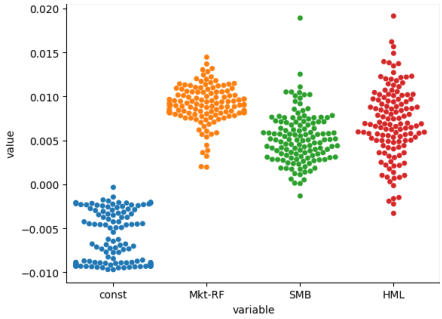
	model	mode	R^2
0	fama	aug	0.33±0.15
1	fama	reg	0.27±0.16
2	lgbm	aug	0.29±0.14
3	lgbm	reg	0.2±0.13
4	mean	reg	0.0±0.0

Table 1. Mean R^2 across all instruments with standard deviations

in Figure 9. Fama-French three-factor model outperformed the *LightGBM* trained on the same three factors. More precisely, the Fama-French three-factor estimations attain out-of-sample (testing dataset) correlation coefficients 13,5% higher acceptability R^2 than the machine learning model indicating that the Fama-French model can explain the REITs return better.

We further compare the average R^2 scores between datasets in Table 1 noting that the Fama-French model performs better than the machine learning model. For the test dataset, the mean R^2 is 27% and 20% consistently confirming Fama and French's findings, namely the contribution of the three factors in explaining portfolio returns is applicable even for REIT returns. The lagging performance of the *LightGBM* model could be explained by that most machine learning models are designed to extract information from larger quantities of data to then infer non-linear relationships the covariates and dependent variable. Here, we only cosider 3 features in total, where the SMT and HML low features already are engineered to explain returns.

We further plot the distribution of the coefficients of the regular Fama-French model



((a)) Leaf plot for variables of the Fama-French model

Figure 10

in Figure 10. Here, we see that the values for the coefficients of the Fama-French model mostly differ from 0 for all instruments. This further confirms that return of REIT's can generally be predicted by Fama-French. In Table 2, we further show that most REITs can be fitted by the Fama-French model with significant coefficients in terms of p-values. In some cases where R^2 where particularly low, we find that the coefficients are not significant with p-values greater than 0.05.

4.3 Portfolio Simulation

The paper ultimately aims to examine the impact of adding REITs to a mixed equities portfolios over a relatively long period of 10 years from 2012–2022. We simulated different portfolios combining varying weight of S&P500 index and the DJ ALL REITS index. Here we weight the index differently with a factor $\alpha \in [0, 1]$. In Figure 11 we see that for different weights of DJ ALL REITS mixed in with S&P 500. The graph is constructed by iterating through $\alpha \in [0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9]$. For each value of α we then considered a portfolio of

$$\alpha \cdot \text{S\&P 500} + (1 - \alpha) \cdot \text{DJ ALL REITS}.$$

To calculate the cumulative returns for each portfolio, we simply do a cumulative product of daily returns for the entire period.

The results indicate that, in contrast to what some previous studies suggested, adding the REIT index exposure leads to a limited portfolio enhancement in terms of lump-sum return. Solely investing 100% in S&P 500 is a better choice than mixing in DJ ALL REITS to the portfolio looking at accumulated returns under the 10 year period analyzed.

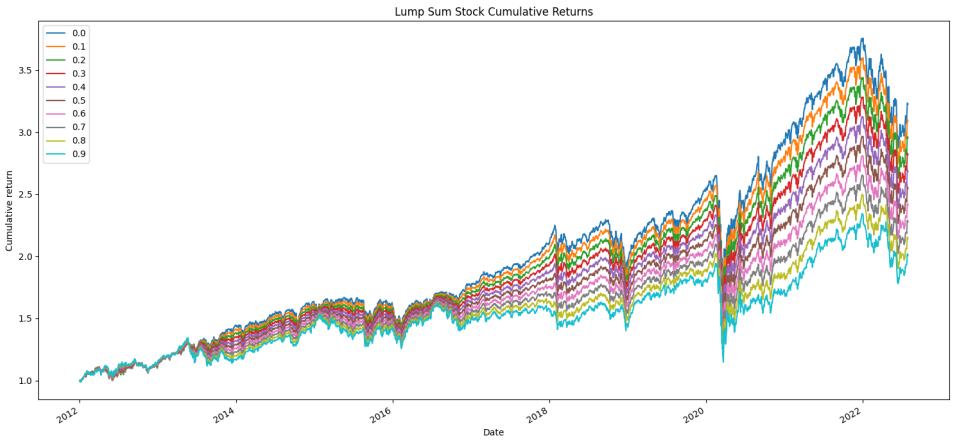


Figure 11. Lump sum returns for different α

Looking at the annualized volatility in Figure 12 for the same α's, we find that the DJ ALL REIT index generally has lower volatility than the S&P 500. This suggests that if the investor should invest passively based solely on the S&P 500 and the investor's profile, it would be prudent to recommend a portfolio with a smaller REITs index for a more conservative investor. It was enough for investors who strife for portfolio improvement over the decade between 2012 and 2022 to have a small portion of their value holdings replaced with the REIT sector exposure to obtain a positive impact on the returns and risk characteristics.

We further analyzed the Sharpe ratio in Figure 13. Here we interestingly find that mixing in a degree of DJ ALL REITS ($\alpha \approx 0.3$ actually achieved an improved Sharpe ratio than just the S&P 500 alone. Although portfolio 2 did not offer the highest return and the least volatility, it outperformed every portfolio by presenting a Sharpe ratio of 1.09 and an expected return of 39.78%. It must be noted that the simulation demonstrated a time-varying sharp ratio performance across the various portfolios.

Based on how each portfolio covered in this study performed, it is possible to conclude that a mixed portfolio of S&P500 index and the DJ ALL REITS index would be the best recommendation for a passive investor.

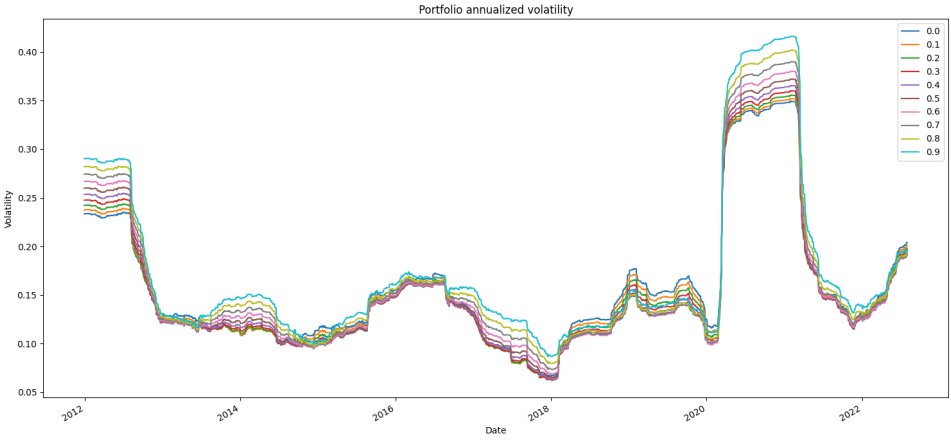


Figure 12. Volatility for different α

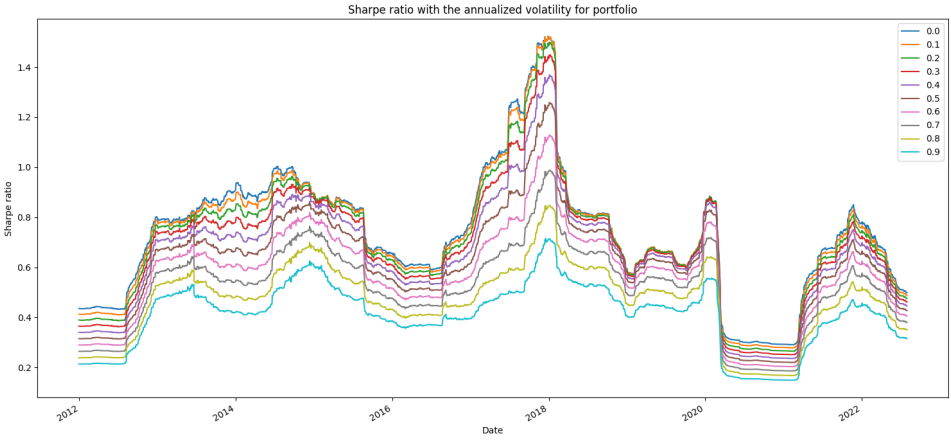


Figure 13. Sharp ratio for different α

	const	Mkt-RF	SMB	HML	const_pval	Mkt-RF_pval	SMB_pval	HML_pval
JBGS	-0.0045	0.0083	0.0014	0.0058	0.0000	0.0000	0.0259	0.0000
UE	-0.0033	0.0095	0.0057	0.0102	0.0000	0.0000	0.0000	0.0000
EQC	-0.0095	0.0094	0.0041	0.0091	0.0000	0.0000	0.0000	0.0000
PDM	-0.0021	0.0083	0.0030	0.0066	0.0000	0.0000	0.0000	0.0000
DOC	-0.0025	0.0071	0.0033	0.0014	0.0000	0.0000	0.0000	0.0003
ALEX	-0.0018	0.0105	0.0071	0.0069	0.0286	0.0000	0.0000	0.0000
SUI	-0.0089	0.0076	0.0048	0.0050	0.0000	0.0000	0.0000	0.0000
VNO	-0.0093	0.0097	0.0039	0.0107	0.0000	0.0000	0.0000	0.0000
WPC	-0.007	0.0059	0.0011	0.0036	0.0000	0.0000	0.0014	0.0000
DEI	-0.0034	0.0109	0.0018	0.0075	0.0000	0.0000	0.0000	0.0000
MPW	-0.0045	0.0113	0.0034	0.0052	0.0000	0.0000	0.0000	0.0000
HR	-0.0092	0.0082	0.0043	0.0065	0.0000	0.0000	0.0000	0.0000
WSR	-0.0022	0.0081	0.0052	0.0088	0.0000	0.0000	0.0000	0.0000
CHCT	-0.0029	0.0094	0.0058	0.0024	0.0000	0.0000	0.0000	0.0000
AHT	-0.0046	0.0105	0.0189	0.0191	0.0000	0.0000	0.0000	0.0000
OHI	-0.0092	0.0084	0.0071	0.0069	0.0000	0.0000	0.0000	0.0000
O	-0.0087	0.0081	0.0042	0.0066	0.0000	0.0000	0.0000	0.0000
SBRA	-0.0022	0.0091	0.0070	0.0050	0.0000	0.0000	0.0000	0.0000
BFS	-0.0092	0.0085	0.0081	0.0086	0.0000	0.0000	0.0000	0.0000
WHLR	-0.0003	0.0057	0.0050	0.0031	0.9100	0.0465	0.3211	0.4184
HT	-0.0068	0.0099	0.0102	0.0140	0.0000	0.0000	0.0000	0.0000
APLE	-0.0034	0.0101	0.0068	0.0084	0.0000	0.0000	0.0000	0.0000
AKR	-0.0093	0.0082	0.0071	0.0089	0.0000	0.0000	0.0000	0.0000
FR	-0.009	0.0116	0.0078	0.0102	0.0000	0.0000	0.0000	0.0000
SOHO	-0.0045	0.0062	0.0045	0.0102	0.0000	0.0000	0.0000	0.0000
GLPI	-0.0028	0.0095	0.0030	0.0026	0.0000	0.0000	0.0000	0.0000
IRT	-0.0023	0.0084	0.0027	0.0036	0.0000	0.0000	0.0000	0.0000
SRC	-0.0024	0.0090	0.0027	0.0057	0.0000	0.0000	0.0000	0.0000
EGP	-0.0091	0.0081	0.0059	0.0057	0.0000	0.0000	0.0000	0.0000
RHP	-0.0073	0.0130	0.0101	0.0114	0.0000	0.0000	0.0000	0.0000
CBL	-0.0097	0.0115	0.0086	0.0149	0.0000	0.0000	0.0000	0.0000
AMH	-0.0024	0.0071	-0.0013	-0.0001	0.0000	0.0000	0.0027	0.6529
CPT	-0.009	0.0083	0.0043	0.0080	0.0000	0.0000	0.0000	0.0000
MAC	-0.0091	0.0105	0.0077	0.0138	0.0000	0.0000	0.0000	0.0000
OPI	-0.0014	0.0073	0.0092	0.0058	0.1512	0.0000	0.0000	0.0000
KIM	-0.0094	0.0100	0.0055	0.0123	0.0000	0.0000	0.0000	0.0000
SPG	-0.009	0.0099	0.0050	0.0120	0.0000	0.0000	0.0000	0.0000
CCI	-0.0063	0.0109	0.0017	-0.0016	0.0000	0.0000	0.0043	0.0016
MDRR	-0.004	0.0036	0.0076	0.0025	0.1055	0.0361	0.0225	0.2152
GOOD	-0.0046	0.0060	0.0062	0.0044	0.0000	0.0000	0.0000	0.0000
LAND	-0.0022	0.0054	0.0043	0.0022	0.0000	0.0000	0.0000	0.0000
IIPR	-0.0022	0.0108	0.0076	-0.0015	0.0067	0.0000	0.0000	0.0635
NHI	-0.0093	0.0078	0.0064	0.0062	0.0000	0.0000	0.0000	0.0000
RYN	-0.009	0.0098	0.0030	0.0059	0.0000	0.0000	0.0000	0.0000
ALX	-0.0091	0.0074	0.0059	0.0070	0.0000	0.0000	0.0000	0.0000
OUT	-0.003	0.0137	0.0044	0.0074	0.0000	0.0000	0.0000	0.0000
IRM	-0.0062	0.0074	0.0015	0.0021	0.0000	0.0000	0.0001	0.0000
GNL	-0.0038	0.0097	0.0068	0.0059	0.0000	0.0000	0.0000	0.0000
HTA	-0.0023	0.0066	0.0001	0.0008	0.0000	0.0000	0.7541	0.0183
EQIX	-0.0038	0.0112	0.0024	-0.0033	0.0000	0.0000	0.0001	0.0000

Table 2. Coefficients of the Fama-French model and their p-values regressed on annualized returns.

Ticker	Mkt-RF	SMB	HML
JBGS	0.5991	0.08015	0.32075
UE	0.31575	0.21262	0.47163
EQC	0.52718	0.07879	0.39403
PDM	0.60296	0.12153	0.27551
DOC	0.88888	0.04039	0.07073
ALEX	0.52993	0.15989	0.31018
SUI	0.61577	0.11468	0.26955
VNO	0.61342	0.04759	0.33899
WPC	0.56773	0.17578	0.25649
DEI	0.70654	0.08932	0.20414
MPW	0.83776	0.0485	0.11374
HR	0.47384	0.15815	0.36801
WSR	0.46868	0.13591	0.3954
CHCT	0.44675	0.29376	0.25949
AHT	0.51913	0.2029	0.27797
OHI	0.50276	0.21187	0.28537
O	0.51527	0.10703	0.37769
SBRA	0.60215	0.13608	0.26177
BFS	0.5241	0.16958	0.30632
WHLR	0.20401	0.66784	0.12815
HT	0.42009	0.27618	0.30373
APLE	0.34654	0.26025	0.39321
AKR	0.61727	0.12251	0.26022
FR	0.48752	0.15691	0.35558
SOHO	0.21569	0.30389	0.48042
GLPI	0.46654	0.25956	0.2739
IRT	0.41327	0.28549	0.30123
SRC	0.43708	0.16094	0.40198
EGP	0.49426	0.16079	0.34495
RHP	0.53696	0.23234	0.23071
CBL	0.38416	0.1666	0.44924
AMH	0.66863	0.13962	0.19176
CPT	0.46345	0.13054	0.40601
MAC	0.47354	0.13394	0.39252
OPI	0.23973	0.46338	0.29689
KIM	0.46034	0.13215	0.4075
SPG	0.59867	0.05674	0.34459
CCI	0.67929	0.14278	0.17794
MDRR	0.10625	0.70263	0.19112
GOOD	0.58213	0.21868	0.19919
LAND	0.53255	0.22476	0.24268
IIPR	0.59641	0.20022	0.20337
NHI	0.52628	0.17612	0.2976
RYN	0.62894	0.13284	0.23822
ALX	0.44213	0.19735	0.36052
OUT	0.41074	0.23447	0.35479
IRM	0.65128	0.16298	0.18574
GNL	0.63153	0.13363	0.23484
HTA	0.65144	0.15671	0.19185
EQIX	0.66221	0.17709	0.1607

Table 3. Feature importance of the LightGBM model.

5 Conclusion

In this thesis, we have examined REITs through several different lenses and the contribution is three-fold: firstly, to verify the earlier studies on how REITs risk and return characteristics compare to that of other asset types; secondly, to apply Fama French and machine learning to explore pricing of REITS through factor analysis; and finally, to examine the impact of adding REITs to mixed equities portfolios over a relatively long and using up-to-date sample for the period of 2012–2022.

In the correlation analysis, we considered macro economical standpoint and examined REITs through correlations with other financial instruments and interest rates. We found that REITs complement other investment products and has a potential to play an important role in a multi-asset portfolio to reduce risk.

We have also successfully applied machine learning to the Fama–French three factor model in an attempt to examine practical implications and effectiveness of Fama French model vis-a-vis a newer and sophisticated lightGBM model. Results shows that adjusted R square of Fama French model is higher than adjusted R square of machine learning model after running regression on the historical REIT data. It means that Fama French model is better predicting variation in return than lightGBM for the REIT companies included in the Dow Jones Equity All REIT over the period of the ten years.

The portfolio simulation mixing the DJ ALL REITS index with the S&P 500 index to examine the impact of adding REITs to a mixed equities portfolios over a relatively long period of 10 years from 2012–2022. The results indicate that, in contrast to what some previous studies suggested, adding REITs exposure leads to a limited portfolio enhancement in terms of lump-sum return. However, the lower volatility motivates recommending a portfolio with even a small REITs index component for a more conservative investors.

We hope that these findings contributes towards a fuller understanding of the significance, risk-adjusted performance and added-value benefits of REITs and explored the strategic implications for utilizing REITs as an effective investment vehicle particularly for investors looking for passive investment opportunity with improved diversification and liquidity characteristics.

We finally encourage academics and practitioners to pursue further studies on REITs as more information on its performance becomes available, as it provides the unique advantage of real estate upside without the added risk of investing in physical properties outright.

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