Optimizing fixed income portfolio performance through enhanced index tracking: a goal programming approach

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DECLARATION

This thesis is entirely original with no submissions for credit towards a degree from any other university.

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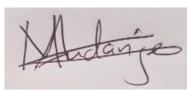
This thesis has been submitted for examination with my approval as University Supervisor.

Supervisor's Signature: _______________ Date: __19/08/2024__

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ABSTRACT

This study aims to optimize fixed income portfolio performance through enhanced index tracking using a goal programming approach. The research focuses on the fixed income market in developing countries, specifically in the Kenyan capital markets. The study's findings will provide insights relevant to investors and stakeholders operating in the Kenyan fixed income market and contribute to the literature on fixed income portfolio management.

The study employs a quantitative research design, collecting and analyzing numerical data to identify patterns, relationships and optimize portfolio performance. The research design is explanatory in nature, seeking to explain the effectiveness of an enhanced index tracking portfolio management approach in the context of the Kenyan Fixed income market. The study's population encompasses all government-issued bonds in the Kenyan secondary market which ensures a sufficient representation of treasury fixed income instruments available in the secondary market at the Nairobi securities exchange.

The study's parameters include maximizing returns, controlling risk and minimizing tracking error. By using goal programming model, we effectively handle multiple objectives to improve the portfolio allocation process. The performance of the enhanced index tracking portfolio is then compared against S&P Kenya Sovereign bonds benchmark, highlighting its potential for superior returns balanced risk management and acceptable tracking error levels.

The findings show that enhanced index tracking is a promising strategy for managing fixed income portfolios in developing markets. This study underscores the benefits of multi objective optimization strategies, offering a practical and insightful guide for investors navigating the complexities of the Kenyan fixed income market.

TABLE OF CONTENTS

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATION

NSE – Nairobi Securities Exchange

S&P – Standard & Poor's

FTSE – Financial Times Stock Exchange

AUM – Assets Under Management

CMA – Capital Markets Authority – Kenya

MPT – Modern Portfolio Theory

CAPM – Capital Asset Pricing model

MCVaR – Mixed Conditional Value at risk

EI – Enhanced Indexing

GP–GoalProgramming

STARR - Stable Tail adjusted return Ratio

CHAPTER ONE

INTRODUCTION

1.1 Background of study

Portfolio management is broadly classified into Passive and Active portfolio management, passive portfolio management is where the portfolio manager holds assets in a market index, a concept pioneered by the Vanguard Group with the launch of the first index mutual fund, the Vanguard 500 index fund in 1975 (Hebner, 2007). Active portfolio management on the other end involves buying assets regularly to beat the market.

Indexing refers to passive management strategy of portfolio management that seeks to replicate the performance of a particular market index. The case for indexing is based on the Efficient market's theory which was coined by (Fama, 1995). According to EMH prices reflect all available information and its near impossible to beat the market through analysis or prediction. In Burton Malkiel work on "why the case for indexing remains strong" he argues that indexing strategy is particularly appropriate in emerging foreign markets, where relative inefficiency makes passive management more suitable. He goes ahead to state that while technical and fundamental analysis may still be useful for some investors, trying to switch between securities to achieve better performance is pointless at best because taxes and transaction costs have a negative impact on performance. Hence overall concluding the case for indexing is a compelling one for investors seeking a simple and effective way to invest in the stock market. (Maikiel, 2014).

An index is a reference portfolio which is used for assessing the relative performance of a portfolio. The selection of an index for a portfolio is key, as it serves as a yardstick against which the portfolio is measured for performance and for portfolio construction, the basket of securities in the index are utilized for constructing the portfolio, rebalancing the portfolio and track the portfolio performance. Marty, W. (2020) categorizes Fixed income benchmarks into two

1. Industry-standard benchmarks, widely recognized and utilized as index portfolios.
2. Tailor-Made benchmarks designed for specific investment strategies, referred to as customized benchmarks.

According to McKee, J. C. (2014) Enhanced indexing is a substitute for traditional active strategies that purport to increase the value of the index while minimizing the risk of deviation from it. For a small fee, the strategy offers index-like returns with attractive upside potential. This makes it ideal for investors who are dissatisfied with fully active managers but are not ready to forgo the passive option entirely, or for institutional investors who are looking for more action in their passively managed portfolios with less downside risk compared to the index.

According to Ahmed and Nanda (2005) Enhanced indexing can be summarized as an alternative investing strategy that combines both active and passive investing. Enhanced index funds strive to surpass a benchmark index by using quantitative models to align with the index based on specific characteristics. Some enhanced index funds may enhance the returns with fundamental analysis.

1.2 Problem Statement

The Fixed income asset class, characterized by its low volatility and inefficiencies of the market, presents an opportunity for investors to construct portfolios that balance risk and return efficiently through indexing given the bulk of the performance of individual bonds are explained by systematic factors rather than security specific risk. While indexing offers systematic approach to portfolio management, its effectiveness is contingent on the optimization of portfolio allocation process which is crucial to achieving investment objectives and managing risk.

In exploring indexing as a strategic approach, institutional investors in developing markets particularly in Kenya predominantly opt for two main vehicles: Index Mutual funds and Exchange traded funds. The substantial growth in assets held by mutual funds, as highlighted in the CMA Quarterly bulletin of Q1-2023, underscores their significant market penetration. Notably, government securities constitute 47.21% (KES 73.44 billion) of the Total AUM out of the KES 161 billion of the Value of assets held by mutual funds, Showing the dominance of this asset class.

Despite the wealth of research on the Kenyan Equities market, exemplified by studies conducted by Koyengo (2007),Osoro and Jagongo (2013) and Kibet (2006) the fixed income market has been relatively neglected, despite being a primary driver of the secondary market in the Kenyan capital markets, this oversight is apparent in the CMA Quarterly bulletin of Q1-2023, where the bonds market boasted a turnover of KES 162.51billion with treasury bonds accounting for KES 162.51 billion and corporate bonds KES0.01 billion. In stark contrast, the equity turnover in the secondary market stood at KES44.82 billion during the same period.

While studies such as Mwenda (2014) have emphasized the positive impact of investment in fixed income securities, there remains a gap in literature regarding optimizing fixed income portfolios to achieve the superior returns given its positive impact in fund performance in the Kenyan context, previous research, such as the study conducted by Gitonga, Kariuki & Kariuki (2021) have shown that robo advisors algorithms are generally based on passive investing and diversification strategies, Akama & Jagongo (2013) also found that index funds in Kenya will promote development and bring in foreign capital in the Kenyan Investment market. The importance of indexing as a strategy in portfolio management is amplified in this notable studies.

Despite being the key driver of the secondary market in the Kenyan capital market, the fixed income market has not received commensurate attention. A comprehensive review of fixed income indexing is essential to address this research gap and gain insights into the challenges and opportunities specific to this market.

1.3 Research Objectives

Thus, this research aims to assess fixed income portfolio performance constructed through an enhanced index approach incorporating the aspect of multiple objectives using goal programming for the optimization process.

1.3.1 Specific objectives

- Defining Optimization Parameters for Enhanced Index tracking.
    - Identifying and defining key parameters crucial for optimizing fixed income portfolio performance through enhanced index tracking focusing on return maximization, controlling risk and tracking error minimization.

- Implementing a Goal Programming Optimization for the portfolio allocation.
    - Utilize goal programming to handle multiple goals in the enhanced index tracking framework.

- Evaluating Portfolio performance based on optimization criteria
    - Asses the performance of the enhanced index tracking portfolio against designated benchmarks, emphasizing the achievement of superior returns, balanced risk return profile and acceptable tracking error levels as per the optimization criteria.

1.4 Research Question.

i) How can an enhanced indexing framework be developed to optimize fixed income portfolio performance?

ii) How can goal programming technique be employed to optimize fixed income portfolio allocation for enhanced index tracking considering multiple objectives?

iii) How does the performance of the enhanced index tracking portfolio compare to the market benchmarks?

1.5 Significance of the Study

1.5.1 To Researches and Academicians

This study will contribute to the academic community by addressing the gap in the existing literature on fixed income portfolio management, it offers insights into enhanced index tracking within the Fixed income asset class and particularly the Kenyan fixed income market it also fosters a deeper understanding of the multi objective optimization strategy as can be applied in fixed income portfolio construction.

1.5.2 To Investors

Investors both institutional and individual are poised to benefit from this study, by delving into the intricacies of fixed income indexing strategies, the research expands investors' horizons beyond traditional active and passive investment strategies. It enables them to make well-informed decisions regarding portfolio construction, herby enhancing their ability to navigate the Kenyan fixed income market. The study's focus on Multi objective optimization adds a nuanced perspective to fixed income portfolio construction.

1.6 Scope of the Study

The study focuses on the fixed income market in developing countries particularly in the Kenyan capital markets. The geographical scope encompasses the dynamics specific to the Kenyan context, providing insights relevant to investors and stakeholders operating in this market.

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Review

This chapter embarks on a theoretical review that provides the underpinning concepts for enhanced indexing. It explores the various theoretical constructs of portfolio management strategies providing a foundation for the current research and providing foundation on later analysis.

2.1.1 Passive Portfolio Management

The historical development of passive management is linked to the pioneering work of the vanguard Group credited to having formed the first index mutual fund in 1975-the Vanguard 500 index fund, that was created to mirror the S&P 500 index. This marked a paradigm shift in the portfolio management from the well-known active management offering investors a low cost and broadly diversified investment option that mimics the performance of the market index. (Malkiel, 2003)

The foundation of passive portfolio management rests on the efficient market theory by Fama (1970). According to EMH, securities markets are incredibly efficient at absorbing information about the securities market in general. Thus, if markets are efficient, they cannot be beaten through technical or fundamental analysis making indexing the only option to invest in an efficient market.

Indexing is a fundamental strategy withing the passive portfolio management. It involves constructing a portfolio to mirror the composition of a specific index. By adopting indexing strategy, investors aim to attain market returns while minimizing costs and transactional complexities associated with frequent buying and selling securities.

In summary, passive portfolio management, driven by the principles of indexing, has become a prominent investment strategy. The historical evolution of passive management, coupled with the foundation of the EMH, this has shaped the landscape of portfolio management, providing investors with a disciplined and cost effective and a straightforward method of investing in the Capital markets (Al-Aradi & Jaimungal ,2021).As an alternative to active investing, several studies suggest that Indexing can yield comparable or superior returns while decreasing both expense costs and complexity linked with security selection (García et al., 2013).However, its crucial to acknowledge that some studies have indicated potential systematic biases and underperformance in indexed portfolios compared to active investing strategies which is well constructed (Shukla, 2004).

2.1.2 Active Portfolio Management

To achieve higher returns, active portfolio managers aim to invest in the financial markets by deviating from the benchmark in order to achieve superior returns (Alexander & Baptista, 2008). According to AZOUAGH & DAOUI (2023), active portfolio management is a strategy in which investment decisions are derived from forecasts and analyses of financial markets and specific assets. By buying and selling assets according to their market forecasts, they optimize returns for their clients. This makes the strategy costly given the transaction, trading, information and acquisition costs associated with it.

2.1.2.1 Strategies in Active Portfolio Management

In order to outperform the market active portfolio managers employs different strategies. According to Gregory-Allen et al. (2009), these strategies can fall into this broad classification: Fundamental, technical and Quantitative analysis.

- Fundamental Analysis: The strategy entails examining individual securities to identify those that are undervalued or have significant growth potential. The common factors considered in fundamental analysis includes company's management team, competitive position in the industry, economic prospects for the industry and the company's financial statements (Gregory-Allen et al., 2009). Dechow et al (2001) explains that Fundamental analysis lays the ground work for active managers to make informed investment decisions based on the intrinsic value of the company.

- Technical Analysis: It is an approach used by active managers to forecast market movements based on historical price and trade volume trends (Schwager, 1995). Chart patterns, moving arithmetic's and other technical indicators are employed to identify market turning points and trends.

- Quantitative Management: it relies on mathematical models and statistical techniques to make investment decisions (AZOUAGH & DAOUI, 2023). Quantitative strategies seek to capitalize on market inefficiencies and anomalies that may not be apparent through traditional fundamental analysis. Quantitative management strategy entails analyzing big data sets, identifying patterns and carrying out trades using computer algorithms also mathematical and statistical models are used (Gregory-Allen et al,2009).

2.1.2.2 Challenges and criticisms of Active Management

While active management strategies offer potential benefits, challenges and criticisms persist:

- Market Efficiency Debate: The debate on market efficiency continues, with opponents of active management arguing that markets are not perfectly efficient, providing opportunities for skilled managers to outperform (Fama,1970). However efficient market proponents contend that any information relevant to prices is quickly reflected making consistent outperformance challenging.
- Performance Consistency: Studies have shown that while some active managers may beat their benchmarks in some periods, maintaining consistent outperformance over the long term is challenging (Cuthbertson & Nitzsche, 2010). Changing market conditions and the managers fees contribute to the difficulty of sustaining performance.
- Costs and Fees: Active managers incur higher costs emanating from expenses such as research expenses and transaction costs (Elton et al,2014). Additionally. Active funds often charge higher management fees compared to passive managers, impacting net returns for investors.
- Behaviors Biases: Behavioral biases, such as overconfidence and herding behavior, can influence active managers decisions, potentially leading to suboptimal investment choices (Barber &Odean,2001)

2.1.3 Fixed Income Portfolio Management

Fixed income portfolio management involves managing and building a portfolio of fixed income securities, taking into account various risk and return factors, fixed income risk factors mostly considered are interest rate risk, credit risk, liquidity risk, return and market conditions.

Similarly, to equites portfolio management a broader classification of fixed income traditional management strategies are passive and active portfolio strategies (Fabozzi,2007).

2.1.3.1 Fixed income Passive investment strategies

In the fixed income world particular strategies in the passive portfolio management are Bond portfolio indexation and bond portfolio immunization.

Volpert (2021) argues that indexing plays a crucial role in bond management offering a broad diversification and low costs this stands in contrast to many active portfolios which often carry heavier specific issuer concentrations, exposing investors to issuer event risk. The low-cost advantage of bond indexing results from diminished transaction fees and reduced portfolio turnover rates along with lesser management expenses. This advantage he proceeds to say is not only durable and predictable but contributes to competitive performance.

2.1.3.1.1 Fixed Income portfolio indexation

Bond indexing entails structuring a portfolio to align its performance with that of a specific fixed income index, typically in terms of total rate of return achieved over a specified investment period (Fabozzi,2013).

2.1.3.1.2 Fixed Income portfolio immunization

The goal of Portfolio immunization is to construct a bond portfolio such that at the conclusion of the investment period, regardless of interest rate fluctuations the required return is achieved. This strategy is geared towards creating a portfolio in which the risks associated with interest rate fluctuations and desired returns are effectively balanced (Fabozzi,2007).

2.1.3.1.3 Advantages and disadvantages of bond indexing

Fabozzi (2007) summarizes the advantages and disadvantages of Fixed income indexing as below**:**

Advantages	**Disadvantages**
There is no reliance on expectations and little chance of underperforming the index.	Bond indices do not reflect ideal performance.
Reduced advisory and non-advisory expenses	Bond index may not match the Investors liabilities
Greater Investors control	Restrictions on fund management ignores opportunities.

Table 2.1: Advantages and Disadvantages of bond Indexing
Source Fabozzi 2007

2.1.3.1.4 Fixed Income Indexing Methodologies

Cell matching and the optimization approach represent two common methodologies employed in portfolio construction aimed at replicating an index. These strategies extensively discussed the works of Fabozzi (2007,2013) and Lochoff (2014), Prioritize the minimization of tracking error utilizing a multi-factor risk model. In the realm of fixed income securities, the performance of an idiosyncratic elements unique to the particular issuance.

Lochoff (2014) notes that full replication is not possible in bond indexing in contrast to equity indexation, where buying all equity securities in an index is feasible. The is impractical for bond indices primarily due to the unavailability of certain bonds in the market as some issues are held entirely by some investors who are unwilling to sell them especially at the index listed price. However, he further notes that illiquidity in the market can arise because of various other reasons.

2.1.3.1.4.1 Stratified Sampling

The segmentation of an index into cells predefined using distinct risk factors this serves as a fundamental principle in portfolio construction methodologies. each cell represents a unique attribute of the index, commonly classified my characteristics such as duration, coupon, maturity, sector and credit rating. The objective is to carefully select one or more securities from each cell, thereby encompassing the entirety of the index's composition. Thus, stratified sampling methods involves a multidimensional matrix that mirrors the subindex structure. Each matrix corresponds to a specific dimension and together they orchestrate a duplication of the comprehensive index composition as discussed by Fabozzi (2007,2013 and (Lochoff,2014)

2.1.3.1.4.2 Optimization Approach

The optimization approach in indexing seeks to formulate a portfolio that optimizes specific objectives, typically centered around maximizing portfolio yield, convexity or expected total return. The process entails the utilization of mathematical programming techniques to derive the optimal solution for the indexing problem. Within this framework, the minimization of tracking error is a common risk factor model. Forward-looking error reduction is prioritized (Fabozzi, 2007,2013, Lochoff,2014).

2.1.3.2 Fixed income Active investment strategies

Active portfolio strategies aim to generate surplus return after accounting for associated risks. These strategies can be broadly categorized into two main approaches (Fabozzi,2007).

2.1.3.2.1 Interest rate expectations and yield curve strategies

Interest rate expectation strategies rely on the investment managers' ability to be able to forecast the uncertainty of the market dynamics. These strategies involve adjusting portfolio duration to take advantage of predicted interest rate fluctuations.

2.1.3.2.2 Individual security selection and inter and intra sector allocations strategies

Identifying securities in the fixed income market that are overpriced is the hinge of the individual security selection strategy. Securities are acquired if the manager perceives their market value to be lower than their intrinsic value.

2.1.4. Enhanced Indexing

Enhanced indexing strategies can be traced back to 1960 when EMH was proposed by Eugene F. Fama. The EMH theory states that it is impossible to consistently surpass market average returns because asset prices fully reflect all available information.

Enhanced indexing integrates aspects of both passive and active investing strategies hence bridging the gap of the two dived, as it strives to beat the market index while maintaining a risk profile akin to that of the underlying index. (Ahmed & Nanda, 2005) define Enhanced Index as a strategy that tries to surpass the index returns while minimizing the tracking error relative to a chosen market index. This approach finds its foundation in the MPT and CAPM, which emphasizes the significance of diversification and risk adjusted returns.

2.1.4.1 Enhanced Indexing strategies

According to Ahmed & Nanda, (2005) enhanced indexing strategies can be classified into four distinct categories:

1. Security Selection – Enhanced index funds employing traditional fundamental and technical analysis or quantitative models to select securities fall under this category. The objective is to capture specific factors such as value, quality or momentum to augment portfolio returns. This strategy may involve overweighting bonds exhibiting attractive valuations or possessing strong credit profiles.

2. Yield Curve enhancement – This category directs a portion of the portfolio towards higher yielding fixed income securities. By adjusting the portfolios duration in response to the shape of the yield curve, investors can capitalize on changes in interest rates to increase returns and manage interest rate risk. Additional alpha may be generated by assuming additional duration or credit risk.

3. Equity Market Neutral – Applied to the Equities market this approach obtains index exposure through the purchase of index futures, while alpha is derived from a market neutral long short portfolio managed using quantitative tool.

4. Derivatives based and leveraged strategies – This category encompasses a derivatives approach that combines future based indexing strategies with an overlay of an options

portfolio. Derivatives are utilized to achieve lower beta. Yates (2008) broadness this definition to encompass other derivatives applicable within an enhanced indexing framework.

2.1.4.2 Enhanced Indexing yardstick

As a portfolio management strategy, a portfolio constructed via Enhanced indexing framework performance has to be evaluated, McKee (2014) outlines several criteria for assessing the performance of Enhanced indexed portfolios.

a. Tracking Error – Minimizing the tracking error is the main goal of an enhanced indexing framework. TE quantifies the extent of risk unaccounted for by the market. It can be used to track how consistently managers remove unexplained risks from the portfolio over time. A lower tracking error indicates a good performance in an enhanced indexing framework.

b. Excess Return – McKee (2014) defines the excess return in this particular case as a relative return measure which is calculated by dividing the portfolios factored return by the index factored return. Unlike the nominal excess return McKee indicates that the measure clearly captures the tree excess performance overtime.

c. Information ratio – Another important metric for assessing the performance of enhanced index portfolios is the information ratio. Calculated as the ratio of excess return to tracking error, the information ratio provides insight into how effectively managers generate excess returns while mitigating index related risk. A higher information ratio indicates that managers are able to deliver higher returns relative to the benchmark with relatively low levels of index risk. This metric is useful in determining the efficacy of enhanced index managers.

d. Detailed performance attribution – Fabozzi (2021) explains that performance attribution analysis is a critical tool for accurately measuring the success of risk factor management and enhancement strategies. The analysis should attribute tracking error to term structure factors, sector, quality and issue selection across sectors and qualities. This should be done at a portfolio level. By conducting attribution managers can identify the sources of value added or lost and adjust their strategies.

2.1.4.3 Enhanced Indexing for fixed income

Similarly, to most traditional assets, bond portfolio management begins with the investors' appetite to risk, circling back to the traditional portfolio management pure bond indexing will offer the lowest risk.

Volpert, (2021) outlines that pure bond index matching is difficult to accomplish and costly to implement given the illiquidity of the bonds in the index and the period of issue which affects the interest rates as they keep changing. This is where Enhanced indexing comes into play giving both worlds. He further proceeds to provide a classification of the strategies of portfolio management for bonds.

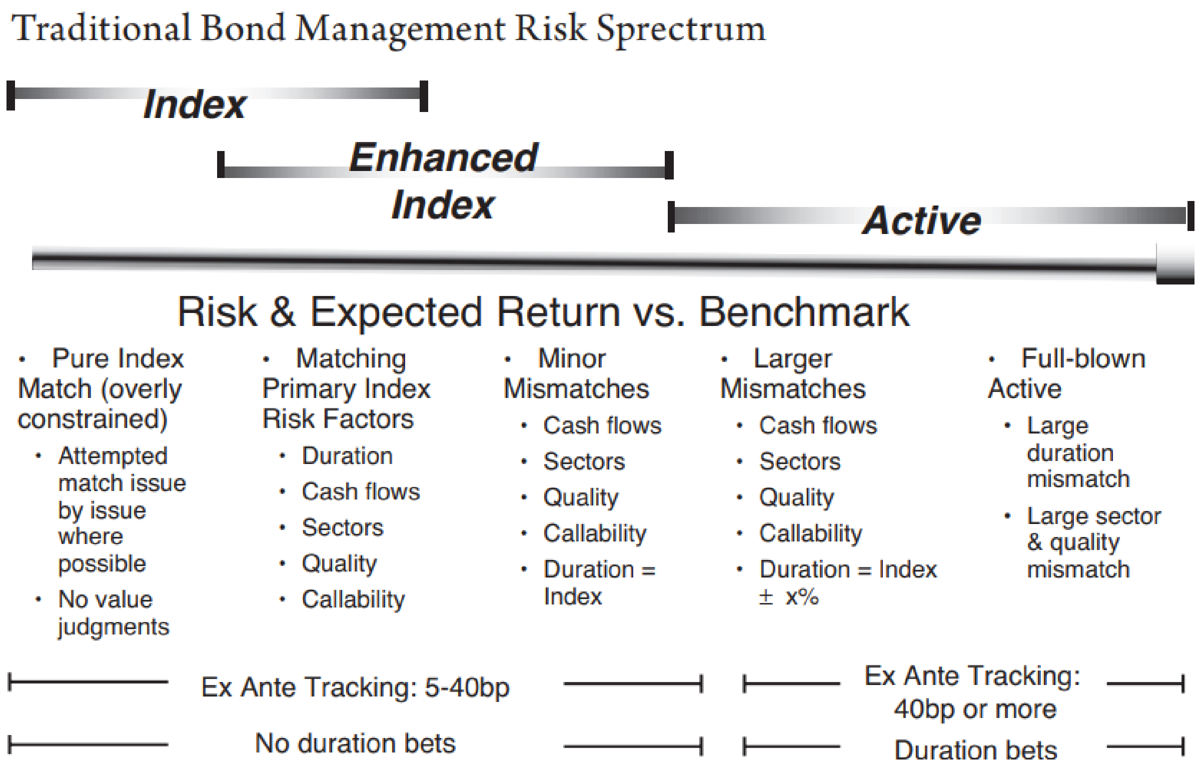

Figure 2.1: Traditional Bond Management Risk Spectrum
Source (Fabozzi & Mann, The Hand Book of Fixed Income Securities, Ninth Edition,2021, P.1076

2.1.4.3.1 Enhanced Indexing Matching Primary Risk Factors

This entails investing in a diverse range of bonds to align the portfolios risk factors with those of the index. It results in a higher average monthly tracking differences compared to full replication but at a significantly lower cost. The approach maintains proximity to the index in terms of net investment performance. The key risk factors to match includes duration, cash-flow distribution, sector, quality and call exposure making this strategy a form of enhanced indexing that enhances returns relative to full replication (Volpert, 2021, Fabozzi 2007).

2.1.4.3.2 Enhanced Indexing Minor Risk Factor Mismatches

This approach permits slight deviations in risk factors, excluding duration to adjust the portfolio in favor of specific areas of relative value, like sectors, credit ratings, term structure, call risk. Despite the minimal impact on tracking due to these minor mismatches, the approach falls under the category of enhanced indexing. These additional refinements can be likened to strategies that optimizes the portfolio for improved performance. (Volpert, 2021, Fabozzi,2007)

2.1.5 Fixed Income Indices

Fixed income indices have done more for investor welfare as an investment innovation besides modern portfolio theory in the century, making investment management to go hand in hand with indices.

Within the realm of asset allocation, effective portfolio management and optimization require the consideration of returns and risks associated with each risky asset. Bond market indices based on returns provide a yard stick to measure performance of the fixed income market in terms of both return and risk (Tang & Xu, 2017). Hence the understanding of the development, characteristics and performance of Fixed income indices is pivotal to portfolio management and optimization (Brown,2002).

Fixed income indices have been subject of numerous empirical studies. Brown (2002) provides a comprehensive overview of the construction and calculation of bond indices. Arnott, Hsu,& Moore (2005) introduce the concept of fundamental indexing, which weights securities based on economic fundamentals rather than market capitalization. Empirical studies have shown that fundamental indexing can outperform traditional market cap weighted indexing in the fixed income market.

2.1.5.1 Development and characteristics of major Kenyan Fixed income indices

Currently S&P and FTSE are the major company's providing and maintaining fixed income indices for the Kenyan secondary market.

2.1.5.1.1 Standard & poor Kenya Sovereign Bond Index

The S&P Kenya sovereign bond index, according to the S&P indices fact sheet as at December 29,2023, is designed to track the performance of local currency denominated debt that is publicly issued by the government of Kenya within its domestic market.

WEIGHTING METHOD	Market value weighted
REBALANCING FREQUENCY	Monthly
CALCULATION FREQUENCY	End of day
CALCULATION CURRENCIES	KES
LAUNCH DATE	November 25, 2014
FIRST VALUE DATE	May 30, 2008

Figure 2.2: S&P Kenya Bond Index Methodology
Source: S&P Kenya sovereign bond index fact sheet December 2023

Index Characteristics

MARKET VALUE OUTSTANDING [KES MILLION]	3,765,939.49
NUMBER OF CONSTITUENTS	71
TOTAL PAR VALUE [KES MILLION]	4,204,508.86
PAR WEIGHTED COUPON	12.88%
WEIGHTED AVERAGE MATURITY	8.57 Yrs
PAR WEIGHTED PRICE	85.5
YIELD TO MATURITY	16.98%
YIELD TO WORST	16.98%
MODIFIED DURATION	3.56
10-YEAR HISTORICAL INDEX LEVEL HIGH [JUNE 13, 2023]	553.25
10-YEAR HISTORICAL INDEX LEVEL LOW [DECEMBER 31, 2013]	184.27

Figure 2.3: S&P Kenya bond index Characteristics.
Source: S&P Kenya sovereign bond index fact sheet December 2023

2.1.5.2 Choosing a benchmark

Bednar, J. M. (2014) navigates the intricate process of selecting an appropriate benchmark for indexing. Benchmark chosen defines the market segment to which the exposure is desired. By selecting a benchmark that reflects the required market exposure, investors can effectively diversify their portfolios. He outlines four key considerations when selecting a benchmark for passive investment strategy that goes beyond index longevity and popularity:

1. Constituent selection and representativeness of the index
2. Turnover and selection criteria of the constituents
3. Liquidity of constituent securities
4. Index Methodologies.

Mariathasan, J. (2004) indicate that when tracking a bond index for market capitalization weighted index, such indices may not accurately reflect the markets pricing of an issuer's debt since the amount of an issuer's debt included in a bond index may not be highly sensitive to market price fluctuations. As a result, financially weaker entities may become disproportionately weighted in the index as debt issuance increases even while their attractiveness declines. This observation highlights a significant difference in how market performance influences the weightings of companies in equity and bond indices.

it should be carefully taken given the amount of an issuer's debt represented in a bond index does not depend very much on the market valuation of its debt. The result is that by issuing more debt, the weaker, financially distressed company is given greater weight, and an index gives the company that greater weight, even as its attractiveness decreases. This highlights a key difference in the influence of market performance on the weighting of companies in equity and bond indices.

Fabozzi, (2013) also outlines two main factors that should be considered when selecting an index for a manager pursuing indexing strategy. First is investors tolerance to risk giving an example that selecting an index that include corporates bonds will expose the investor into more credit risk hance if this amount of risk is not acceptable the investor can use treasuries only bond index. The second one is the investors' objective if it's minimizing the variability of total returns or portfolio duration and so on.

Dynkin (2020) discusses the significance of benchmarks in investment management, particularly in the context of fixed income portfolios. They propose the concept of designing custom benchmarks with zero idiosyncratic risk such as treasury benchmarks for passive investing. Such benchmarks are crafted to minimize security specific risk and provide no long-term spread advantage reducing the need for investment managers to demonstrate ability in issuer selection. Dynkin concludes that the selection of benchmarks for passive investing is dependent on investor objectives and the need for precise measurement of investment manager performance

Fixed income index construction is a pivotal aspect of portfolio management especially for indexation strategies. Proper index construction ensures the accurate representation of the market while incorporating various factors such as yield, maturity and credit rating.

2.1.6 Goal Programming in portfolio selection

Goal programming is a multi-objective programming method that was pioneered by Charnes in 1955.Its main objective is to address decision making problems that involve several conflicting objectives in the field of management science (Azmi & Tamiz, 2010).

The mean variance portfolio optimization introduced by Markowitz can be considered as a goal programming problem entailing two objectives of return and risk optimization. Additional objectives representing other variables can be introduced to make the portfolio selection more realistic in the real-world scenario.

In decision making context where minimizing the difference between goal attainment and desired levels is crucial, Goal programming emerges as a pivotal approach. Several studies have emphasized the sustained importance of Goal programming as the primary multi objective technique in management science. This recognition stems from its adaptability in managing decision making challenges that are characterized by multiple conflicting goals and incomplete or imprecise information (Romero,1991,2004, Chang,2007).

Optimization involves identifying the most advantageous compromise among conflicting interests, considering the limitations inherent in any decision-making scenario. In portfolio optimization these conflicting interests encompass various factors, notably risk mitigation and return augmentation (Kritzman,2003).

Callin (2011) outlines the elements key for solving portfolio Selection optimization problem:

- Finite Possible Future scenarios
- Correspondence function- The function is an essential component that links the possible future scenarios with individual securities, this elucidates how each security might perform under different scenarios providing insights into potential outcomes.
- Probability function – This assesses the likelihood of each possible future scenario occurring, providing quantifiable measure of the potential outcomes and their associated probabilities allowing for a more accurate assessment.
- Performance measurement to determine which portfolio is preferable to the other.

2.1.6.1 Various forms of goal programming for portfolio selection

Azmi (2014) discusses three main variants of Goal programming for portfolio selection: Weighted, Lexicographical and the Minmax Goal programming. According to (Romero,2004) the achievement function is the fundamental component of Goal programming which gauges the extent of minimizing undesired deviational variables related to the goal. The different achievement functions bring about the various variants.

2.1.6.1.1 Weighted variant of Goal programming

The method of weighted GP assigns weights to individual objectives, which are determined by their perceived importance to the decision maker. The main primary aim is to maximize the total weighted deviations from the set goals. In the context of portfolio selection, this objective function is tailored to simultaneously minimize risk and maximize return. This is achieved by penalizing instances of excess risk and underperformance relative to the specified goals.

2.1.6.1.2 Lexicographical Variant of Goal Programming

The goal of this approach is to minimize deviations from each goal according to the relative importance. Unlike other variants, there are no fixed trade-offs among goals of different importance. Instead, numerical weights are assigned to prioritize goals within the same priority level, reflecting their relative importance.

A LGP model for portfolio selection may prioritize objectives such as maximizing the portfolios expected return simultaneously minimizing specific measures of portfolio risk. Subsequently, other risk factors may be targeted for minimization, followed by the optimization of the portfolios cost of rebalancing.

2.1.6.1.3 Minmax Variant Goal Programming

The Minmax variant aims to minimize the maximum deviation from the individual goals, resulting in a solution that reflects a balanced allocation across the attainment of diverse objectives. Applied within the context of portfolio selection, Minmax GP in the context of portfolio selection may seek to minimize the maximum deviation from any one objective within the portfolio. These objectives might include reducing risk or increasing return.

The aim of Minmax is to minimize the maximum deviation from any one goal. The corresponding solution shows how the achievement of the various goals is distributed fairly. As part of portfolio selection, Minmax GP can aim to minimize the maximum deviation from a portfolio objective, such as maximizing returns or minimizing risk

2.1.6.1.4 Other Variants.

The weighted, lexicographical and Minmax are the mainstream variants as identified by (Azmi, R.,2014) he further proceeds to state that like any other field there are recent developments on how the decision makers preference can be represented in a more flexible manner, a notable one is fuzzy Goal programming.

Fuzzy GP address uncertainties and vagueness in decision making processes. It is designed to handle situations where aspirations levels for objectives are not precisely known and goals are given as fuzzy numbers due to the expertise or subjective judgement of decision makers.

In portfolio selection Fuzzy GP allows the decision maker to incorporate non quantifiable constraints and objectives that are challenging to express in mathematical terms by considering implicit and mathematically weak requirements, Fuzzy GP provides a framework for addressing problems that are not easily formulated as mathematical models.

2.2 Empirical literature

2.2.1 Fixed Income Indexing

Bond indexing involves structuring a portfolio to replicate the performance of a fixed income index. Empirical observations indicate that historically, the overall performance of active long term fixed income managers has been poor. Secondly bond indexing provides a reduced advisory managements fees charged compared to active managers counterpart. Moreover, opting for an indexing strategy provides investors with greater control over external managers. This are some of the reasons for the popularity of fixed income indexing as presented by (Fabozzi, 2007).

According to Lochoff, R. (2014), the emergence of fixed income indexation was a natural response to the equity markets move towards indexation. As fund sponsors begun to adopt more sophisticated methods of valuing fixed income investments, the goal of bond investing evolved. Initially they focused on return, then the objectives switched to total return, then active return relative to a benchmark, and finally risk adjusted active return. This advancement resulted in a careful calibration of benchmark returns and associated risks and enabled a more accurate comparison between the performance of actively managed portfolios and their benchmarks.

Despite the inefficiencies in the bond market, Lochoff argues that fixed income indexing can bring fixed income market into a more modern era where brokerage firms have less control but individual investors can invest in bonds without worrying about illiquidity and effectively manage their capital market risk and spread them across multiple asset classes.

Another study done on Fixed income indexing is (Kornbluth, J. S. et.al,1993) which amplifies the similar advantages as the above authors, the authors state that fixed income indexing plays a pivotal role in providing investors with diversified exposure to the bond market while offering the potential for enhanced risk adjusted returns. It also allows investors to gain broad market exposure at a relatively low cost. The authors emphasize the importance of considering the specific characteristics of fixed income securities and the implications of the market dynamics when employing fixed income indexing strategies.

Volpert (2021) also answers the question on why choose indexing by arguing that indexing is compelling in bond management due to its proven effectiveness. Whether utilized for a portion or the entirety of a portfolio, indexing offers significant advantages. The key strengths include broad diversification and low costs which is crucial for achieving tight tracking of an index. This results in competitive and consistent performance aligned with the market or specific market segments. Additionally, indexing provides a psychological benefit by allowing investors to concentrate on asset allocation.

The major shortcomings of indexing as an investment strategy for fixed income is because of the inefficiencies in the fixed income indices. Fixed income indices lack diversification therefore introducing concentration risk this being a major inefficiency, The fixed income indices are also considered to be backward looking in composition unlike their equities counter parts fixed income composition often reflects historical issuance dynamics to a larger degree than differences in forward looking valuation finally Liquidity challenges, due to its liquidity challenge investing in a broad fixed income index can be challenging on the other hand fixed income indices are expected to represent returns for an average market investor but the sum of the outstanding instruments does not always add up to the sum total of investor position due to the liquidity challenge (Staal et.al ,2015).

2.2.2 Enhanced indexing for optimal portfolios

Jorion, P. (2002) conducted a study testing the tracking error optimization that predicted that active managers optimizing portfolios subject to a constraint in the tracking error will end up with higher total risk than the index.

The study explored the implications of this optimization process. Jorion P. (2002) hypothesized that active managers, while striving to minimize tracking error by maximizing the excess returns they totally ignore the investors overall portfolio risk

The study offers significant contribution to the understanding of enhanced indexing strategies, offering critical perspective on the relationship between tracking error optimization and total portfolio risk.

Additionally, Guastaroba, Mansini, Ogryczak, and Speranza in their 2020 paper, "Enhanced Index Tracking with CVaR-based Ratio Measures." Also did a study on enhancing index tracking strategies, incorporating the Conditional value at risk-based ratio measures. Their research aimed to refine and optimize portfolio management techniques, offering an alternative methodology to achieve enhanced index tracking.

The authors introduced “bi-criteria optimization models” which is a new class of models for the enhanced index tracking problem based on Conditional value at Risk measure. They compared their proposed models and provided numerical results to demonstrate the effectiveness of their approach.

The paper contributes to the existing literature by offering a novel perspective on enhanced index tracking. Particularly by incorporating CvaR-based ratio measures. The findings suggest that the proposed CvaR-based ratio measures offer promising results in the context of enhanced index tracking, potentially outperforming traditional risk measures. Overall, the paper provides a valuable contribution to the understanding of enhanced index tracking performance using risk measures.

Similar studies involving different forms of VaR of enhanced index portfolio is Goel (2018), Which employs the MCVaR in portfolio construction. This study assigned the optimized weights to the filtered assets using two iterations of the STARR which included the MCVaR or the STARR ratio with deviation. Empirical evaluation shows the effectiveness of the proposed Enhanced indexation model, outperforms existing models in terms of excess returns relative to the benchmark index. The linear programming framework of the proposed models adds to their tractability. The results contribute significantly to portfolio construction methodologies, providing practitioners and researchers with insights into the application of MCVaR for achieving superior performance in both tracking and outperforming benchmark indices.

2.2.3 Enhanced indexing based on Goal programming

Liang-Chuan et.al (2007) conducted a study aimed an investigating exploring the effectiveness of enhanced indexing through the utilization of goal programming with an emphasis on passive management of a limited number of equites securities; by integrating goal programming into the optimization process, this study contributes significantly to the field of enhanced index investing. This approach facilitates a comprehensive analysis that considers multiple objectives concurrently, enabling the management of the bargain between active risk (tracking error) and alpha (active return). The findings of the study indicated enhanced performance in terms of both the consistency of returns above the benchmark (excess return) and the information ratio compared to existing enhanced indexing products in the Taiwan financial market. This approach not only provides valuable insights into the potential benefits of enhanced indexing investing but also offers practical implications for portfolio management. Additionally, the inclusion of passive management of limited securities in the methodology further enriches the discourse, highlighting the potential advantages of a streamlined yet effective approach to enhanced index investing framework.

Liang-Chuan et.al (2007) study highlights that the use of goal programming in enhanced indexing, particularly through passive management yielded favorable results in optimizing portfolio performance.

In their study Siew, Jaaman, and Ismail (2014) applied goal programming approach to address decision making challenges associated with conflicting objectives in enhanced index tracking. The primary objective of their model was to achieve a harmonious balance between maximizing the mean return while simultaneously lowering risk or tracking error within the portfolio management context. Through the formulation of a GP model the researchers aimed to assess the optimal composition and performance of portfolios in the context of enhanced index tracking.

The study's conclusions indicated that the application of the goal programming approach resulted in the creation of an optimal portfolio that outperformed the Malaysia index, namely the FTSE Bursa Malaysia Kuala Lumpur composite index. This superior portfolio performance was attributed to the attainment of a higher mean return coupled with a reduction in risk, achieved without the need to acquire all equites securities included in the market index. Consequently, the research highlighted the effectiveness of the GP model in enhanced index tracking, ultimately leading to better portfolio performance compared to the market index

Through the utilization of a goal programming framework Siew, Jaaman, and Ismail (2014) addressed the complexities inherent in portfolio optimization within the context of enhanced index tracking. Their findings highlighted the potential for achieving enhanced performance relative to a benchmark.

2.4 Research Gap

Despite the valuable contributions made by existing studies, there exist notable research gaps. One critical gap lies in the integration of enhanced indexing strategies specifically tailored for fixed income portfolios. While enhanced indexing has gained attention in equity markets, its application and effectiveness in the fixed income domain remain un explored. Addressing this Gap would provide a deeper understanding of how enhanced indexing can be optimized for the unique characteristics of the fixed income market.

The empirical analysis involved scrutinizing portfolios constructed using Enhanced indexing framework and comparing their performance against benchmark indices. The findings provided compelling evidence demonstrating that portfolios constructed using the enhanced indexing framework exhibited enhanced index tracking capabilities, capturing market movements more effectively and managing downside risks.

2.5 Conceptual Framework

The research examines the dynamics of optimizing fixed income portfolios by utilizing an Enhanced indexing strategy through a goal programming approach. The foundation of this study lies in the identification and manipulation of variables crucial to fixed portfolio performance. The dependent variable is the performance of the fixed income portfolio which is the outcome under scrutiny while the independent variable is enhanced indexing strategy utilizing a goal programming technique.

The association of this variables is illustrated below:

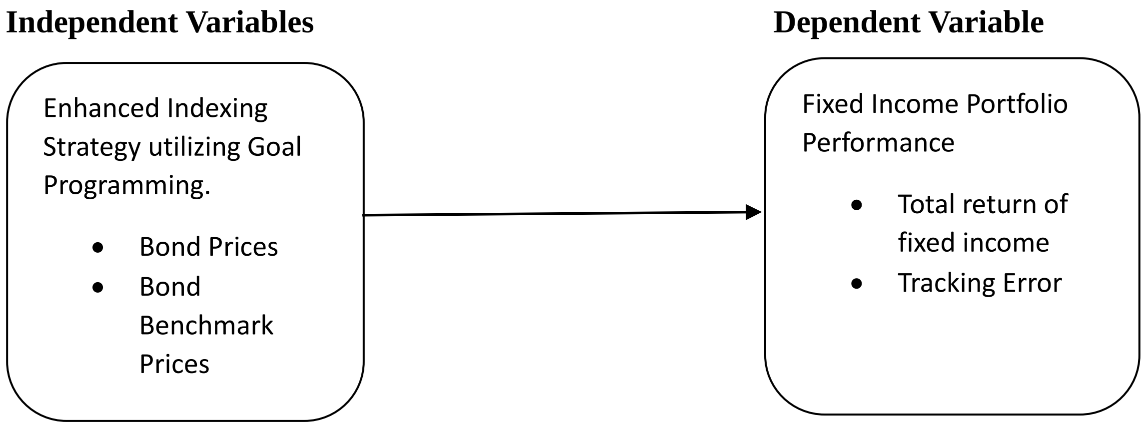

Figure:2.4 Conceptual Framework
Source Author (2024)

2.6 Literature review Summary

A thorough theoretical and empirical literature review has been illustrated on how fixed income indexing and particularly enhanced indexing can be used to achieve higher performance for a portfolio, it extends to how goal programming employed in the construction of such a portfolio employing indexing can even better the performance of the portfolio and optimize security selections.

The theoretical review delves into the historical development of portfolio management strategies which started with Active portfolio management then to passive portfolio management, further providing insights into the principles of indexing and the efficient market hypothesis. Proper ground work is for understanding the context in which enhanced indexing and indexing emerged is laid by the challenges of and criticism of active portfolio management.

Turning to the empirical literature review, the section scrutinizes existing studies on fixed income indexing and enhanced index tracking. Noteworthy studies by Jorion (2002) and Guastaroba et al (2020) illuminated the complexities of tracking error optimization and introduced methodologies such as CvaR based ratio measures to enhance index tracking precision and risk management. The incorporation of goal programming in enhanced index tracking strategies is also discussed by Siew, Jaaman, and Ismail (2014), showcasing its potential in achieving superior portfolio performance.

In essence, the chapter presents a wealth of theoretical and empirical insights offering an understanding of fixed income portfolio management and the evolution of enhanced indexing strategies. The identified research gap paves the way for the current study.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter introduces the research methodology applied in optimizing fixed income portfolio performance through enhanced index tracking, utilizing Goal programming approach. The chapter outlines the planned research design, explains the criteria for population selection, defines the sampling frame, expounds on the sampling technique and details the process of data collection. Additionally, we review the methodology for data processing and highlights the data analysis approach too in the context of the topic.

3.2 Research Design

The study utilizes a quantitative research design employing a goal programming approach recognized for its efficacy in addressing multi-objective optimization problems in financial portfolio management ensuring investors achieve their fundamental objective of selecting an efficient portfolio (Lee, & Chesser, 1980).

It aims to apply theoretical concepts to practical issues within the fixed income portfolio management field. To identify trends and relationships and improve portfolio performance, the quantitative approach involves collecting and analyzing numerical data. The research design is explanatory in nature seeking to explain the effectiveness of an enhanced index tracking portfolio management approach in the context of the Kenyan fixed income market.

Constructing a fixed income portfolio through enhanced indexing is the core of the study making it imperative to identify and define the key parameters or objective functions that will guide the optimization process. Parameters integral to the research design entail:

Maximizing returns: The primary objective is to achieve excess returns compared to an assigned index, reflecting the enhanced nature of the indexing strategy.

Controlling Risk: Managing risk is crucial to portfolio management as well, this includes considerations for volatility models such as convexity and duration to ensure a balanced risk return profile.

Minimizing Tracking error: While not the sole focus as in passive investing, minimizing tracking error remains important to stay withing acceptable bounds relative to the chosen benchmark.

3.3 Population

The study will encompass the universe of all the government issued bonds in the Kenyan Secondary Market (NSE), given most local fund managers largely invest in government issued bonds and the study is specific to the Kenyan Fixed income secondary market Moreso available benchmarks for the study are also government fixed income indices. Building a portfolio from these securities will enable proper benchmarking and will represent the universe of fixed income instruments available to investors who want to invest in the Fixed income space in the capital markets.

3.4 Sampling Framework

The sampling process is aimed at ensuring comprehensive representation of the relevant Treasury fixed income instruments available in the secondary market at the Nairobi Securities Exchange specifically bonds. The framework is designed to encompass all long-term treasury fixed income securities in the secondary fixed income market.

3.5 Sample and Sampling technique

The data to be used in the study will involve a 5 years' worth of historical bond market data given the nature of stationarity in financial time series data (Campbell, Lo, MacKinlay,1998). The 5-Year timeframe is chosen to strike a balance between capturing a sufficiently long-term perspective of market dynamics and addressing the challenges associated with maintaining stationarity in financial data.

3.5 Data Collection Procedure

The data for this study will be secondary data acquired from historical records. The selected secondary data will encompass key variables such as bond prices, yields, maturity dates, issue dates, Coupon payment frequency and other relevant bond metrics.

3.7 Pilot Test

Before fully implementing the Goal programming approach on the complete dataset a pilot test will be conducted to assess the feasibility, validity and reliability of the research design and methodology. During this phase a subset of the historical long-term treasury instruments market data spanning 2 years' time period, will be used to apply Goal programming model.

3.8 Data Processing and Analysis

The raw data will be subjected to some processing, validation and manipulation to derive insights. Quantitative data will be predominantly utilized hence the employment of statistical techniques for comprehensive analysis. The chosen tool for data analysis is Python a versatile programming language with powerful libraries for efficient data manipulation. The heart of the study lies in the application of goal programming to optimize fixed income portfolio performance, implemented using python's optimization libraries.

3.8.1 Bond Risk Models

3.8.1.1 Bond Duration

The duration of a bond measures the sensitivity in a bond's price when interest rates change (Brooks & Livingston,1992).

- $D_{Mac} = \frac{\partial P}{\partial y} \times \frac{(1+y)}{P} = \frac{n+y}{ny} - \frac{(n+y)+t(c-y)}{nc[(1+y)^{t} -1]+ky}$
- $D_{mod} = -\frac{1}{P}\frac{\partial P}{\partial y} = \frac{1}{(1+y)}D_{mac}$
- Where:

D_{mac} is the Macauley duration

D_{mod} is the Modified duration

P is the Bond Price

y is the yield to maturity

c is the coupon rate

n is the coupon frequency

t is the years to maturity

3.8.1.2 Bond Convexity

The value of a bond as a function of interest rates is convex hence the concept of convexity, it is a second order approximation of the sensitivity of a bond price to interest rate changes. Grantier (1988) found that bonds with higher convexity are preferred to bonds with lower convexity when duration and yield are equal.

$$C = \frac{1}{P}\frac{\partial^2 P}{\partial Y^2}$$

Where: $Y\ is\ the\ yield\ to\ maturity$

$P\ is\ the\ bond\ Price$

3.8.2 The Goal Programming Model

According to (Romero,2004) the fundamental component of a GP model is the achievement function. This function quantifies the extent to which undesired deviational variables associated with the models' objectives are minimized.

3.8.2.1 MinMax Goal Programming

Minmax Goal programming allows for achievement of several factors in one model and well suited for a balanced solution (Romero,1991). Given its conservative nature, it is well suited for enhanced indexing. The primary goal of enhanced index tracking is to closely track the underlying index while maintain a neutral stance on market views. Instead of focusing on specific market predictions, investors aim to gain across all scenarios regardless of the margins.

$$Minimise\ \lambda$$

$$Subject\ to : \alpha_i n_i + \beta_i p_i \leq \lambda\ for\ i = 1,..,m$$

$$f_i(X) + n_i - p_i = b_i\ \ for\ \ i = 1,..,m$$

$$x \in C_s$$

$$X \geq 0, \quad n_i, p_{i,\lambda\geq 0\ \ for\ i=1,..,m}$$

Where:

$\lambda\ represents\ the\ maximum\ deviation$

$n_i\ is\ the\ i^{th}\ negative\ deviational\ variable$

$\alpha_i\ is\ the\ weighting\ factor\ for\ negative\ deviational\ variable\ i$

$p_i\ is\ the\ i^{th} positive\ deviational\ variable$

$\beta_i\ is\ the\ weighting\ factor\ for\ positive\ deviational\ varaible\ i$

$X\ is\ the\ vector\ of\ the\ decision\ variables$

$f_i(X) is\ the\ i^{th}\ objective\ function$

$b_i\ is\ the\ i^{th} target\ value$

$C_s is\ an\ optional\ set\ of\ hard\ constraints$

3.8.2.2 Percentage Normalization

Normalization is crucial in goal programming to ensure that the objectives which might be measured in differing units before being combined in the achievement function are comparable. The absence of normalization might lead to difficulties in effectively balancing different objectives hence (Jones & Tamiz, 2010) propose normalization to overcome the problem.

Azmi, R (2014) found that percentage normalization is the most suitable normalization method for goal programming in the context of portfolio selection. Percentage normalization involves dividing weights of deviational variables in the achievement function by their respective target values. For MinMax GP when normalized we have:

$$\frac{\alpha_i}{b_i} n_i + \frac{\beta_i}{b_i} p_i \leq \lambda \quad for\ i = 1, .., m$$

3.8.3 The MinMax Goal Programming Model for Enhanced index tracking

Building upon the theoretical foundation and insights from the literature review, we formulate a GP model to guide the optimization of the fixed income portfolio performance through enhanced index tracking this model encapsulates the key objectives of maximizing return, minimizing tracking error and managing risk in terms of convexity and portfolio duration.

Decision variables

Let x_i represent the allocation of funds to the *i-th* fixed income instrument in the portfolio.

Objective Functions:

1. Return Maximization:
    - Maximize the expected return of the portfolio

$$Z_1 = -\sum_i (-Expected\ Return_i \times x_i)$$

2. Tracking Error Minimization
   - Minimize the tracking error, representing the deviation of the portfolio return from the benchmark index return.

$$Z_2 = \sum_i (Weight \times (Return_i - BenhmarkReturn)^2)$$

3. Risk Management
   - Minimizing the portfolio convexity

$$Z_3 = \sum_i (Convexity_i \times x_i)$$

4. Duration Management
   - Minimizing the portfolio duration

$$Z_4 = \sum_i (Duration_i \times x_i)$$

Constraints:

1. Budget Constraint:
   - Ensures that the total allocation of funds does not exceed the available budget

$$\sum_i x_i = 1$$

2. Maximum and Minimum Allocation constraints
   - Set limits on the minimum and maximum allocation to individual assets

$$MinAllocation_i \leq x_i \leq MaxAllocation_i \ for\ all\ i$$

Goal Programming formulation:

Minimize:

$$\phi = w_1 \; . \; Z_1 + w_2 \; . \; Z_2 + w_3 \; . \; Z_3 + w_3 \; . \; Z_4 + \; \lambda \, . \, \max \left(Z_1, Z_2, Z_3, Z_4\right)$$

Subject to:

$$Z_1 = \; \sum_i (-ExpectedReturn \; \times x_i)$$

$$Z_2 = \; \sum_i (weight_i \; \times \; (Return_i \; - BenchmarkReturn)^2)$$

$$Z_3 = \; \sum_i (Convexity_i \; \times x_i)$$

$$Z_4 = \; \sum_i (Duration_i \; \times x_i)$$

$$\sum_i x_i = 1$$

$$MinAllocation_i \leq x_i \leq MaxAllocation_i$$

Where:

- w_1, w_2, w_3, w_4 are weighting factors reflecting the importance of each objective.
- λ represents the trade off between minimizing deviations and maximizing the minimum deviation.
- $Benchmark\ Return$ is the expected return of the benchmark index.
- $Weight, Return, Convexity, Duration$ are the weight, return, convexity and duration of the i-th fixed income instrument respectively.

3.9 Ethical Considerations

Ethical considerations are paramount in the execution of this study and the research will adhere to established ethical principles and guidelines. Proper citation and acknowledgement of the original sources will be maintained in reporting the methodology, results and conclusions, ensuring that the research process is open and accessible. Moreover, the study will avoid any conflicts of interest, and the findings will be presented objectively without bias

CHAPTER 4

Data Analysis, Findings and Discussion

In this chapter, we delve into the results of the study, focusing on constructing a fixed income portfolio aimed at enhancing returns and outperforming the market benchmark. The analysis is based on the optimization of the portfolio through goal programming.

4.1 Data Preparation

The initial phase of the analysis involved preparing the fixed income bonds data, the bond data was obtained from the Nairobi Securities Exchange which issues the data on a weekly basis. Monthly log returns were also used for return calculations. The data preparation involved filtering out bonds that would have matured within the study period, Essential bond risk measures were also calculated at this stage that is convexity and duration.

4.2. Fixed Income Portfolio Construction

The study aimed to construct a portfolio that would enhance income for fund managers, in doing so the process was broken down into two steps. First was selecting of issues that would be constituted in the portfolio and secondly performing optimization process to allocate weights efficiently while observing the objectives.

4.2.1 Bond Selection

The objective was to construct a portfolio using enhanced indexing which uses both active and passive strategies and in order to avoid using all the issues within the index universe, Monte Carlo simulation was employed to be able to find a mix of bonds withing the Five tenors' bands that would give minimum convexity and would also have a coupon above the average for the particular tenor. This aligns with studies such as one conducted by (Ángel, 2005), which analyzed portfolio optimization using US treasury bonds with various maturities and coupon rates to understand the behavior of different risk measures. Furthermore (Bolder, 2015) when analyzing fixed income instruments contribution to the overall position. He proposes organizing them by Tenors primarily and goes further ahead to state that for complex portfolios this can be furthered grouped by currency, country, instrument, or credit class. The constraints for the tenors were as follows:

Tenor	Name	Band	Number of issues selected
1-5 years	Short term	Less Than or Equal to 5 Years to Maturity	7
5-10 years	Medium term	Greater than 5 years and less than or equal to 10 years to Maturity	5
10 -15 years	Semi medium term	Greater than 10 years and less than or equal to 15 years to Maturity	10
15-20 years	Long term	Greater than 15 years and less than or equal to 20 years to Maturity	5
Above 20 years	Very Long	Greater Than 20 Years	3

Table 4.1: Tenors bands used for the portfolio construction.
Source: Author 2024

Table 4.1 indicates the various Tenors and a description of its Lower and upper bounds and finally the last column indicates how many bonds from a tenor were selected for the portfolio optimization.

From this simulation 30 bonds were selected to be used in the portfolio optimization

Code	Tenor
FXD1/2020/005	1-5 years
FXD1/2009/15	1-5 years
FXD1/2014/10	1-5 years
FXD1/2014/10 (Re-open)	1-5 years
IFB1/2017/7Yr	1-5 years
IFB1/2016/9Yr	1-5 years
FXD1/2022/003	1-5 years
IFB1/2017/12Yr	5-10 years
FXD2/2018/10	5-10 years
FXD1/2008/20	5-10 years
FXD1/2017/10	5-10 years

FXD1/2017/10 (Re-opened)	5-10 years
FXD1/2018/015	10-15 years
FXD1/2019/015	10-15 years
FXD1/2016/20	10-15 years
IFB1/2018/15Yr	10-15 years
FXD1/2020/015	10-15 years
FXD2/2019/15	10-15 years
FXD2/2019/015	10-15 years
FXD1/2018/15	10-15 years
FXD1/2022/15	10-15 years
FXD2/2018/015	10-15 years
FXD1/2016/020	15-20 years
FXD1/2018/20	15-20 years
FXD1/2021/20	15-20 years
FXD1/2019/20	15-20 years
IFB1/2022/19	15-20 years
FXD1/2021/025	Above 20 years
FXD1/2018/25	Above 20 years
FXD1/2021/25	Above 20 years

Table 4.2: List of the selected issues used in the portfolio construction.
Source: Author 2024

4.2.2 Portfolio Optimization

The study follows the objective function described in (3.8.2 The Goal Programming Model) to find the optimal weights allocation. The underlying optimization engine is the NSGA II Genetic algorithms from pymoo for the multi objective optimization (Blank & Deb,2020). This is chosen given the conflicting objectives of the optimization problem. The optimization was done with a monthly rebalancing. The weights allocated overtime can be per tenor:

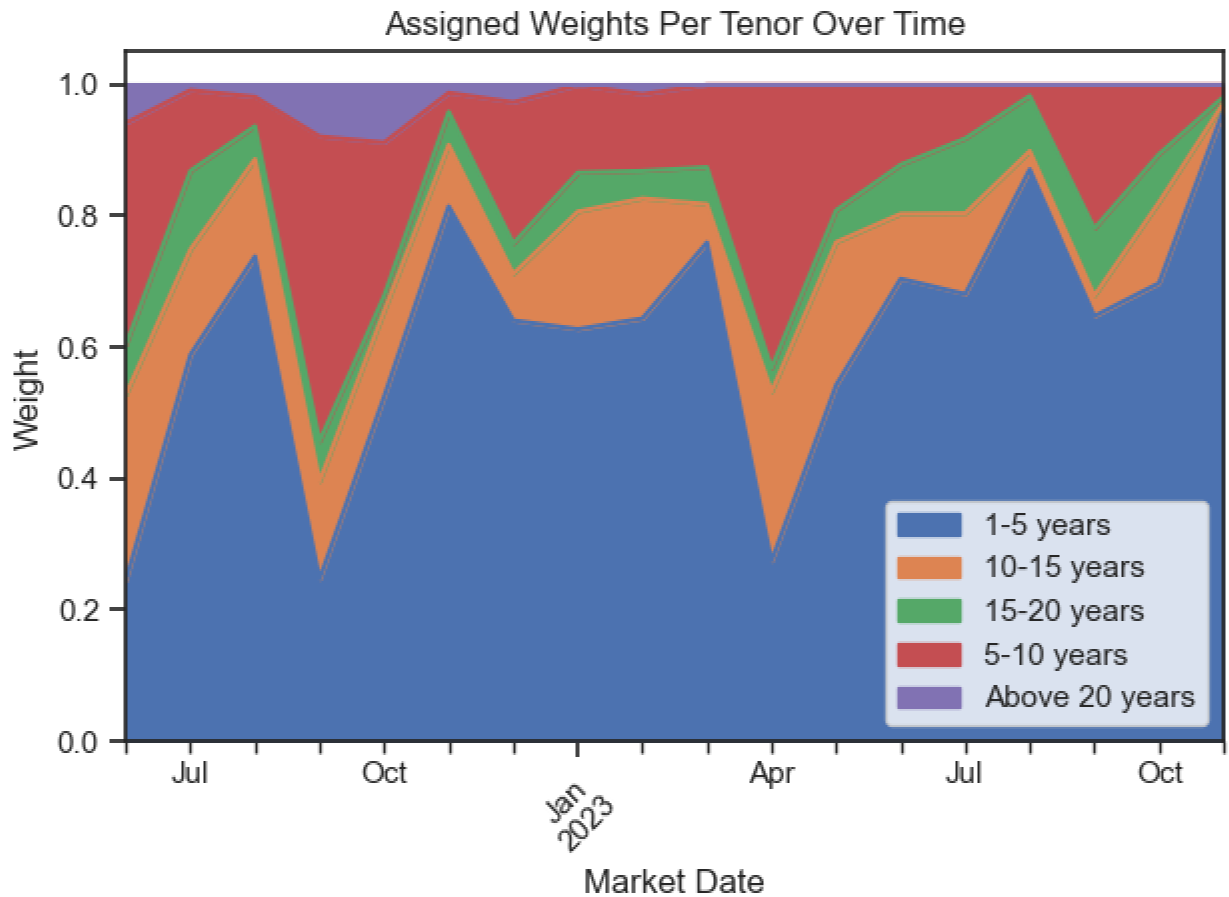

Figure 4.1: Assigned Weights Overtime Per Tenor
Source: Author (2024)

Bonds From the 1-5 Years get assigned more weights throughout the testing period followed by the 5-10 Tenor band.

4.2.3 Measuring Portfolio Performance.

Portfolio	Number of Bonds	Total Return (%)	Tracking Error (%)	Excess Return (%)
S&P Kenya Sovereign Index	70	-12.20	___	__
Goal Programming Model	30	0.9223	1.29	0.77

Table 4.3: Portfolio Performance Summary
Source: Author 2024

As shown in Table (4.3), the optimal portfolio constructed via a multi objective optimization criteria model consists of 30 bonds to track the S&P Kenya Sovereign Index which comprises 71 stocks. This implies that you need there are about 42% of the S&P Kenya Sovereign bond index components to construct the optimal portfolio. The aggregate monthly return obtained by the index within the period of the study was -12.20%, While on the other hand for the constructed portfolio a return of 0.92% was achieved. This was higher than the monthly total return for the index. This generated an excess monthly return of 0.77% for the constructed goal programming portfolio. Additionally, the tracking errors for the optimal portfolio of goal programming model was only 1.29%. In summary, the constructed multi objective criteria portfolio outperforms the index because of higher total return with only 42% of S&P Sovereign bond index components.

Fabozzi (2013) states that an optimal Enhanced indexing tracking error should range between 15 to 50 basis points anything above 50 basis points is an active portfolio while anything below 15 basis points is a passive portfolio. The goal programming portfolio constructed does attain this indicating that the portfolio is an enhanced index portfolio attaining superior returns.

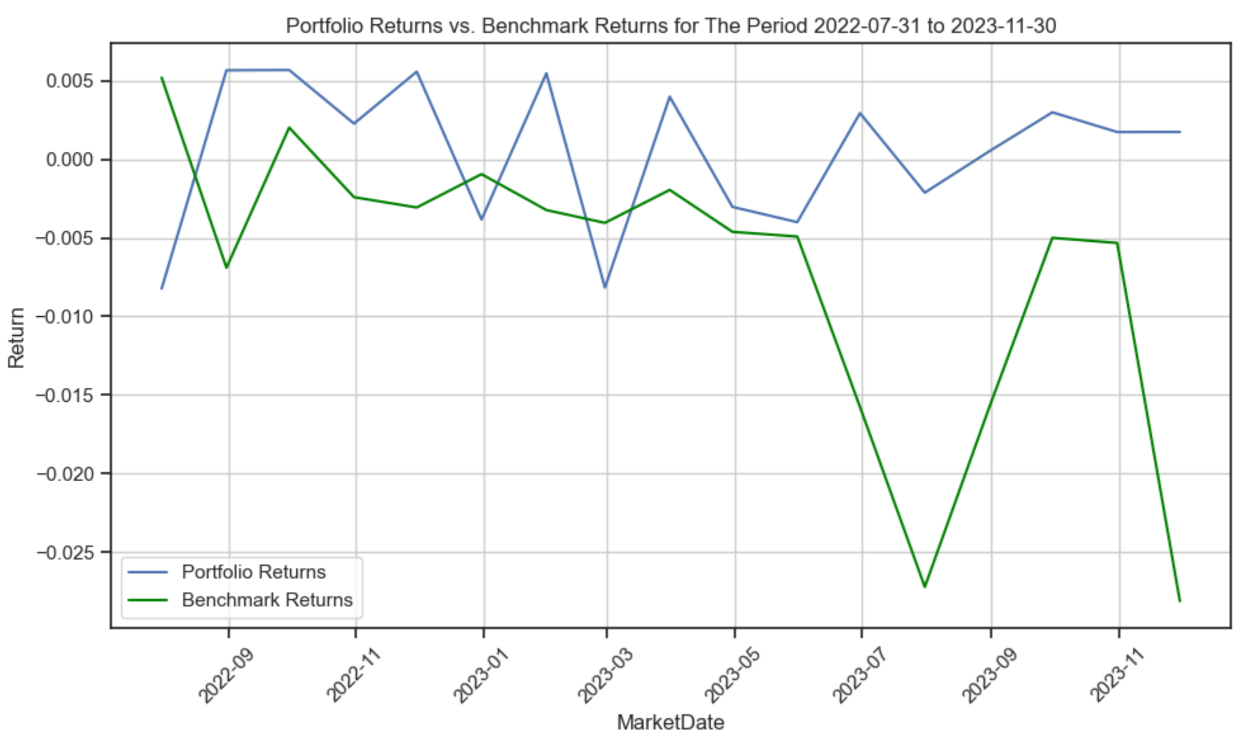

Figure 4.2: Portfolio Performance Against S&P Kenya Sovereign Bond Index.
Source: Author 2024

In the latter part of 2023, a significant decline in the benchmark returns was observed, which can be attributed to the persistent increase in the yield to maturity on the 10-year Kenyan government bond yield curve. Mishkin and Eakins (2006) provide a comprehensive discussion on the inverse relationship that explains how rising yields have a negative impact on bond prices in their chapter "What does Interest rates mean and what is their role in valuation?" This relationship elucidates how rising yields negatively impact bond prices, thereby affecting overall benchmark returns.

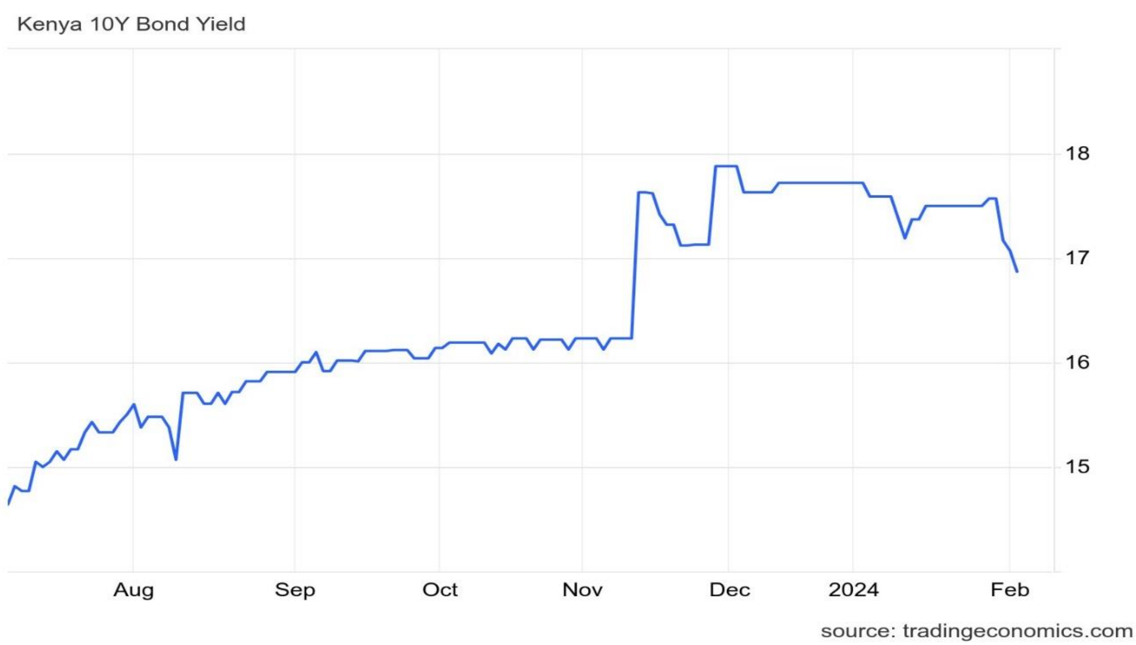

Figure 4.3: Kenya 10 Year Government bonds Yield curve.
Source: tradingeconomics.com

4.2.4.3.1 Measuring Risk Adjusted Performance

Portfolio	Sharp Ratio
S&P Kenya Sovereign Index	-28.8050
Goal Programming Model	-30.3886

Table 4.4 Risk Adjusted Performance
Source: Author (2024)

Mukherji (2011) posits that “Treasury bills are the better proxies for the risk-free rate than longer-term securities, regardless of investment horizon, due to lower market and inflation risk”. A risk-free rate of 15.9829% was used for computing the sharp ratio, this was the weighted average rate of the 91day Treasury bill Both the benchmark and portfolio return's Sharpe ratios are negative, which suggests underperformance in comparison to the risk-free rate of return (Sharpe, 1994). However, the portfolio lost less per unit of risk than the benchmark given it had a lower sharp ratio compared to the index’s sharp ratio.

CHAPTER 5

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussions

The study set out to construct an enhanced indexed portfolio within the fixed income asset class, targeting to outperform the Kenyan Sovereign Bond index benchmark provided by Standard and Poor. A goal programming model was employed to address multiple objectives, including maximizing returns, minimizing tracking error, and managing risk via convexity and duration considerations.

The enhanced indexing strategy utilizing goal programming demonstrated superior performance compared to the selected Bond Index. The constructed portfolio, consisting of 30 bonds, achieved a monthly total return of 0.92%, which was higher contrasted to the -12.20% total return of the index. Additionally, the portfolio's tracking error was 1.29%, this depicted a high level of accuracy in tracking the benchmark with an excess return of 0.77%.

The goal programming model's efficacy aligns with findings from similar studies by siew, Jaaman, and Ismail (2014), confirming that enhanced indexing can yield attractive returns while managing risk effectively. This study's results also support the theoretical foundations proposed by Fabozzi (2013), where an optimal enhanced indexing tracking error ranges between 15 to 50 basis points.

Fund managers in the Kenyan market can leverage the enhanced indexing strategy to construct portfolios that not only minimize risk but also maximize returns and maintain proximity to benchmarks. This dual approach of active and passive strategies offers a balanced solution for portfolio management.

5.2 Conclusions

The study conclusively demonstrates that the enhanced indexing strategy employing a goal programming model significantly outperforms traditional benchmark indices. The key findings are:

1. Superior Returns: The goal programming portfolio achieved a higher monthly total return compared to the S&P Kenya Sovereign Bond Index.

2. Effective Risk Management: The Portfolio maintained a low tracking error, indicating effective risk management and alignment with benchmark performance.
3. Optimization Efficiency: Utilizing a multi objective optimization approach particularly the goal programming model allowed for efficient optimization of the fixed income portfolio, balancing multiple objectives and constraints effectively.

The outcomes indicate that enhanced indexing, through goal programming, is a viable strategy for achieving superior portfolio performance in the fixed income market.

5.3 Recommendations

Exploration of Optimization Engines: The conclusion obtained from the study suggests two further research directions have been proposed to further explore the performance. First proposal is to explore more optimizations engines and to see their performance in terms of the performance\returns of the generated portfolios.

Inclusion of Additional Fixed Income Instruments: Consideration to incorporate a diverse range of fixed income instruments into the pool of bonds for a more robust and well-balanced portfolio that is Treasury bills, corporate bonds and fixed deposits into the portfolio.

Further analysis of the risk associated with the constructed portfolio should be incorporated and not only evaluate this using the tracking error.

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APPENDIX A ETHICAL APPROVAL

Strathmore
UNIVERSITY

28th February 2024

Mr Abok Elly,
ellyandrew.abok@strathmore.edu

Dear Mr Abok,

<u>RE: Optimizing Fixed Income Portfolio Performance through Enhanced Index Tracking: A Goal Programming Approach</u>

This is to inform you that SU-ISERC has reviewed and **approved** your above **SU-masters** research proposal. Your application reference number is **SU-ISERC2050/24.** The approval period is from **28th February 2024 to 27th February 2025.**

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC.
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
v. Clearance for the export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.

Before commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) https://research-portal.nacosti.go.ke/ and obtain other clearances needed.

Yours sincerely,

Mr Ambrose Rachier,
Chairperson; SU-ISERC

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