

# Examining non-parallel interest rate risk premia with a focus on South African markets

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## Abstract

In this thesis we analysed sovereign yield curves for emerging and developed markets to identify the proportion of parallel and non-parallel shifts over time. We found that non-parallel shifts were more prevalent in emerging markets due to relatively higher political and economic risks. Key drivers included systemic risk events like wars, debt distress, and pandemics. Geopolitical risks were seen to increase in frequency in the modern era and developing a strategy to exploit non-parallel risk premia is an attractive proposition.

We determined which policy regimes are appropriate to extract non-parallel risk premia. Our research suggests that countries with opposing monetary and fiscal policies possess greater non-parallel return opportunities whilst countries with complementing policies require tactical non-parallel strategies to optimise returns. We identified the South African (SA) swap and bond interest rate markets as suitable candidate for maximising non-parallel risk premia via a long butterfly strategy (which is immune to parallel curve shifts but exposed to non-parallel curve shifts). Various butterfly weighting methodologies were analysed with a cash and duration neutral methodology being the preferred option due to its conservatism and practicality.

Ten swap and bond butterfly risk factors were defined using monthly SA data from 2001-2024. We back-tested and analysed these factors during interest rate cycles, curve scenarios and risk-off periods. Most of the top ranked swap and bond butterfly factors displayed strong and persistent outperformance over their corresponding bottom ranked factors, resulting in improved risk-adjusted and absolute returns especially during positive and steep twists, and bull and bear flattening curve scenarios. The All-Factor Rank which combined all the factors demonstrated improved diversification by balancing upside and downside risks. By demonstrating this outperformance our results contradict the strong efficient market hypothesis of not being able to consistently outperform the market on a risk-adjusted basis.

Trade costs were an important factor that required pragmatic management, we compared monthly and quarterly rebalancing frequencies which resulted in monthly rebalancing producing greater gross returns but due to high trade costs, less frequent rebalancing as in the quarterly frequency reduced trade costs and improved net returns. Trade costs can be significant so having a pragmatic rebalancing strategy with efficient market makers that limit trade costs to one basis point of spread duration make these butterfly risk factors an effective and successful portable alpha strategy.

**Keywords:** swap butterfly strategies, factor rank, fixed income, risk premia, level, slope, curvature, parallel and non-parallel shifts, curve scenarios, monetary and fiscal policy.

## The following articles were published in accredited, peer-reviewed journals, as part of the research:

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## Declaration

I, the undersigned, declare that this thesis, which I hereby submit for the degree Philosophiae Doctor at the University of Pretoria, is my own independent work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Pretoria, January 29, 2025



Sanveer Hariparsad

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## List of Abbreviations

Abbreviation	Full Name
ALBI	SA All Bond Index
ALSI	SA All Share Equity Index
AUS	Australia
BAS	Bond Absolute Spread
B-AFR	Bond All-Factor Rank
BEI	Break-Even Inflation
BP	Basis Point
BNSS	Bond Nelson Siegel Svensson
BRA	Brazil
BSD	Bond Spread Duration
B/C+R	Bond Carry and Roll
BTS	Bond Term Spread
BCVX	Bond Convexity
B-DEF	Defensive bond factors
B-DOM	Dominant bond factors
BRev	Bond Reversion
BRP	Bond Risk Premium
CAN	Canada
CILI	SA Inflation Linked Bond Composite Index
CNY	China
CVaR	Conditional Value at Risk
DM	Developed Markets
DXY	US Dollar Index
EM	Emerging Markets
EMBISPRD	Emerging Market Bond Index Spread
EMH	Efficient Market Hypothesis
EPU	Economic Policy Uncertainty
FRA	France
FSI	Financial Stress Index
GER	Germany
GPR	Geopolitical Risk
IDR	Indonesia
INR	India
ITL	Italy
JPN	Japan
Max DD	Maximum Drawdown
MEX	Mexico
MPU	Monetary Policy Uncertainty
MOVE	Implied volatility of U.S. Treasury Options (across various maturities)
NSS	Nelson-Siegel-Svensson
PCA	Principal Component Analysis
PLN	Poland
RSR	Real Swap Rates
RUS-UKR	Russia-Ukraine War
SA	South Africa
SABAL	SA Budget Balance
SABANKS	JSE Banks Index

<b>SACORECPI</b>	SA Core Inflation
<b>SACURRACC</b>	SA Current Account Deficit
<b>SAGENR</b>	JSE General Retailers Index
<b>SAGDP</b>	SA Real GDP
<b>SA-US</b>	SA less US Swap Spread
<b>SAVI</b>	JSE All Share Index Implied Volatility Index
<b>SA5YCDS</b>	SA Sovereign 5-Year Credit Default Swap Spread
<b>SBS</b>	SA Swap less SA Bond Spread
<b>SCVX</b>	Swap Convexity
<b>S-DEF</b>	Defensive swap butterfly factors
<b>S-DOM</b>	Dominant swap butterfly factors
<b>S/C+R</b>	Swap Carry and Roll
<b>SD</b>	Standard Deviation
<b>S-AFR</b>	Swap All-Factor Rank
<b>SNSS</b>	Swap Nelson Siegel Svensson
<b>SRP</b>	Swap Risk Premium
<b>SSD</b>	Swap Spread Duration
<b>SRev</b>	Swap Reversion
<b>STS</b>	Swap Term Spread
<b>TRL</b>	Turkey
<b>UK</b>	United Kingdom
<b>US</b>	United States
<b>USDZAR</b>	1 USD in South African Rands
<b>USGDP</b>	US Real GDP
<b>USHYSPRD</b>	US High Yield Bond Spread
<b>US10YTR</b>	US 10-year Treasury Total Return Index
<b>VIX</b>	S&P500 1-Month Implied Volatility Index

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## Preamble

The purpose of the preamble is to provide the reader with relevant background that will be used throughout this thesis. We outline the various types of fixed income risk premia with non-parallel risk premia being the focal point of this research. We also expand on several important topics, including the various forms of efficient markets and yield curve theories, the measurement of non-parallel risk premia using principal components analysis (PCA), and the definition of a fixed income butterfly trade. Additionally, we discuss risk statistics, global risk-off events, economic indicators, the mechanics of monetary and fiscal policies, and provide a brief description of the data used.

### P1-Monetary Policy:

Refers to the actions taken by a country's central bank to manage the money supply, interest rates, and overall liquidity in the economy. While each central bank has its own defined goals, typical objectives include one of or a combination of inflation control, currency stabilisation and/or promoting economic growth. Popular tools employed by central banks are to adjust the level of interest rates (e.g. raising rates to curb inflation or lowering rates to encourage economic activity), open market operations (buying and selling of government or other securities) and to adjust the reserve requirement for banks (i.e. the amount of cash that banks must hold in reserve against deposits made by their customers).

### P2-Fiscal Policy:

Involves government decisions on taxation and public spending to influence economic growth and stability. Taxes will be adjusted to balance the national budget and control disposable income. Government spending will include infrastructure, education and welfare to boost economic activity. Fiscal policy is managed by the legislative and executive branches of government and so is implemented relatively slower than monetary policy.

### P3-Economic Indicators:

An economic indicator is a statistical measure used to evaluate the health, trends, and performance of an economy. Policymakers, investors, and businesses rely on these indicators for decision-making and forecasting.

#### **Types of Economic Indicators**

##### *Leading Indicators:*

Are indicative of future economic trends (e.g. stock market performance, consumer confidence index, building permits).

##### *Lagging Indicators:*

Confirm trends after they occur (e.g. unemployment rate, gross domestic product, corporate profits, debt levels and trade balances).

##### *Coincident Indicators:*

Reflect the current state of the economy (e.g. retail sales, industrial production, consumer and producer price inflation).

### P4-Yield Curve Theories:

The yield curve represents the relationship between interest rates (or yields) and different maturities of debt securities. Understanding its shape and movement is crucial for investors and policymakers. There are four main theories to explain yield curve behaviour with a graphical illustration provided in Figure P2:

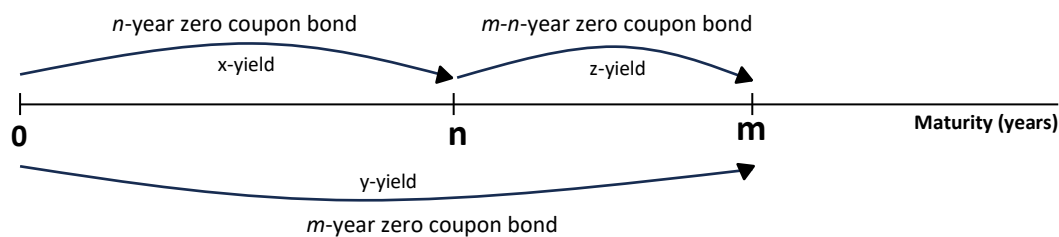
## Pure Expectations Theory:

The shape of the yield curve reflects investors' expectations of future short-term interest rates. A rising curve implies higher future short-term rates, while an inverted curve suggests lower future short-term rates.

### Key Assumption:

Bonds of all maturities are perfect substitutes and differences in yields are purely due to expected changes in interest rates. An upward sloping yield curve implies that future shorter-term interest rates would be higher than current short-term interest rates. A downward sloping or inverted yield curve implies that future short-term interest rates would be higher than current interest short-term rates.

### Example:



**Figure P1** – Illustrates a maturity timeline of an *n*-year, *m*-year and *m-n*-year zero coupon bond with annual yields of *x*%, *y*% and *z*% respectively. This will provide a graphical representation of the maturities and yields we are assessing.

To explain the pure expectations theory we utilise zero coupon curves which are calculated from conventional yield curves, they map interest rates to instruments that only pay a par amount at maturity (i.e. zero coupons prior to maturity) and are used to price any cash flow series. The above timeline in Figure P1 illustrates the profile of three zero coupon bonds, an *n*-year, *m*-year and an *m-n*-year with annual yields of *x*, *y* and *z* respectively. If we know what the *n*-year and *m*-year bond yields are, we can backout the *m-n*-year bond yield of *z* by using the no arbitrage equation as below:

Equation 1 : No Arbitrage Interest Rates

$$(1 + x)^n(1 + z)^{m-n} = (1 + y)^m$$

If in practice, this no arbitrage equation does not hold, then we would be able to buy and sell the relevant *n*-year and *m*-year bonds to lock in an arbitrage profit assuming low trade costs

and sufficient liquidity. Rearranging the terms we find that the yield on the  $m$ - $n$ -year bond is  $z$  which is given by:

$$z = [(1 + x)^{-n}(1 + y)^m]^{1/(m-n)} - 1$$

Inputting numbers into Equation 1, if we assume the yield on a 1-year zero coupon bond is 3% and the yield on a 3-year zero coupon bond is 5%, then the yield on a 2-year zero coupon bond starting in 1-years' time would be  $6\% \approx [(1 + 3\%)^1(1 + 5\%)^3]^{1/(3-1)} - 1$ . Thus, the expected 2-year zero coupon yield in 1-years' time is 6% based on the current, upward sloping term structure of interest rates. Based on the expectations theory we would anticipate future short-term interest rates to be higher. If the current interest rate term structure is downward sloping, we would anticipate future short-term interest rates to be lower.

### **Liquidity Preference Theory:**

Investors demand a liquidity premium for holding long-term bonds relative to short-term bonds due to the increased risks (e.g. price volatility, inflation uncertainty). As a result, the yield curve is typically upward sloping.

#### *Key Assumption:*

Investors prefer short-term bonds for their lower risk and higher liquidity.

#### *Example:*

Even if future interest rates are expected to remain constant, long-term bonds may have higher yields to compensate investors for the risks and illiquidity.

### **Market Segmentation Theory (MST):**

The yield curve is shaped by supply and demand within different maturity segments. Each maturity segment operates independently, influenced by the preferences of different investors.

#### *Key Assumption:*

Bonds of different maturities are not substitutes; investors have distinct maturity preferences.

#### *Example:*

Pension funds may prefer long-term bonds for liability matching, while banks may favour short-term bonds for liquidity. If demand for long-term bonds increases, the yield curve for long maturities may flatten or even invert. According to MST the yield curve can take any shape depending on the relative demand and supply for bonds in each segment.

### Preferred Habitat Theory:

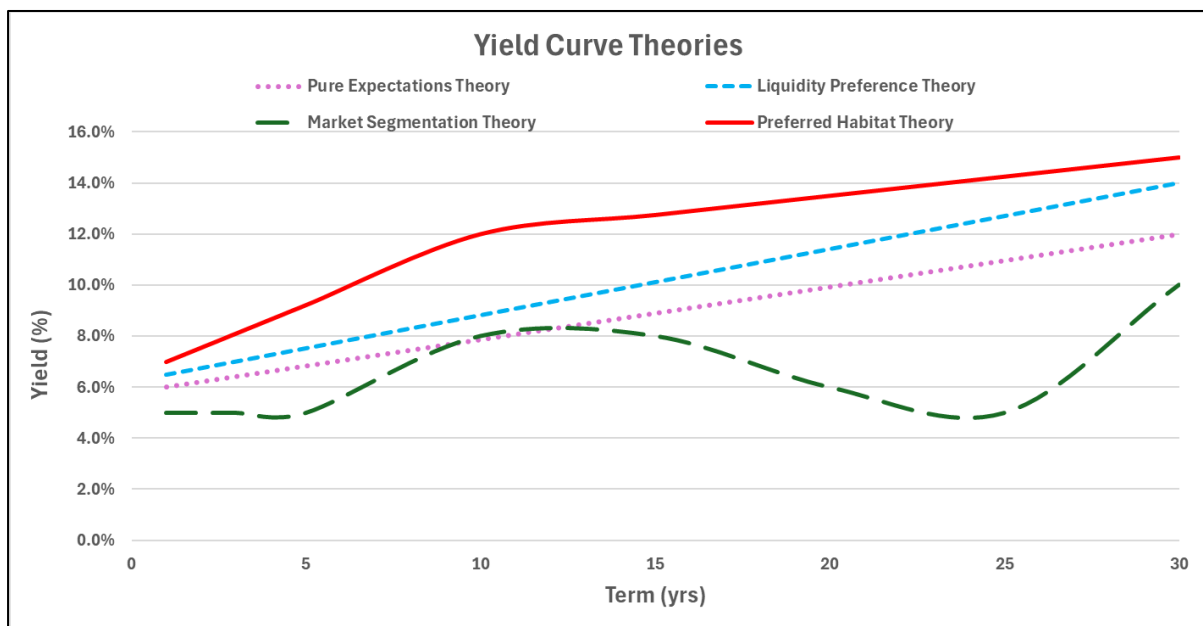
A hybrid of MST and Liquidity Preference theories, it suggests investors prefer certain maturities but will move to others if compensated with a higher return.

#### Key Assumption:

Investors have a preferred range of maturities but can be incentivised to deviate from it.

#### Example:

A pension fund preferring 30-year bonds might purchase 20-year bonds if the yields are significantly higher. This is similar to MST, but the curve adjusts more fluidly based on yield incentives.



**Figure P2** –Graphical Illustration of the four yield curve theories (pure expectations, liquidity preference, market segmentation and preferred habitat theories). Pure expectations theory (purple, dotted) reflects rising future interest rate expectations with a linear increase, liquidity preference theory (blue small dashed) shows an upward-sloping curve due to liquidity premiums added to future interest rate expectations, market segmentation theory (green large dashed) demonstrates distinct segments with varying slopes based on supply and demand dynamics, and preferred habitat theory (red solid) is a combination of liquidity preference and market segmentation that modifies the liquidity curve slightly to show preferences and incentives for shifting maturities.

## P5-Risk Premia:

Refers to the additional return an investor expects to earn (or to be compensated for) by taking on risk beyond a risk-free rate. The concept arises from the fact that investors demand higher returns to compensate for bearing higher uncertainty or exposure to unfavourable outcomes. Risk premia in the fixed income space can be associated with various sources of risk, including duration risk, credit risk, inflation risk, curve risk or liquidity risk.

### **Duration risk premia:**

Compensation for interest rate risk associated with holding bonds with a higher sensitivity to interest rate changes, such as those with longer maturities (e.g. a 10-year bond with higher duration might offer a higher yield than a 2-year bond with lower duration due to greater uncertainty in interest rates over the longer term).

### **Credit risk premia:**

Compensation for the possibility of default and/or a negative credit rating event in corporate or sovereign bonds (e.g. a junk bond might yield 8% compared to 3% for a government bond due to its higher credit risk).

### **Curve Risk Premia:**

Compensation for non-parallel shifts in the yield curve, such as steepening or flattening (e.g. butterfly strategies in bond markets exploit curve risk premia by taking positions on different parts of the yield curve, short, medium, and long maturities).

### **Inflation Risk Premia:**

Compensation for the risk that inflation might erode the real return of a bond (e.g. returns on a nominal bond will be higher than the equivalent inflation linked bond. to compensate for inflation uncertainty).

## Liquidity Risk Premia:

Bonds that are difficult to source or do not have a high percentage of free float may offer higher yields to compensate for illiquidity relative to a tradeable government bond.

These concepts allow investors to construct portfolios tailored to risk-return objectives, whether through leveraging bond-specific factors or broader macroeconomic considerations. Our thesis focuses on identifying specific curve risk premia on the South African swap and bond yield curves.

## P6-Non-Parallel Curve Movements:

Refers to changes in the yield curve where interest rates across different maturities do not move by the same magnitude or direction. Unlike a parallel shift—where all maturities increase or decrease by the same amount—non-parallel movements involve changes to the curve's shape or slope, leading to steepening, flattening, or curvature adjustments. These movements are significant in fixed income investing because they can impact the valuation of bonds and other interest rate-sensitive securities differently depending on their maturity.

- *Steepening* - Occurs when the difference between long-term and short-term interest rates increases and generally implies expectations of higher future inflation or economic growth.
- *Flattening* - Occurs when the difference between long-term and short-term interest rates decreases and is prominent when economic growth is accelerating, and tighter monetary policy is anticipated which would increase short-term interest rates relative to long-term interest rates.
- *Curvature Changes* - Involve changes to the middle portion of the curve (belly) relative to the short and long ends (wings) and is most common during specific supply-demand dynamics, technical factors in the belly of the curve or changes in global risk sentiment.

Chapter 2 - Curve Scenarios provides more detail on the popular non-parallel curve changes including graphical depictions.

## P7-Fixed Income Butterfly Strategy:

Is an interest rate trading strategy that involves simultaneously buying and selling bonds or other fixed-income instruments to profit from changes in the shape of the yield curve (in most cases the butterfly strategy aims to profit from slope or curvature changes). The "butterfly" refers to the selection of three points on the yield curve: short-term, medium-term (the "body"), and long-term (the "wings").

### **Structure:**

Short-dated bonds/swaps (Wings): Represents short-term interest rates.

Medium-dated bonds/swaps (Body): Represents the belly of the curve.

Long-dated bonds/swaps (Wings): Represents long-term interest rates.

### **Positioning:**

Long Butterfly: Buy the body (medium-term) and sell the wings (short- and long-term).

Short Butterfly: Sell the body and buy the wings.

### **Duration Neutrality:**

The strategy is typically constructed to be duration-neutral, meaning it is not affected by parallel shifts in the yield curve (when all rates rise or fall by the same amount). Instead, it profits from changes in the slope or curvature of the curve. The strategy bets on either:

- Convergence: If the curve shape is expected to revert to a normal level.
- Divergence: If the curve shape is expected to deviate further from its current form.

### *Short Butterfly Example:*

Assume you observe an abnormally steep yield curve with medium-term interest rates much lower than expected. In this scenario you anticipate convergence or reversion so that the medium-term interest rate would rise relative to the short- and long-term interest rates. Thus, to realise a profit in a cash and duration neutral manner you would:

Sell R1M of 5-year bonds (Body) and buy R500K of 2-year bonds (Short-Dated Wing) and R500K of 10-year bonds (Long-Dated Wing).

#### *Long Butterfly Example:*

Assume you observe an extremely flat yield curve with the spread between medium- and long term interest rates at very low levels. If we anticipate central bank easing, then a steeper yield curve is expected. In this scenario you also anticipate convergence or reversion so that the long-term interest rate would rise relative to the short- and medium-term interest rates. Thus, to realise a profit in a cash and duration neutral manner you would:

Buy R1M of 5-year bonds (Body) and Sell R500K of 2-year bonds (Short-Dated Wing) and R500K of 10-year bonds (Long-Dated Wing).

The advantages of the fixed income butterfly strategy are that it:

- Helps manage slope and curvature risks in portfolios,
- Identifies mispricing in medium-term instruments, and
- Can be applied by hedge funds, pension funds, or liability-driven strategies.

The challenges of the fixed income butterfly strategy are that it:

- Has low return potential and often requires leverage,
- Demands advanced analytics and market understanding, and
- Depends on accurate yield curve predictions.

### **P8-Efficient Market Hypothesis (EMH):**

Asserts that financial markets are "efficient," meaning that asset prices fully reflect all available information at any given time. According to EMH, it is nearly impossible to consistently achieve returns higher than average market returns on a risk-adjusted basis since prices already incorporate all known information. Below we present the forms of EMH:

#### **Weak Form:**

- Asset prices reflect all historical market data, such as past prices and trading volumes.

- Technical analysis (e.g., identifying patterns in price charts) is ineffective in predicting future price movements.
- Example: If a stock has been steadily increasing in price, this trend cannot be used to reliably predict further increases.

### **Semi-Strong Form:**

- Prices incorporate all publicly available information, including financial statements, news, and economic indicators.
- Fundamental analysis (e.g., evaluating a company's intrinsic value) cannot consistently outperform the market.
- Example: If a company announces higher-than-expected earnings, its stock price adjusts almost immediately to reflect this news.

### **Strong Form:**

- Prices reflect all information, both public and private (insider information).
- Even insiders with non-public information cannot consistently outperform the market.
- Example: A corporate executive's knowledge of an upcoming merger would already be factored into the stock price, making insider trading ineffective.

### **P9-Global Risk-Off Event:**

Occurs when investors, driven by heightened uncertainty or fear, shift their investments from riskier assets to safer, more stable options. Such events typically involve significant market volatility, declining equity prices, and a surge in demand for "safe-haven" assets like government bonds, gold, or the US dollar. Investors' reduced risk appetite would result in capital outflows from emerging markets and capital inflows into developed markets causing a tightening of financial conditions globally. Investors would typically sell equities, corporate bonds, and emerging market assets and purchase safe-haven assets such as US Treasury bonds, gold, and the Japanese yen. Equity indices (e.g. S&P 500, FTSE, Nikkei) would experience sharp declines, developed market bond prices would rally (falling yields), and volatility as measured by indices like the VIX ("fear gauge") would increase. These events are often triggered by geopolitical tensions, economic downturns, pandemics, or financial crises that create uncertainty about the future economic landscape.

## P10-Risk Statistics:

In this thesis several investment strategies are back-tested with important risk statistics. The general limitations of the risk statistics are that they use historical data which may not reflect future performance, and they do not account for the timing of returns. Thus, risk statistics should be combined and not used in isolation. The definitions of these key risk statistics are provided below:

### **Standard Deviation:**

Measures the dispersion or variability of a set of data points (e.g., investment returns) around their mean and assumes the data follows a normal distribution. In finance, it quantifies the risk or volatility of an asset's returns, Markowitz (1952).

Equation 2 : Standard Deviation

$$\sigma = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2},$$

where  $x_i$  is each return,  $\bar{x}$  is the mean return, and  $n$  is the number of returns.

### **Skewness:**

Measures the asymmetry of the data distribution. Positive skewness indicates a distribution with a long right tail (higher returns or data points are more probable), while negative skewness suggests a long left tail (lower returns or data points are more probable), Pearson, K. (1895).

Equation 3 : Skewness

$$\text{Skew} = \frac{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^3}{\left( \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2} \right)^3}.$$

### **Kurtosis:**

Measures the "tailedness" of a distribution. High kurtosis indicates heavy tails (outliers are more likely), while low kurtosis indicates light tails, DeCarlo (1997). As an example, if extreme outliers like a +25% gain or loss in an asset is observed in one month, this would indicate an asset with high kurtosis (called leptokurtic). An asset would be low kurtosis (called platykurtic) if it maintains returns consistently between -1% and +1%. Kurtosis helps assess the likelihood of extreme returns or data points.

Equation 4 : Kurtosis

$$\text{Kurtosis} = \frac{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^4}{\left( \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2} \right)^2}.$$

### **Omega Ratio:**

Compares the probability-weighted gains to losses for a given return threshold. It is a risk-return metric that emphasises both the magnitude and frequency of returns above a benchmark. An omega ratio greater than 1 suggests that the potential gains outweigh the potential losses, making the investment more attractive to investors who are risk-averse., An omega ratio less than 1 indicates the opposite and that the investment might not be a good choice for risk-averse investors. An omega ratio of 1 means that the potential gains and losses are equally likely. Below is the formula to calculate the omega ratio

Equation 5 : Omega Ratio

$$\Omega(r) = \frac{\int_r^{\infty} [1-F(x)] dx}{\int_{-\infty}^r F(x) dx},$$

where  $F(x)$  is the cumulative distribution function of returns, and  $r$  is the return threshold, Keating and Shadwick (2002).

### Maximum Drawdown (Max DD):

Is the largest observed loss of an asset or portfolio from a cumulative peak to a trough before a new cumulative peak is achieved. It measures the downside risk of an investment, Zakamulin (2015).

Equation 6 : Max Drawdown

$$\text{Max Drawdown} = \max_{t \in [1, T]} \left( \frac{\text{Peak}_t - \text{Trough}_t}{\text{Peak}_t} \right).$$

### Value at Risk (VaR):

Estimates the potential loss in portfolio value over a specified period at a given confidence level. It answers, “What is the worst-case loss one might expect with X% confidence?”, in a given timeframe such as a day, Jorion (2007). The VaR formula assuming a normal distribution of returns is given below:

Equation 7 : Value at Risk

$$\text{VaR}_\alpha = F^{-1}(\alpha)\sigma\sqrt{t} + \mu t ,$$

where  $F^{-1}(\alpha)$  is the inverse cumulative standard normal distribution at confidence level  $\alpha$ ,  $\sigma$  is the portfolio standard deviation,  $\mu$  is the portfolio mean return and  $t$  is the time period. VaR can also be computed assuming a different return distribution (e.g. Weibull, Students T, Pareto, Logistic etc.), based on historical return data or using Monte Carlo simulated returns.

As an example, if a portfolio of stocks has a one-day 5% VaR of R1 million, that means that there is a 5% probability that the portfolio will fall in value by more than R1 million over a one-day period if there is no trading. Informally, a loss of R1 million or more on this portfolio is expected on 1 day out of 20 days (5% probability).

### Conditional Value at Risk (CVaR):

CVaR or expected shortfall, estimates the average loss beyond the Value at Risk (VaR) threshold at a given confidence level, Rockafellar and Uryasev (2000). In other words it can be described as “What is the maximum percentage one can expect to lose with 95% or 99% confidence over the next year?”. The CVaR can be calculated using the variance covariance method, historical returns or using Monte Carlo simulation.

### Present Value per Basis Point (PV01):

Is a measure of a bond's volatility. It represents the change in a bond's value when its yield changes by 0.01%. PV01 is used to calculate how a bond's price changes in response to interest rates, Fabozzi (2007). It can be calculated as the bond's modified duration multiplied by the all-in bond price (e.g. 6 years modified bond duration multiplied by R105 all-in bond price = R630 PV01 per R1 million nominal or R0.063 PV01 per 100 nominal). Thus, if the bond's yield moves up (down) 1bp, we can expect a R0.063 decrease (increase) in the all-in bond price. Note that the PV01 assumes a linear bond price to yield relationship and does not account for the convexity of the bond.

### Convexity

Captures the curvature of the bond price to yield relationship. It is important for estimating bond price changes for larger yield or interest rate shifts, Fabozzi (2007). Convexity adjusts duration estimates for non-linear shifts using the below formula:

Equation 8 : Convexity

$$\Delta P = -D_{Mod} \cdot \Delta y \cdot P + \frac{1}{2} \cdot Convexity \cdot (\Delta y)^2 \cdot P ,$$

where  $D_{Mod}$  is the modified duration,  $\Delta y$  is the change in yield,  $P$  is the all-in bond price and  $Convexity$  is the measure of curvature. If precision is required for larger yield changes, a convexity adjustment should supplement PV01 or duration-based calculations.

## P11-Data

The data utilised in this thesis was sourced from Bloomberg, IRESS, and The World Bank. A comprehensive review of the data was conducted to identify and address any anomalies or outliers. The swap and bond curves, as well as time series of market and economic indicators, were visually inspected to ensure consistency with realistic patterns. Missing or erratic data points (e.g., irregular or extreme curve shapes) were examined, and any detected anomalies were assessed to confirm that they fell within an acceptable tolerance relative to surrounding points.

To quantitatively detect outliers and anomalies, we applied a Z-Score analysis to each data series based on its six most recent observations. Data points with Z-Scores within the interval  $[-2.5, +2.5]$  were deemed acceptable. For values falling outside this range, we performed a detailed inspection of the affected data series and related series to determine whether the observation represented an unacceptable outlier or an acceptable anomaly.

For missing yield curve data, we used linear interpolation between the corresponding points (e.g. interpolating between the 12-year and 15-year bond yields to determine the 14-year bond yield) and used a simple linear regression model with correlated variables to assess the accuracy of the missing point (e.g. regressed the USDZAR exchange rate on the 14-year bond yield to determine the sensitivity and expected values).

## Introduction

*"Risk premia are the rewards for bearing systematic risks in financial markets. Understanding their dynamics is key to constructing robust investment portfolios." - Andrew Ang (Managing Director of BlackRock's Systematic investment team)*

### Objectives:

- Briefly discuss active versus passive versus factor investing and the extension to fixed income factors, fixed income butterfly strategies, non-parallel risk premia, the efficient market hypothesis and market segmentation theory.
- Provides an outline of the various chapters, contributions to the literature and objectives of the thesis.

### I-1 Active versus Passive Investing

The debate between active and passive investment strategies has long been at the forefront of how investors approach portfolio management. Historically, active management dominated the investment landscape, with fund managers striving to outperform the market through stock selection, market timing, and other discretionary techniques. However, the past few decades have witnessed a seismic shift towards passive investing, driven by the rise of index funds and exchange-traded funds (ETFs). This shift has also given rise to factor investing and smart beta strategies, which seek to blend elements of both concepts, offering a rules-based approach that captures systematic risk premia. Ang (2014) and Bender (2013) provide a systematic approach to factor investing, discussing how to construct portfolios based on persistent risk factors like value, size, momentum, low volatility and profitability. Asness et al. (2013) introduce a quality-minus-junk (QMJ) factor, which captures the premium associated with high-quality firms (those with strong profitability, low debt, and stable earnings) and argue that quality stocks tend to outperform junk stocks over time. While initially prominent in equities, factor investing is gaining traction in the fixed income space, promising to reshape the landscape of bond investing. Bieri and Chincarini (2005) identify a fixed income factor that exploits an upward-sloping yield curve by purchasing longer-term bonds, holding them for a period, and then selling them before maturity as they move down the curve to shorter maturities. They note the strategy is effective over the long-term but risky over the short-term due to its higher duration and reinvestment risk.

## I-2 The Rise of Passive Investing

The popularity of passive investing can be largely attributed to the Efficient Market Hypothesis (EMH) which is described in-depth in the appendix. EMH posits that financial markets are highly efficient, making it exceedingly difficult for active managers to consistently generate alpha. The EMH suggests that asset prices reflect all available information, so consistently outperforming the market on a risk-adjusted basis is near impossible. Fama (1970) introduced weak, semi-strong, and strong forms of EMH based on liquidity, investor sophistication, and information access. The early 1900s were characterised by weak-form efficiency at best, with significant inefficiencies due to limited information flow, lack of regulation, and insider trading. Post the 2008 financial crisis market efficiency improved due to greater information flow and technological advancements suggesting semi-strong to strong forms of EMH. Seminal studies such as Jensen (1968) have provided empirical support for this view, highlighting the challenges faced by active managers in outperforming market benchmarks after accounting for fees and transaction costs. Research by Martineau (2021) questions long-term predictability, citing post-earnings announcement effects and attributing them to time-varying risk premia or behavioural biases. Risk premia is the reward for taking on risk and is defined as the expected return over a known risk-free asset. Our analysis challenges the strong EMH idea specifically in bond markets, identifying swap and bond risk premia as a source of consistent excess returns over the study period.

Passive strategies, by contrast, aim to replicate the performance of market indices at a lower cost, offering investors broad diversification and transparency. The exponential growth of ETFs and index funds over the past two decades underscores this trend. According to Morningstar (2023), global assets under management in passive funds (ETFs) surpassed \$11 trillion in 2023, with the traditional asset classes of equity and fixed income attracting the most flows. Figure 1 is reproduced from State Street Global Advisors which uses data from Morningstar (2023). The bar chart shows the growth in total ETF assets under management from just under \$1 trillion in 2008 to \$11 trillion in 2023.

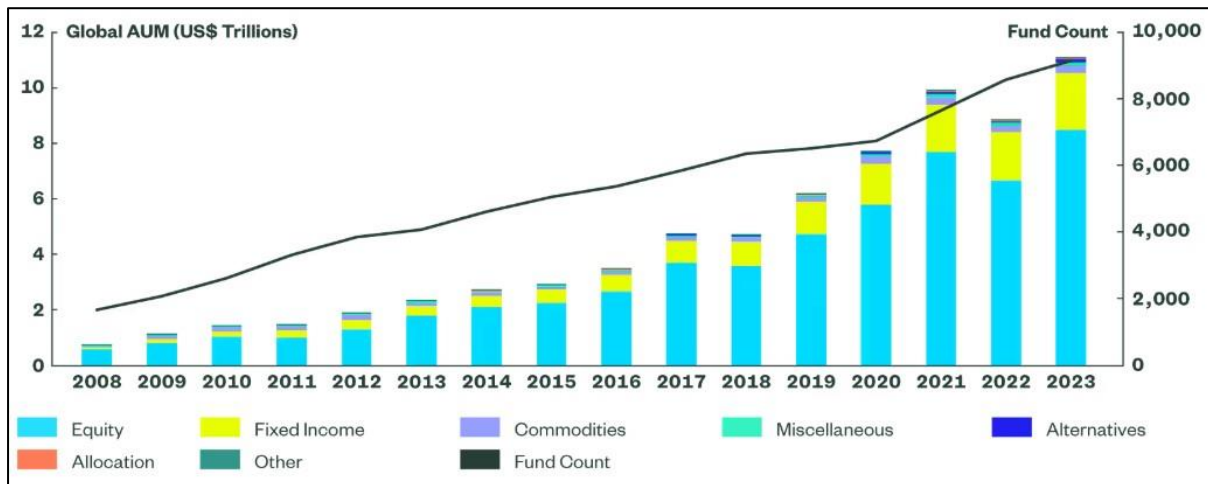


Figure 1 – Reproduced from State Street Global Advisors which uses data from Morningstar. The bar chart shows the growth in total ETF assets under management from just under \$1 trillion in 2008 to \$11 trillion in 2023. Equity and fixed income being the traditional asset classes attracted the most ETF flows.

Despite their popularity, passive strategies have limitations. For instance, traditional market-cap-weighted indices often exhibit a concentration risk, with a small number of large issuers dominating performance. Additionally, by merely tracking the market, passive funds may expose investors to unintended factor tilts, such as momentum or value biases.

### I-3 Factor Investing and Smart Beta: Bridging the Divide

Factor investing emerged as a middle ground between active and passive management, seeking to capture systematic sources of return, or risk premia, that have been empirically shown to persist over time. Common factors include value, size, momentum, quality, and low volatility, which have been extensively studied in academic literature (e.g., Fama and French, 1993; Carhart, 1997). Smart beta, a subset of factor investing, applies these principles to index construction, offering investors a cost-effective way to access factor exposures through ETFs.

The advantages of factor investing are manifold. By targeting specific drivers of return, investors can tailor portfolios to align with their risk-return preferences. Additionally, factor-based strategies often exhibit lower costs than traditional active funds while providing the potential for enhanced returns relative to market-cap indices. However, factor investing is not without challenges. Factors can experience extended periods of underperformance, requiring investors to maintain a long-term perspective. Furthermore, factor crowding, where too many investors chase the same factors, can diminish returns.

## I-4 Expansion into Fixed Income

While factor investing has become well-established in equities, its adoption in fixed income markets has been slower. Fixed income securities, such as government and corporate bonds, exhibit unique characteristics, including varying maturities, credit ratings, and liquidity profiles. These complexities have historically limited the applicability of equity-based factor models to bonds. However, recent advancements in data availability and modelling techniques have paved the way for factor-based approaches in fixed income.

Research has identified several factors that drive returns in fixed income markets, including term, credit, liquidity, and carry premiums. For instance, the term premium reflects the compensation investors receive for holding long-duration bonds, while the credit premium captures the additional yield associated with default risk and/or credit rating changes. Liquidity risk is the risk that an investor may not be able to buy or sell a bond quickly or at a fair price due to a lack of interested market participants. Carry risk refers to the risk that the expected return from holding a bond (the carry trade) does not materialise due to changes in interest rates, credit spreads, or funding costs. Initial research was conducted by Fama and French (1993) who suggested that factors driving stock returns could also drive bond returns of the same company assuming frictionless markets. Houweling and van Zundert (2017) and Dekker, Houweling and Muskens (2021) and Henke, Kaufmann, Messow and Fang-Klingler (2020) have used issuer's accounting ratios to define factors such as size, low volatility, value, growth, quality and momentum.

The proliferation of fixed income ETFs has further facilitated the adoption of factor investing in this asset class. According to BlackRock (2023), fixed income ETFs saw record inflows of \$500 billion in 2022, highlighting growing investor interest. These products offer a convenient way to implement factor-based strategies in bond portfolios, combining the transparency and cost-efficiency of ETFs with the targeted exposure of smart beta indices.

## I-5 Challenges for Active Management

The rise of passive and factor-based strategies has posed significant challenges for active managers. One key reason is the growing efficiency of financial markets, driven by advancements in technology, data availability and sophisticated trading algorithms which decreases the potential for active managers to exploit informational advantages.

Moreover, the high fees associated with active management have come under increasing scrutiny. Studies such as those by S&P Dow Jones Indices (2023) consistently show that most active managers underperform their benchmarks over the long term, even before accounting for fees. This has led many investors to question the value proposition of active management, particularly in low yielding environments and heightened competition.

## I-6 Factor Investing - A Compelling Alternative

Factor investing addresses many of the shortcomings of both active and passive approaches. By focusing on systematic drivers of return, factor strategies offer the potential for outperformance in a transparent and cost-effective manner. Unlike traditional active management, factor investing relies on a disciplined, rules-based approach, reducing the reliance on human judgment and minimising behavioural biases.

Moreover, factor investing aligns well with the principles of EMH. While the hypothesis suggests that markets are generally efficient, it also acknowledges the existence of risk premia that represent compensation for bearing specific types of risk.

In the fixed income space, factor investing is particularly appealing given the limitations of traditional benchmarks. Market-cap-weighted bond indices, for example, often overweight the most indebted issuers, potentially exposing investors to greater credit risk. Factor-based approaches provide a more nuanced framework, allowing investors to optimise their risk exposures and enhance diversification.

The evolution of the active versus passive debate has given rise to innovative investment approaches that combine the best of both worlds. Factor investing and smart beta strategies have emerged as powerful tools for capturing systematic sources of return, offering investors a cost-effective and transparent alternative to traditional active management. While equities have been the primary focus, the growing adoption of factor investing in fixed income markets underscores its versatility and appeal.

As the investment landscape continues to evolve, the interplay between active, passive, and factor-based strategies will remain a critical area of exploration. By leveraging the insights of academic research and advancements in technology, investors can navigate the complexities of modern markets with greater confidence and precision.

## I-7 Fixed Income Butterfly Risk Premia

In this thesis we will identify cross-sectional risk premia/factors within the South African interest rate market by focusing on so-called butterfly factors. The South African market was selected as we found it to be optimal in terms of monetary and fiscal regimes to maximise risk premia returns.

A fixed income butterfly strategy is an active bet on the shape of the yield curve. It involves selecting three points on the interest rate curve (a short-, medium-, and long-dated point). The medium-dated point is known as the body whilst the short- and long-dated points are known as the wings. A long butterfly strategy takes a long position in the body and a short position in the wings, whilst a short butterfly takes a short position in the body and long position in the wings all in a duration neutral manner.

A duration neutral position is taken so that the butterfly strategy is immune to parallel curve changes and instead, takes active bets on the slope and curvature of the yield curve. Duration neutral refers to the average level of interest rates across all maturities. So, if all interest rates across the curve move up or down by the same amount there will be no capital gain or loss and a duration neutral strategy will be immune to parallel curve shifts. If however, interest rates across the curve move by varying amounts, a duration neutral strategy will be exposed to slope and curvature changes resulting in capital gains or losses. In most cases, a reversion butterfly strategy is employed where the three points on the yield curve have deviated from their fair values and are expected to revert to these fair values to realise a profit. We also introduce several duration neutral weight schemes to illustrate their effect and how to apply them given slope and curvature changes.

Butterfly strategies offer much lower return potential relative to the returns available from parallel curve shifts, but this can be solved by leveraging up the position sizes and employing the butterfly strategies as a portable alpha overlay to existing duration strategies. Butterfly strategies are traditionally used by hedge funds due to the required leverage but can also be applied to better manage higher-order interest rate risk in liability-driven investment strategies or to identify over- and under-valued areas of the yield curve for active, long-only funds. For our purposes, we will assume that the butterfly strategy is applied within a hedge fund setting.

Butterfly strategies can also be used to take advantage of idiosyncrasies in the bond market via the expectations theory. An application of MST is that bond and swap investors have preferred maturities to manage their risks and will only invest outside these maturities if the expected

returns on other maturities are more attractive. In the SA context, liability-driven investors and pension funds prefer long-dated bonds/swaps as they provide an efficient hedge against their long-term liability risks. Commercial banks have short-term liabilities in the form of customer deposits so prefer to hedge these risks with short-term bonds/swaps. A governments funding strategy is also an important consideration, which in SA has been to issue long-dated bonds resulting in yield curve steepening. As such, the belly of the SA bond/swap curve is least impacted by institutional demand and supply characteristics and a better reflection of economic fundamentals. Thus, butterfly strategies which emphasise medium-dated bond/swap exposure provide attractive opportunities to exploit non-parallel risk premia.

## I-8 Contribution to the Literature

The contribution of our thesis to the literature is to:

1. Analyse non-parallel risk premia beyond the usual absolute spread factor by identifying new butterfly factors/risk premia and assess their performance under various curve scenarios, interest rate cycles and market regimes. (Chapters 6 - 9).
2. Identify which interest rate markets and butterfly weighting methodologies are appropriate to maximise non-parallel risk premia (Chapters 1 - 5), and
3. Develop a profitable and pragmatic non-parallel risk premia investment strategy by minimising trade and rebalancing costs (Chapters 8 - 10).

The absolute spread factor was adopted in the literature due to its ease of calculation, high convexity and safety margin. This is a plausible criteria selection in that a long butterfly strategy with a positive absolute spread is attractive relative to a long butterfly with a negative absolute spread as positive interest is earned over the holding period which offers a margin of safety. This was demonstrated by Jones (1991) who considered a small sample of US butterfly strategies and compared their performance under non-parallel curve scenarios. They concluded that butterfly strategies with higher absolute spreads offered improved absolute and risk-adjusted returns over the long-term relative to butterfly strategies with lower absolute spreads. We also confirm that the absolute spread factor is a credible butterfly factor but sought to expand the butterfly factor universe to understand their unique characteristics so that a successful investment strategy could be developed.

## I-9 Objectives:

1. Addressing the effects of non-parallel curve movements caused by global risk-off events on several sovereign yield curves by using a PCA approach (see Appendix B which describes PCA in detail).
2. Identifying which monetary and fiscal regimes are appropriate to maximise non-parallel risk premia.
3. Analysing several butterfly weight schemes in the South African swap and bond markets to determine which weight scheme is appropriate for our non-parallel risk premia application.
4. Develop and evaluate cash and duration neutral butterfly strategies to optimise non-parallel risk premia in South Africa which was shown to have the optimal monetary and fiscal environment to maximise non-parallel risk premia returns.
5. Assess the behaviour of the non-parallel risk premia in the South African interest rate market under various curve scenarios, interest rate cycles, risk-off events and their relation to financial and economic indicators.
6. Highlight the importance of pragmatic rebalancing frequencies which can severely impact non-parallel risk premia returns if the strategy is rebalanced too frequently.

## I-10 Outline of Chapters

To optimise and extract non-parallel risk premia we will provide context, definitions and results within the thesis outlined as follows:

- Chapter 1 explores the application of principal component analysis and butterfly strategies across sovereign yield curves in emerging (EM) and developed markets (DM), identifies key drivers of yield curve movements and global risk-off events, and highlights financial globalisation's dual impact on growth and volatility and provides evidence of a rise in global risk-off events. Applies PCA to SA swap and bond curves to assess the relationship between non-parallel risk and global risk-off events, including a brief discussion on EMH.
- Chapter 2 outlines yield curve scenarios and their implications for butterfly strategies, highlighting frequent bullish trends in EMs.

- Chapter 3 evaluates long butterfly strategies in EM and DM using zero-coupon bonds, showing higher returns in steeper, positively curved markets.
- Chapters 4-5 analyses the interplay between monetary/fiscal policies and butterfly weight schemes, focusing on South Africa's unique dynamics.
- Chapter 6 develops methodologies for exploiting non-parallel risk premia.
- Chapters 7-9 assesses butterfly factor performance across interest rate cycles, curve scenarios, and rebalancing frequencies.
- Chapter 10 delves and factor correlations with financial and economic indicators.
- Finally, Chapter 11 synthesises findings, emphasising tactical allocation insights and suggesting future research directions.

## Rationale and Primary Aims

### Rationale for our Topic:

#### Challenges in Fixed-Income Markets Amid Rising Macro Risks

The frequency and impact of high-risk macroeconomic events on financial markets have increased significantly, creating a challenging environment for investment. Within fixed-income markets, duration and credit risk premia have traditionally been the primary drivers of returns. However, these premia have become increasingly precarious due to declining yields and compressed credit spreads.

#### Persistence and Intensification of Macroeconomic Risks

Given the current backdrop of social and political polarisation, cost-of-living crises, economic downturns, geopolitical tensions, the influence of modern monetary theory, escalating debt issuance, and persistent fiscal deficits, it is anticipated that high-risk macroeconomic events will not only persist but potentially intensify. Consequently, identifying alternative fixed-income risk premia to diversify risk and mitigate capital volatility has become imperative.

#### Exploration of Alternative Fixed-Income Risk Premia

In response to these challenges, this study explores the development of alternative risk premia by defining and utilising several butterfly factors. These factors are designed to extract non-parallel risk premia under conditions of heightened macroeconomic risk and to determine the financial markets in which such premia are most effective.

#### Butterfly Factors and Investment Strategy Development

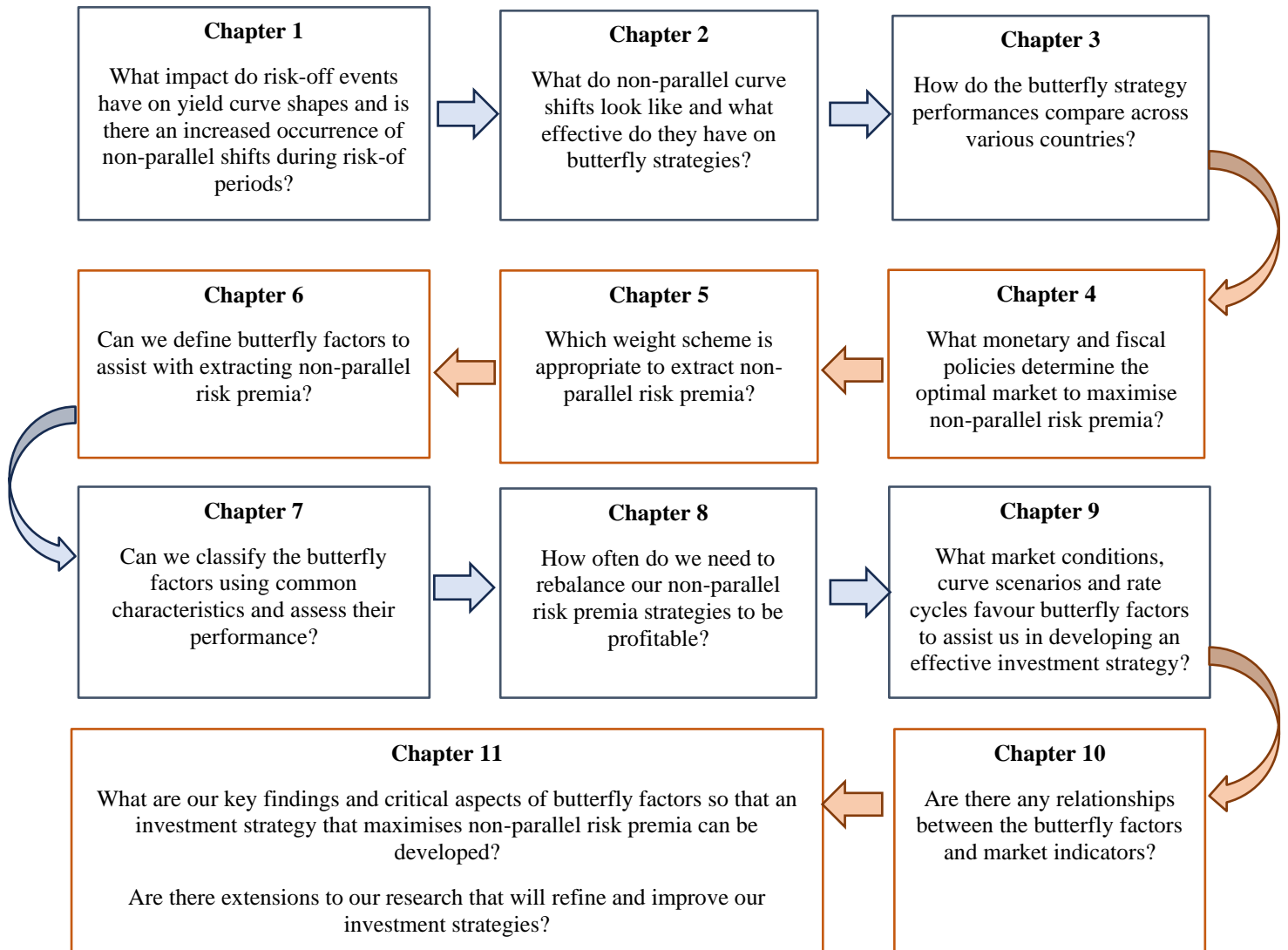
Through an in-depth analysis of the risk and return profiles of butterfly factors across various yield curve scenarios, market regimes, and interest rate cycles, this research explains their characteristics and behaviour. Furthermore, by optimising the weighting schemes of butterfly factors and refining rebalancing frequencies, a robust and profitable investment strategy was developed, demonstrating the viability of these factors as an alternative source of fixed-income risk premia.

### Our primary aims in this thesis are to:

1. Understand how the yield curve shifts during risk-off events.
2. Determine which markets and policies are optimal for extracting non-parallel risk premia.
3. Define and understand butterfly factors under several curve scenarios, market conditions and rate cycles.
4. Select the appropriate weight scheme and rebalancing frequencies to increase profitability.
5. Use our findings to develop an investment strategy to extract non-parallel risk premia.

## Idea Flow Chart

The flow chart below provides the key questions that each chapter seeks to answer. This high-level picture will assist the readers in navigating through the detailed chapters of this thesis.



## Thesis Flow

A brief flow of this thesis is provided on below which outlines the objectives and key points of each chapter to provide the reader with a holistic representation of our topic. We also provide a preamble to provide the reader with relevant background that will be used throughout this thesis.

### Introduction

- Discussing the active versus passive investment debate, extension into fixed income factor investing, our contribution to the literature and objectives.
- Defining butterfly strategies and their applications to the fixed income market which will be used to extract non-parallel risk premia throughout this thesis beyond the popular absolute spread factor.
- Adapting the efficient market hypothesis and market segmentation theory to the SA fixed income market. The strong form EMH will be disproved in the later chapters as select risk premia with positive returns will be identified in the SA market.

### Chapter 1: Principal Component Analysis and Risk-Off Events

- PCA is used to determine the variation explained by parallel shifts (duration) and non-parallel shifts (slope, curvature) in several EM and DM sovereign yield curves.
- Identify prominent global risk-off events, correlations and discuss how idiosyncratic events in major DM countries impact other economies, particularly EMs.
- The analysis highlights that while financial globalisation has spurred growth, it also increases the risk of financial crises due to heightened price volatility especially from rising debt levels, geopolitical risk, inequality, social and political polarisation and cost-of-living crises. These volatile periods were expected to continue given monetary policies, and rising inequality and geopolitical risk.
- PCA was applied to monthly South African swap and bond data and found that periods of high macro-economic risk coincide with increased occurrences of non-parallel curve shifts.
- We elaborate on the weak, semi and strong efficient markets hypothesis (EMH)

### Chapter 2: Curve Scenarios

- This chapter describes 1st, 2nd and 3rd-order yield curve scenarios that have occurred in both EM and DM countries.
- A summary of these scenarios and impact on long and short butterfly strategies is presented.
- We also analyse the frequency of interest rate cycles and curve changes in EM and DM, noting a higher proportion of bullish interest rate scenarios due to lower inflation over the historical period.

### Chapter 3: EM and DM Butterfly Analysis

- This chapter assesses the return prospects of a cash and duration-neutral long butterfly strategy across the various EM and DM countries using generic zero-coupon sovereign bonds. Performance is evaluated using monthly rebalancing and assuming zero trade costs.
- Performance statistics for EM and DM long butterfly strategies are presented, highlighting the relationship between slope, curvature, volatility, and returns.
- We see that countries with steeper slopes and positive curvature tend to have higher butterfly return potential.

### Chapter 4: Monetary and Fiscal Scores

- This chapter gives a brief history on the transition from the gold standard to the fiat currency system describing the impact on inflation and debt.
- It also explores the impact of monetary and fiscal policies on the profitability of butterfly strategies by utilising a quantitative approach to assess the tightness or looseness of monetary and fiscal policies in different countries using various economic indicators.
- The chapter concludes that South Africa offers significant potential for butterfly strategies due to its unique combination of tight monetary and loose fiscal policies, high absolute yields, sensitivity to risk-off events, and a cyclical economy dependent on commodity exports.

### Chapter 5: Butterfly Weight Schemes

- This chapter introduces five butterfly weight scheme that are adapted from Hariparsad and Maré (2023.2) and Martellini et.al (2002).
- The various approaches to weighting the short and long-dated points in a fixed income butterfly strategy are explained.
- Slope durations are defined with a sensitivity example and a back-test methodologies using SA swap and bond markets is applied to determine the appropriate butterfly weight scheme to be used for our non-parallel risk premia.

### Chapter 6: Exploiting Non-Parallel Risk Premia

- This chapter delves into the methodology for exploiting non-parallel risk premia, introducing ten swap and bond butterfly factors.
- It also describes the process of selecting butterfly strategies based on these factors, ranking them based on month-end values to choose the top and bottom three for analysis.

## Thesis Flow (continued...)

### Chapter 7: Performance and Risk Statistics of Swap and Bond Butterfly Factors

- This chapter presents the performance and risk statistics for the selected swap and bond butterfly factors.
- It highlights the top-performing factors and their key characteristics, such as high absolute spreads, risk premiums, positive NSS differences, strong carry and roll metrics, wide break-even inflation spreads, and low swap spreads.
- The chapter introduces the concept of dominant and defensive factors, grouping the factors based on their risk and return profiles. Dominant factors displayed higher returns but greater volatility and drawdowns. Defensive factors displayed lower returns and volatility and acted as a hedge with reduced drawdowns.

### Chapter 8: Rebalancing Frequencies

- This chapter explores the impact of rebalancing frequencies on the performance of butterfly strategies.
- It compares monthly and quarterly rebalancing frequencies, considering trade costs.
- The analysis shows that monthly rebalancing generally yields higher gross returns but incurs greater trading costs.
- The choice of rebalancing frequency depends on the specific factors and strategies employed.

### Chapter 9: Scenario Analysis

- This chapter analyses the performance of the swap and bond butterfly factors under various curve scenarios, interest rate cycles, and risk-off events.
- Cutting cycles have occurred more frequently relative to hiking cycles owing to declining and relatively stable inflation in SA due to a hawkish central bank and below trend growth post the 2008 global financial crisis.
- The most common types of scenarios under interest rate cuts are bull steepening, bear steepening and bull flattening. During interest rate hikes short-dated rates rise more than long-dated rates leading to curve flattening, thus bear flattening, bull flattening, and flat twists would be expected.
- Average gross monthly butterfly factor returns were analysed under different scenarios, including parallel shifts, bull/bear steepening/flattening, twists, and global risk-off events.
- The chapter provides insights into the performance characteristics of dominant and defensive factors across these scenarios, demonstrating their strengths and weaknesses under specific market conditions.
- It emphasises understanding the behaviour of different factors in diverse market environments for effective tactical asset allocation.

### Chapter 10: Correlations to Financial and Economic Indicators

- This chapter explores the correlations between swap and bond butterfly factors and various financial and economic indicators.
- It uses bar charts and tables to illustrate the relationships between these factors and indicators like bond indices, currencies, commodities, equities, economic indicators, volatility measures, and credit spreads.

### Chapter 11: Summarised Chapter Conclusions

- This chapter summarises the key findings of this thesis, highlighting the superior performance of top-ranked swap and bond factors, particularly the all-factor rank (AFR) approach.
- It reiterates the importance of considering trade costs when evaluating butterfly strategies.
- The chapter suggests future research directions, including further analysis of rebalancing frequencies, optimisation techniques, and incorporating macroeconomic variables into factor models.
- The analysis helps to understand the drivers of factor performance and identify potential signals for tactical allocation decisions.
- The chapter emphasises the importance of integrating factor analysis with macroeconomic and financial market insights for successful portfolio management.



# Chapter 1



## Chapter 1 - Principal Component Analysis and Risk-Off Events

*"In financial markets, higher-order risk is often rooted in psychology and collective behaviour, where small events accumulate into large systemic risks." - Robert Shiller (Economist, Nobel Laureate)*

### Objectives:

- Analyse the variation in EM and DM sovereign yield curves caused by parallel shifts (duration) and non-parallel shifts (slope, curvature).
- Identify prominent global risk-off events and their correlations.
- Examine how major idiosyncratic events in DM economies influence EM economies.
- Highlight how financial globalisation fosters growth but also increases financial crisis risks due to heightened price volatility especially from rising debt levels, geopolitical risk, inequality, social and political polarisation and cost-of-living crises.
- Apply principal component analysis to monthly South African swap and bond data.
- Show that periods of high macro-economic risk coincide with increased occurrences of non-parallel curve shifts.
- Propose continued volatility due to modern monetary policies, rising inequality, and geopolitical risk.
- Discuss weak, semi-strong, and strong efficient markets hypotheses (EMH), which will be disproved by defining SA non-parallel risk premia in Chapter 7 - Performance and Risk Statistics of Swap and Bond Butterfly Factors.

The work in this chapter is based on the below publications:

- Investments Analysts Journal - Hariparsad, S. and Maré, E (2023.1),
- The South African Journal of Economic and Management Sciences - Hariparsad, S. & Maré, E. (2024.1),
- The Journal of Risk and Financial Management - Hariparsad, S. and Maré, E. (2024.2).

## 1.1 PCA Methodology for Yield Curves

In this chapter we compare and analyse several EM and DM sovereign yield curves using a PCA (principal component analysis) approach. The DM countries that we compare are the United States (US), United Kingdom (UK), Germany (GER), France (FRA), Canada (CAN) and Australia (AUS). The EM countries that we analyse consist of South Africa (SA), Brazil (BRA), Turkey (TRL), Mexico (MEX), Indonesia (INR), India (IND) and China (CNY). We obtain generic sovereign yields (i.e. generic 3-month, 2-, 3-, 5-, 10-, 15- and 30-year yields) for each sovereign curve. For some countries generic yields did not exist so we linearly interpolated for those points. If no 30-year generic yield existed, we assumed the curve was flat from the next closest generic point (i.e. 10- or 15-year yield out to 30-year yield) to reduce extrapolation error and extreme values. From this we fitted a Nelson Siegel Svensson curve so that smooth approximations were created, and we could obtain yields for all points on the sovereign curve (please see the appendix for more detail about Nelson Siegel Svensson). The generic yield curve data was obtained from Bloomberg for all countries except SA as we were able to obtain a longer history from IRESS.

Once we obtained smooth yield curves for all the EM and DM countries, we calculated the average annual yields for integer maturities in the 0-3 year, 3-7 year, 7-12 year, 12-20 year and 20+ year maturity buckets. From this, monthly yield changes for each of the five maturity buckets were calculated such that each maturity bucket represented a fixed income asset class. We then calculated a rolling one-year PCA by using the last 11 monthly yield changes for each maturity bucket. PCA is a fundamental technique in statistical analysis and machine learning used for dimensionality reduction. Abdi and Willaims (2010) and Jolliffe and Cadima (2016) describe PCA as a statistical technique to transform a large set of correlated variables into a smaller set of uncorrelated variables called principal components, which capture the most significant variance in a dataset. PCA identifies patterns and relationships more discernibly, helps reduce noise, recognises key variables and reduces overfitting risk. Nath (2012) applied PCA to the Indian sovereign bond market and found that 2-3 principal components capture most of the variability in the yield curve. Duffie and Singleton (1999) applied PCA to analyse the structure of corporate bond yields and credit spreads and found that corporate bond spreads are systematically linked to PCA risk factors including liquidity, default and firm specific risks. Ang and Piazzesi (2003) used a vector autoregression framework where yield curve factors (from PCA) were linked to inflation, GDP, and monetary policy. They found that the PCA factors were linked to the above macroeconomic factors which improved bond pricing accuracy

compared to standard PCA-based models. Joshlin et al. (2014) also used PCA to extract systematic risk factors in bond markets and linked macroeconomic factors to yield curve movements. As can be seen, PCA helps in better understanding interest rate movements and in developing strategies for risk management and bond portfolio optimisation. Chapter 6.1 Background and Literature on Non-Parallel Fixed Income Factors provides a comprehensive PCA and fixed income factor literature review.

PCA is applied to each of the smooth EM and DM sovereign yield curves across time so that the variation explained by the first moment (known as duration or parallel shifts) can be determined. The remaining variations (second, third, fourth and so on) are known as non-parallel shifts (e.g. slope, curvature and other higher order curve changes). Bauer and Hamilton (2018) elaborate on the work by Litterman and Scheinkman (1991) and go further to describe fourth and fifth order principal components and macroeconomic variables responsible for yield curve changes.

## 1.2 Global and Idiosyncratic Risk-Off Events in EM and DM Regions

Figures 1 and 2 illustrate the proportion of parallel curve shifts for EM and DM regions respectively with EM and DM averages plotted in Figure 3. When the proportion of parallel shifts decreases below its long-term average of 90% it is likely that this was during a risk-off period.

A summary of the prominent global risk-off events is given below:

- 1991 – Gulf war
- 1992/3 – End of the Cold war, splitting of Soviet states and the formation of the Euro.
- 1997/8 - Asian financial crisis and Russian debt default.
- 2000 - Dotcom bubble burst.
- 2001 - 9/11 attacks.
- 2008/9 – Global Financial crisis.
- 2010/12 – European Debt crisis.
- 2015 – Greek debt default and systemic risk to other European nations.
- 2017 – Brexit negotiations begin, far left Republican, Donald Trump US president.
- 2019/20 – COVID pandemic and supply chain disruptions.
- 2022/23 – Ukraine/Russia conflict and cost of living crisis.

The prominent EM and DM idiosyncratic crises are described below with a more detailed summary provided in the appendix:

#### Idiosyncratic events for emerging markets

- Indonesia (2006/07) – Commodity price volatility, natural disasters, and political instability.
- South Africa – End of Apartheid (1992), ANC political party winning majority 70% of national vote, Black Economic Empowerment, mishandling of HIV/AIDS (2003/04). Jacob Zuma elected as South African president after Arms deal and financial corruption charges are withdrawn (2009), Cyril Ramaphosa elected ANC leader and incoming South African president (2017).
- Mexico – Drug-related violence (2010), Energy and telecom sector reforms (2014), political corruption scandals and instability, fiscal policy reforms, and NAFTA renegotiations (2016/17).
- India – Kargil conflict with Pakistan (2001), weak banking sector (2003), corruption scandals (e.g. Commonwealth Games) (2010), GST implemented and increased non-performing assets in banking sector (2018).
- China - Overheating housing market (2010), economic slowdown, US-China trade wars and increased industry regulation (2016-18).
- Turkey – Political instability about government policies (2008), high inflation and government intervention (2010-12), failed coup attempt and economic mismanagement (2015-2019).
- Brazil - Corruption scandals, economic slowdown, high inflation, and political instability (2012-14), political uncertainty from elections, corruption investigations and economic mismanagement (2018).
- Poland – Leadership changes, new economic reforms, and EU ascension (2001-06), slow growth prompted policy adjustments impacting the rule of law and causing economic disruptions (2010-17).

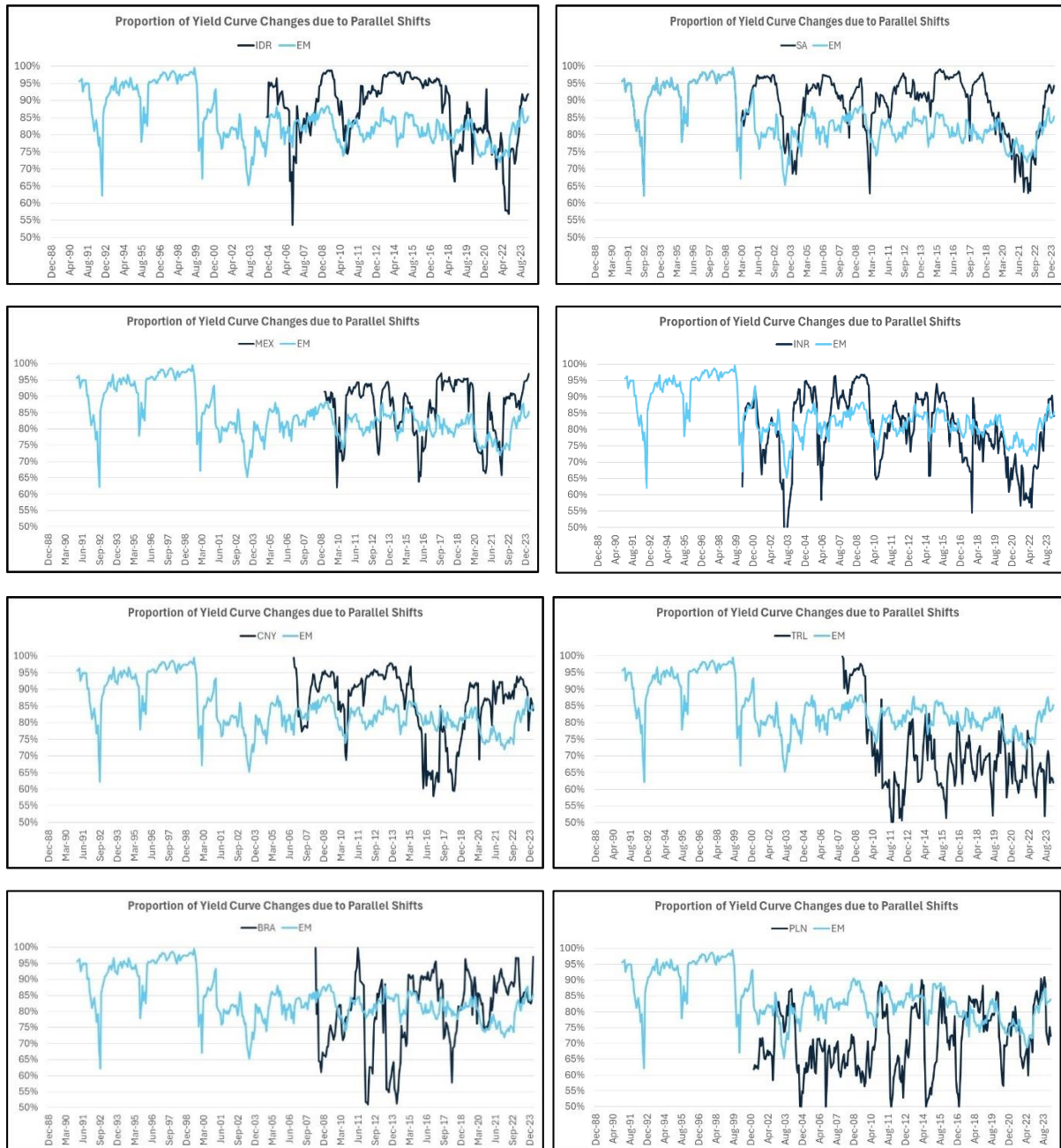
#### Idiosyncratic events for developed markets

- France – Strikes and labour protests over pension reform (1998), yellow vest protests (2018-19), Eurozone debt crisis impacting bank sector (2010-14).

- Germany – Reunification impacting fiscal policies (1997-98), German banks under financial strain from global financial and Eurozone debt crises (2008-14), Volkswagen emission scandal impacting corporate profits.
- Japan – Domestic banking sector crises (1993-97), deflation and continued banking sector concerns (2000-03), Abenomic policies to stimulate growth (2014-16).
- United Kingdom - Maastricht Treaty aimed at European integration and a unified currency (1993), BOE granted operational independence in 1997 impacting monetary policies and business confidence, pension fund deficits (1998-2001), austerity measures resulting in economic stagnation and double-dip recession fears (2010-12), Scottish independence and Brexit uncertainty (2014-15), 2019 elections, cost of living crisis and Brexit transitions (2018-23).
- Canada - Economic policy adjustments, volatile currency and managing public debt (1999-2001), Energy exports suffered from strong currency (2004-05), housing market bubble, fiscal austerity, and volatile commodity prices (2011), new government under Justin Trudeau and commodity price decline (2015), cost of living crisis, extreme weather and green energy transition (2021-22).
- United States – President Clinton’s administration pushing for healthcare reforms following election victory over President Bush, high fiscal deficits (1991-93), corporate scandals and LTCM failure affecting market confidence (1997-98), 9/11 attacks and dotcom bubble (2000-02), housing market collapse and banking failures (2008-10), budgetary and fiscal concerns (2012), Obamacare and affordable healthcare act (2014), US-China trade tensions, Donald Trump’s victory at 2020 elections creating political uncertainty, supply chain disruptions (2019-23).
- Australia – GST introduction and large spending for Sydney Olympics (2000), severe drought and housing affordability issues (2003-05), severe natural disasters, reduced exports caused by Eurozone debt crisis and the introduction of a carbon tax (2011), frequent political changes, economic reforms and diversification away from resources (2013-14), increased immigration, housing affordability and energy reliability concerns (2016-17), COVID-19 pandemic induced recession and renewable energy debates.
- Italy – Corporate scandals, banking sector vulnerabilities, weak regulation and transition to Euro (2000-02), high debt levels, and contentious labour and pension reforms (2004-05), severe recession and banking stress from global financial crisis, austerity and political stability (2008-10), constitutional referendum and continued banking sector stress (2016), new government and EU budget disputes (2018), cost of

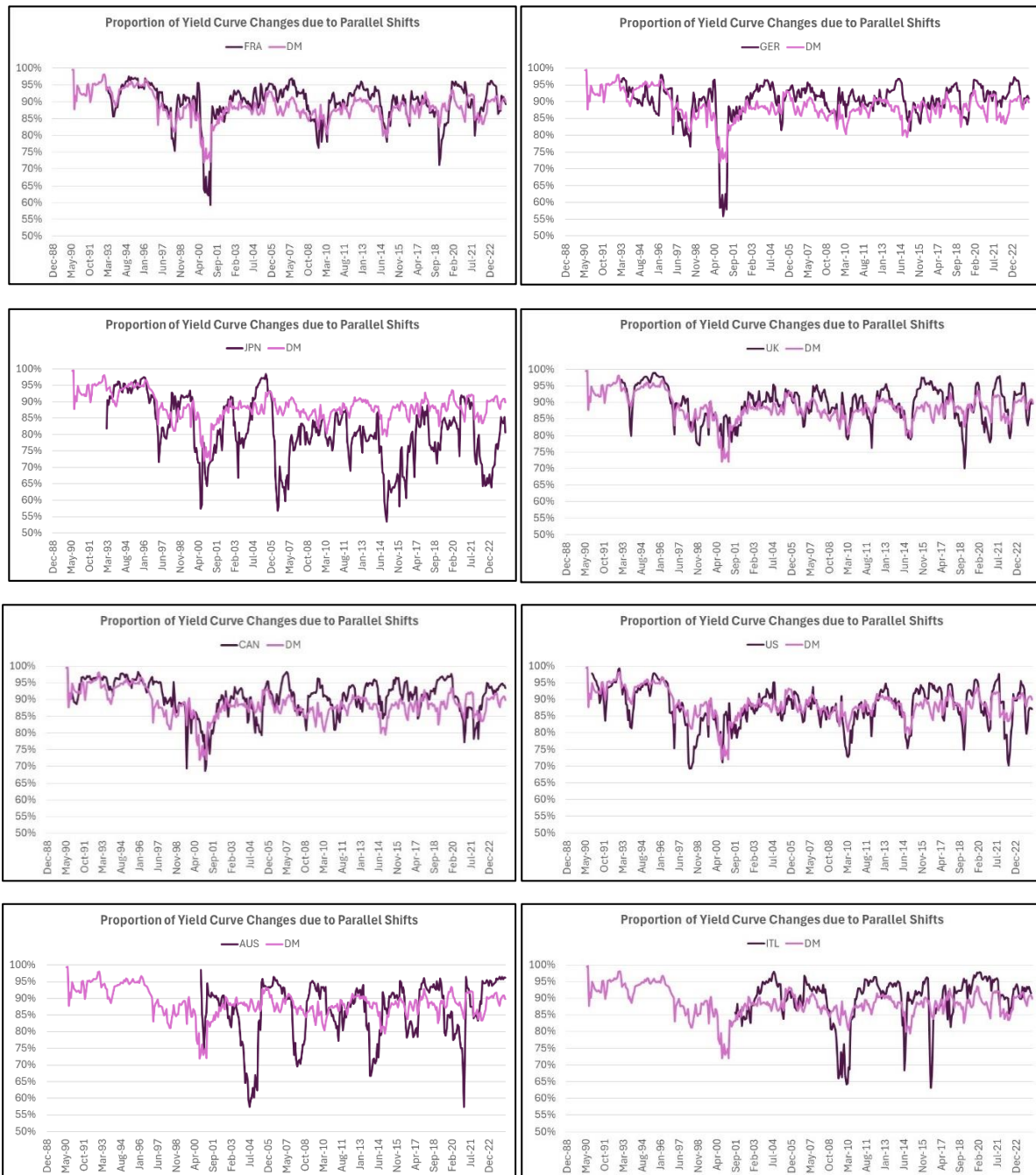
living crisis, EU recovery fund assistance and fragmented government policies (2022 - 23).

### Proportion of Parallel Curve Changes for Emerging Markets

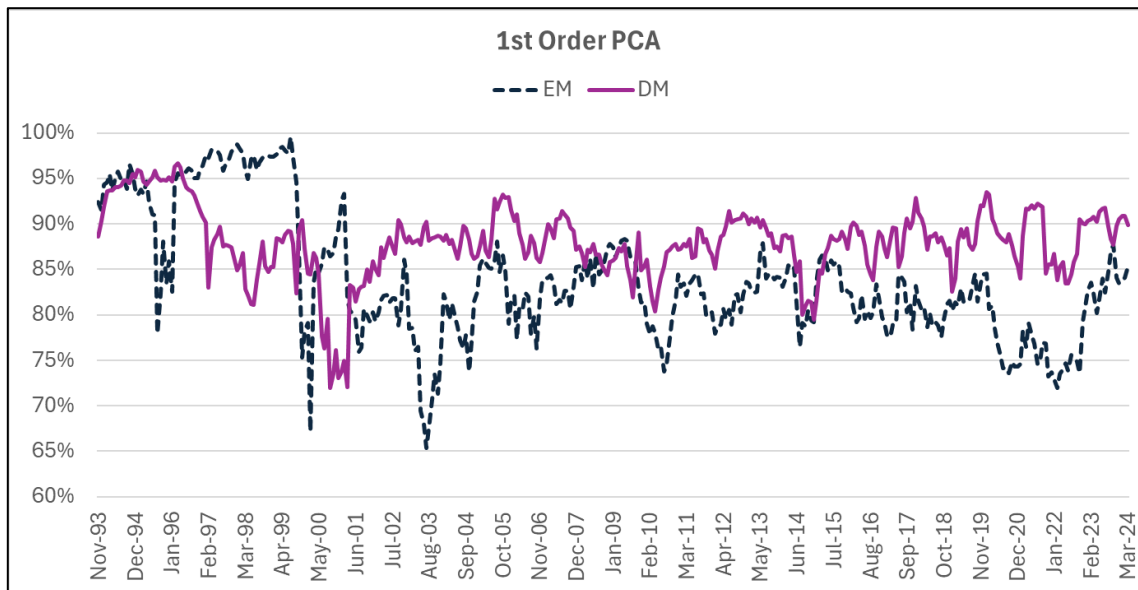


**Figure 2** – Proportion of sovereign curve changes due to parallel curve shifts for several emerging markets (Indonesia, South Africa, Mexico, India, China, Turkey, Brazil and Poland) with the overall EM average from 1990 to 2023. Source Data: IRESS and Bloomberg.

## Proportion of Parallel Curve Changes for Developed Markets



**Figure 3**– Proportion of sovereign curve changes due to parallel curve shifts for several developed markets (France, Germany, Japan, United Kingdom, Canada, United States, Australia and Italy) with the overall EM average from 1990 to 2023. Source Data: IRESS and Bloomberg.



**Figure 4** – Proportion of sovereign curve changes due to parallel curve shifts for emerging and developed markets from 1993 to 2024. The average of the eight EM and eight DM sovereigns are shown with DM curves illustrating a greater occurrence of parallel shifts relative to EM. This implies that DM regions have less volatile curve shapes and risk-off periods relative to EM regions. Source Data: IRESS and Bloomberg.

### 1.3 PCA Comparisons and Correlations

Analysing the proportion of parallel curve shifts through time we notice the following:

- On average, parallel shifts account for 80-90% of DM sovereign curve variations and 70-90% of EM sovereign curve variations. Given the higher frequency of non-parallel shifts in EM relative to DM we can conclude that EM offers greater non-parallel opportunities relative to DM. A reasonable explanation is that DM in comparison to EM has a narrower dispersion of parallel curve shifts due to relatively lower inflation volatility. Bems et al. (2018) highlights that EM experience greater inflation volatility and persistence than DM economies. The authors attribute this to factors such as higher pass-through of external shocks to local prices and a larger share of volatile items in consumption baskets within EM. Lower, absolute inflation levels and inflation volatility are consequences of credible central bank and fiscal policies in keeping to primary mandates of price stability and secondary objectives of economic and employment growth. Marioli et al. (2024) examined the volatility of fiscal policy in EM and DM noting that fiscal policy has been more volatile in EM compared to DM. Such fiscal volatility can contribute to macroeconomic instability, including higher inflation volatility.

- Table 1 shows the 1st order PCA correlations (or relationship of parallel curve shifts between two countries) of the various EM and DM countries from 2009 as this is when all countries had congruent data. We see that there is a slight +18% correlation between EM and DM suggesting that parallel shifts in DM regions have some carry over to EM regions. Drakos (2001) indicated that if the expectations hypothesis holds, monetary policy actions should cause a parallel shift of the yield curve. This finding implies that monetary policy changes in DM could lead to parallel shifts in EM yield curves, especially in economies with close financial ties to DM.
- If we look between the EM countries, we see the largest positive correlations exist between SA, IDR and INR, with the largest negative correlations existing between IDR and BRA, INR and BRA, and SA and CNY. A possible reason could be the resource heavy SA economy that is dependent on CNY. A CNY slowdown will result in accommodative monetary policy and lower interest rates with increased fiscal risks in SA due to reduced exports to CNY. BRA has the least correlation with all EM regions (-4%) given its relatively low domestic debt compared to offshore debt resulting in a muted domestic yield curve. TRL has a -28% correlation to DM countries given its unorthodox economic and political policies. PLN has +45% correlation to DM countries given its EU proximity.
- Amongst DM countries the highest positive correlations exist between GER, FRA, US and UK, and the lowest between JPN, CAN and AUS. For the most part parallel shifts in DM regions occur in unison which could be because of their highly integrated economies and policy objectives. The US, UK, FRA and ITL are the most synchronised given their large bond markets.
- Amongst EM and DM regions, the highest correlations are between CAN, SA, MEX and INR due to their commodity exports, UK and BRA, and US and PLN. The lowest correlations are between GER, IDR, SA, INR and BRA, US and TRL, IDR and AUS, and JPN and INR. Overall, concurrent parallel shifts between EM and DM regions are relatively distinct but can occur with leads or lags.
- Key characteristics of DM relative to EM is strong governance and institutions, stable politics, sound economic policies, reserve currency status, developed infrastructure, quality education and healthcare, innovation and technological advancements, open and competitive markets, social inclusion and equity, and a sustainable environment. EM countries can have vastly different characteristics. This is emphasised by the seminal book by Acemoglu and Robinson (2012) which explores the role of political and

economic institutions in shaping the success or failure of nations. It argues that inclusive institutions are characterised by strong governance, stable politics, sound economic policies, and open markets, which are fundamental to economic prosperity, distinguishing developed countries from emerging ones.

		EM								DM									
		IDR	SA	MEX	INR	CNY	TRL	BRA	PLN	FRA	GER	JPN	UK	CAN	US	AUS	ITL	EM	DM
EM	IDR																		
	SA	57%																	
	MEX	-1%	26%																
	INR	62%	57%	34%															
	CNY	-1%	-29%	14%	20%														
	TRL	19%	-9%	-13%	12%	0%													
	BRA	-32%	-19%	-14%	-31%	-20%	-16%												
	PLN	-25%	4%	26%	-3%	-7%	-19%	5%											
DM	FRA	-4%	4%	-9%	-13%	11%	-23%	-6%	20%										
	GER	-30%	-23%	-1%	-20%	1%	1%	-22%	29%	62%									
	JPN	-1%	-20%	11%	-14%	6%	9%	-10%	18%	12%	17%								
	UK	14%	12%	-3%	0%	-9%	-24%	32%	25%	39%	10%	2%							
	CAN	19%	37%	35%	48%	-6%	-3%	-13%	16%	-3%	0%	-16%	11%						
	US	16%	24%	14%	10%	-10%	-29%	24%	31%	39%	12%	14%	84%	21%					
	AUS	-20%	7%	23%	8%	-11%	8%	24%	3%	-21%	-18%	-23%	15%	23%	0%				
	ITL	-22%	0%	17%	-11%	14%	-42%	6%	33%	48%	20%	7%	10%	-6%	32%	-13%			
EM	55%	57%	52%	78%	26%	21%	-4%	28%	-5%	-21%	-1%	17%	41%	27%	13%	0%			
DM	-9%	8%	25%	-1%	0%	-28%	13%	45%	64%	41%	38%	67%	26%	76%	21%	56%	18%		

**Table 1** – Proportion of sovereign curve changes due to parallel curve shifts for emerging and developed markets from 1993 to 2024. The average of the eight EM and eight DM sovereigns are shown with DM curves illustrating a greater occurrence of parallel shifts relative to EM. This implies that DM regions have less volatile curve shapes and risk-off periods relative to EM regions. Source Data: IRESS and Bloomberg.

During risk-off periods we see an increase in non-parallel shifts due to increased volatility and investor uncertainty. Risk-off periods can be systematic or idiosyncratic, Tables A1 and A2 in the appendix summarise the calendar years of major idiosyncratic and systemic events of each EM and DM respectively where non-parallel shifts increased in frequency. This can be observed by comparing the proportion of parallel curve shifts between DM and EM from Figure 4. We compute the average contribution to parallel shifts in DM from 1990 to 1999 to be 92%, and from 2000 to 2024 to be 87%. This translates into the frequency of non-parallel shifts in DM increasing from 8% to 13%. For EM, the increase in non-parallel shifts is more substantial, from 1990 to 1999, parallel and non-parallel shifts accounted for 93% and 7% of curve changes respectively. From 2000 to 2024, EM parallel and non-parallel shifts accounted for 81% and 19% of curve changes respectively. Thus, EM non-parallel shifts increased in frequency from 7% to 19% on average, much greater than the increase in DM frequency from 8% to 13%.

In the modern age, world trade and financial systems are well integrated. Thus idiosyncratic, economic risk-off events in major DM countries have a greater impact on other economies, specifically EM (e.g. US global financial crisis, Eurozone debt crisis or unified currency,

monetary/fiscal policy tightening or the US dotcom bubble). There are also instances such as natural disasters, contagious diseases, supply chain issues or wars that create systemic risk throughout the globe (e.g. Japanese earthquakes and tsunamis, Australian wildfires, US hurricanes, US-China trade tensions, Gulf, Russian-Ukraine or Middle East wars, HIV/AIDS or COVID-19 pandemic). Research by Chang et al. (1998), Feldstein (2002) and Llaudes (2010) highlight the significant impact that economic downturns, and financial and currency turmoil in DM can have on EM. The authors emphasise the importance of robust economic fundamentals and diversified financial linkages for EM resilience.

Reinhart and Rogoff (2009) who studied financial crises over the past 800 years conclude that financial crises are a persistent and recurring phenomenon throughout history. They argue that the same types of financial vulnerabilities and policy mistakes that led to past crises continue today. The authors cite typical warning signs such as rapid credit expansion, asset price bubbles, and rising debt levels as a precursor to financial crises. These crises have severe economic consequences including deep recessions, prolonged recoveries, and long-lasting effects on public debt and unemployment. They stress that the aftermath of crises often involves significant social and political upheaval. Reinhart and Rogoff (2009) recommend prudent fiscal policies, robust financial regulation, international co-operation to address financial vulnerabilities and transparent financial markets to reduce the fallout from financial crises.

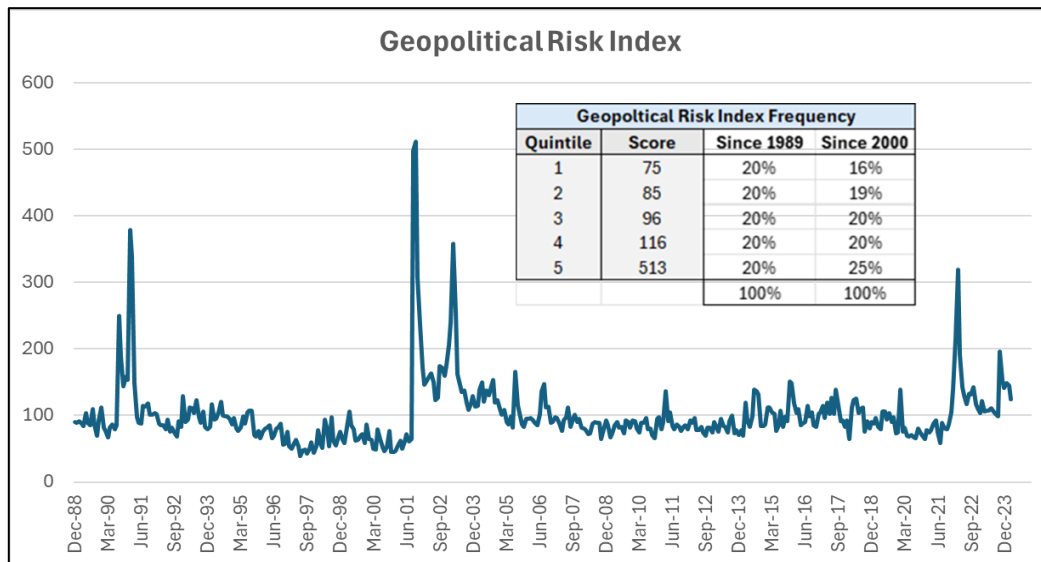
Obstfeld (2012) concludes that financial globalisation has significantly increased the volume and volatility of cross-border capital flows, which enhances global growth and development, but also increases the risk of financial crises. Volatile current account balances reflect underlying structural issues that can spread across countries and regions given the interconnection of financial markets. Obstfeld (2012) advocates for macroprudential policies that can address systemic risks and the resilience of financial systems. These policies include measures to monitor and control credit growth, leverage, and other financial vulnerabilities.

During the above risk-off periods, we see an increased occurrence of non-parallel shifts on global yield curves due to amplified monetary and fiscal frameworks, and volatile risk premiums. Rakotonratsimba and Jaffal (2012) observe that the frequency of non-parallel shifts increased following the global financial crisis. Caldara and Iacoviello (2022) identify that heightened geopolitical risks tend to induce financial market volatility, create uncertainty, and delay investment decisions. Their custom geopolitical index reveals that geopolitical risk surged dramatically during both World Wars, remained high in the early 1980s, and has been

rising since the start of the 21st century, thereby increasing the likelihood of future, negative macroeconomic events.

The IMF's Global Financial Stability Report by Catalán et al. (2023) raises alarms about escalating geopolitical tensions among major nations. These tensions are expected to trigger a reversal of capital flows towards safer assets, leading to higher funding costs, decreased profitability, and elevated default risks. Emerging markets (especially small, open economies) are likely to be severely impacted. The World Economic Forum Report (2024), based on a survey conducted in September 2023, revealed that 54% of respondents foresee instability and moderate global catastrophes within the next two years, and 63% anticipate a turbulent outlook for the next decade. Key risks include extreme weather events, AI-driven misinformation, social and political polarisation, cost-of-living crises, economic downturns, supply chain disruptions, and interstate armed conflict. Predicting these high-risk macroeconomic events is a formidable challenge. However, it is evident that they are rising in frequency and breadth due to rising geopolitical tensions between the East and West, in uncoordinated monetary and fiscal policies (or modern monetary theory), mounting debt issuances and fiscal deficits, uncensored media and sensationalism, and a widening wealth inequality gap, leading to social unrest. These unpredictable trends are likely to persist, increasing the likelihood of non-parallel curve movements relative to their historical norms.

It is difficult to predict these high-risk macro events but we do know that they have become more prevalent as mentioned above. To demonstrate the increased prevalence of high-risk geopolitical events we divide Caldara and Iacoviello's (2022) geopolitical risk index into quintiles from 1989 (entire period) and 2000 (recent period). Figure 5 illustrates the geopolitical risk index with a table of quintile frequencies. Since 1989 the quintiles are 20% as expected but using truncating the data from 2000 we see that frequency of scores in quintile 5 (which represents the highest geopolitical risk-off events) increased from 20% to 25% confirming that high-risk geopolitical events have increased in prevalence. As mentioned earlier, the IMF's Global Financial Stability Report by Catalán et al. (2023) also reiterates intensifying geopolitical tensions among major nations with spillover effects to the rest of the world. These rising trends and highly volatile environments are likely to continue, resulting in an increased occurrence of non-parallel curve movements relative to their historic average.



**Figure 5** – Illustrates the Caldara and Iacoviello Geopolitical Risk Index from January 1989 to March 2024. Large spikes were observed in the early 1990’s Gulf War and US economic recession, 2000’s Dotcom bubble and 9/11 and during the COVID pandemic in 2020. The embedded table shows the frequency of geopolitical scores based on quintiles, we see that frequency of scores in quintile 5 (which represents the highest geopolitical risk-off events) increased from 20% to 25% since 2000 confirming that high-risk events have increased in prevalence.

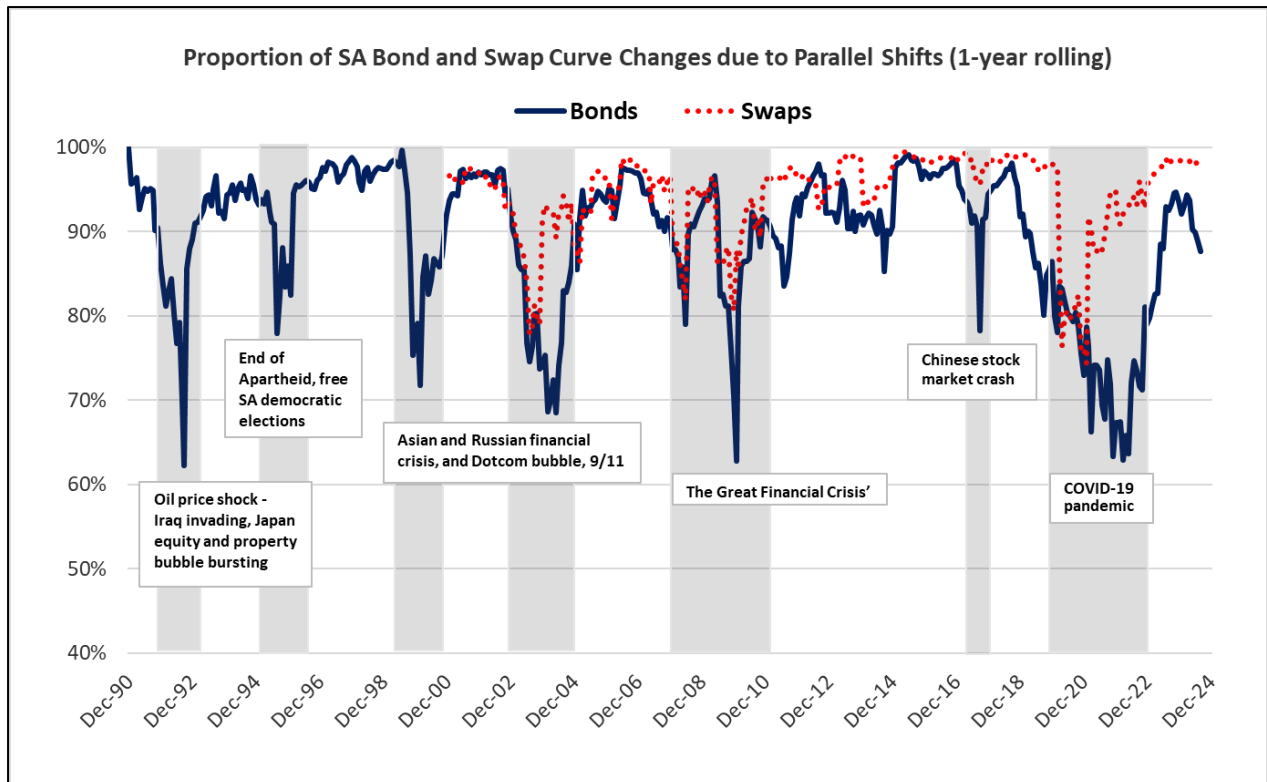
### 1.4 PCA on South African Swap and Bond Curves

To assess the South African principal components, the same approach used earlier in this chapter for DM and EM yield curves were applied. Monthly sovereign bond yields and swap rates (short-, medium- and long-dated) are used with the PCA calculated over a rolling one-year period (i.e. using the last 11 monthly yield/swap rate changes). Our results are adapted from Hariparsad and Maré (2023.1) and Hariparsad and Maré (2024.1).

Our analysis reveals that, since 1990, approximately 90% of SA sovereign bond yield changes and 94% of swap rate changes, since 2000 can be attributed to parallel shifts. Brooks and Moskowitz (2017) also confirm that 99.9% of sovereign yield changes across several countries are attributable to the first three principal components (level, slope and curvature). Willner (1996) established level, slope and curvature sensitivities to determine bond risk exposures to both parallel and non-parallel curve shifts. This provided for more effective hedging and risk management against non-parallel curve changes relative to only managing risk against modified duration.

By observing the first principal component of SA swap rates and bond yields in Figure 6, we see that there are periods where parallel curve changes account for only 60-70% of the total swap and bond curve changes. These periods coincide with high-risk macro-economic events such as the Asian financial crisis, the collapse of Long-Term Capital Management, the 9/11

terrorist attacks, the global financial crisis and the COVID-19 pandemic. As such, during these periods, non-parallel curve changes are accounting for 30-40% of curve movements, much higher than their long-term average of 5-10%. This means that the return opportunities from non-parallel curve changes have much greater potential during high-risk macro events and devising a strategy to exploit them becomes much more viable. In fact, Rakotondratsimba and Jaffal (2012) observed that post the great financial crisis, non-parallel shifts increased in frequency.



**Figure 6** – One-year moving average of the first principal component of a PCA on the SA swap and bond curves using monthly data obtained from Bloomberg from January 1991 to July 2024. The grey shaded blocks represent global risk-off environments where the proportion of parallel curve shifts is below its long-term average of 90% for both swap and bond curves. Source: IRESS data. Source Data: IRESS and Bloomberg.

The efficient market hypothesis (EMH) claims that asset prices reflect all available information, that it is impossible to consistently beat the market on a risk-adjusted basis, and markets will only react to new information. Fama (1970) proposed a weak, semi-strong and strong form of EMH depending on liquidity, investor sophistication and access to information. The literature is mixed on EMH with the early 1900s supporting the notion of strong EMH as market professionals were unable to outperform the market whilst the late 1900s and early 2000s brought about some predictability due to improved information and computing power. However, given the rise of trading technologies and education there are signs that risk premia

are more elusive post the 2008 financial crisis. This was described by Martineau (2021) who showed weak post-earnings announcement effects suggesting that most stock information had been captured before key announcements. Therefore it is open to debate if asset prices possess long-term predictability and whether this is due to time-varying risk premia or behavioural biases.

If the strong EMH is true, then it will not be possible to identify risk premia that consistently delivers excess returns. Our methodology disproves the strong EMH notion and identifies interest rate risk premia in South Africa that achieves excess returns over the period of study. We define the non-parallel risk premia that achieves this outperformance in Chapter 6 - Exploiting Non-Parallel Risk Premia .

### Conclusions:

1. DM curves experience parallel shifts 80-90% of the time, while EM is slightly lower at 70-90% due to higher inflation and fiscal volatility (Bems et al., 2018; Marioli et al., 2024). Thus, EM offers more non-parallel trading opportunities than DM.
2. Drakos (2001) suggests DM policy changes can influence EM shifts.
3. SA experiences greater non-parallel risk opportunities in bonds relative to swaps.
4. Non-parallel shifts increase during risk-off periods due to investor uncertainty.
5. DM non-parallel shifts rose from 8% (1990s) to 13% (2000s-2024). EM non-parallel shifts increased more significantly, from 7% to 19% over the same period.
6. High-risk events are becoming more prevalent (Caldara & Iacoviello, 2022; IMF, 2023) due to financial instability (Chang et al., 1998; Feldstein, 2002), geopolitical tensions, policy uncertainty, and social unrest (WEF, 2024)
7. Early 1900s supported strong EMH, followed by the late 1900s–2000s which saw semi-strong EMH due to improved data and computing power. Post-2008 crisis: Risk premia appear more elusive due to advanced trading technology and financial education (Martineau, 2021).

Next, we analyse which EM and DM yield curve movements have been most prevalent throughout our historic period.

## Chapter 2 - Curve Scenarios

*"Inflation is taxation without legislation." – Milton Friedman (Nobel laureate, American economist and statistician)*

### Objectives:

- Describe 1st, 2nd, and 3rd-order yield curve scenarios in EM and DM countries.
- Summarise how these scenarios affect long and short butterfly strategies.
- Analyse the frequency of interest rate cycles and curve changes in EM and DM, highlighting a higher occurrence of bullish scenarios due to historically lower inflation.

The work in this chapter is based on the below publications:

- Investments Analysts Journal - Hariparsad, S. and Maré, E. (2023.1),
- The South African Journal of Economic and Management Sciences - Hariparsad, S. & Maré, E. (2024.1),
- The Journal of Risk and Financial Management - Hariparsad, S. and Maré, E. (2024.2).

### 2.1 Curve Descriptions

This chapter defines various EM and DM curve scenarios that relate to slope and curvature risk and assess how they have evolved over time. The curve scenarios are presented in Table 2, which outline changes in short-, medium-, and long-dated sovereign bond yields, including curvature changes. 1st-order changes, such as parallel up and down scenarios, affect the average yield level and are explained by a single point on the curve. 2nd-order changes, like steep/flat twists and bull/bear steepening/flattening, focus on two points on the curve whilst 3rd-order changes, like positive and negative twists, compare three points on the curve. In general, flattening scenarios reduce curvature, whilst steepening scenarios increase curvature. The long butterfly strategy benefits from decreased curvature or curve steepness (curvature is high and should revert lower), whilst a short butterfly strategy benefits from increased curvature or curve flattening (curvature is low and expected to increase). Curvature represents the relationship between short, medium, and long-dated points on a yield curve. High curvature occurs when the medium-dated point is significantly higher than the average of the short and

long-dated points, and the medium-dated point is expected to revert lower to historical norms, favouring a long butterfly strategy. Conversely, a short curvature strategy benefits from increasing curvature. Over the long-term we can say that a long butterfly strategy outperforms during curve steepening and positive twists but underperforms during flattening and negative twists.

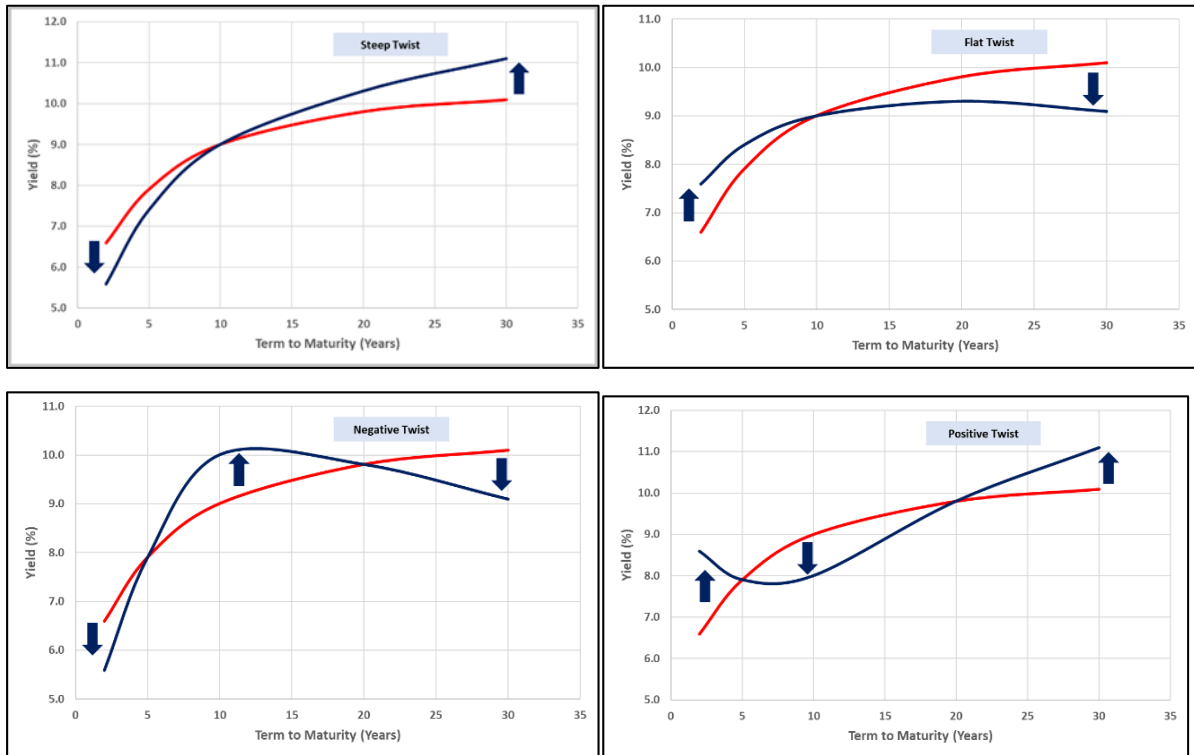
Curve Scenario	Degree of Change	Short Bond Yields	Medium Bond Yields	Long Bond Yields	Curvature
Parallel Up	1st Order	Higher↑	Higher↑	Higher↑	Little Change
Parallel Down	1st Order	Lower↓	Lower↓	Lower↓	Little Change
Steep Twist	2nd Order	Lower↓	Little Change	Higher↑	Increased↑
Flat Twist	2nd Order	Higher↑	Little Change	Lower↓	Decreased↓
Bear Steep	2nd Order	Slightly Higher↑	Higher↑	Much Higher↑	Increased↑
Bull Steep	2nd Order	Much Lower↓	Lower↓	Slightly Lower ↓	Increased↑
Bear Flattening	2nd Order	Much Higher↑	Higher↑	Slightly Higher↑	Decreased↓
Bull Flattening	2nd Order	Slightly Lower↓	Lower↓	Much Lower↓	Decreased↓
Negative Twist	3rd Order	Lower↓	Higher↑	Lower↓	Increased↑
Positive Twist	3rd Order	Higher↑	Lower↓	Higher↑	Decreased↓

**Table 2** - Changes in short, medium, and long-dated sovereign bond yields and overall curvature are provided. 1st order changes such as parallel up and down scenarios do not have material changes in slope or curvature as most bond yields across the curve move by similar amounts.

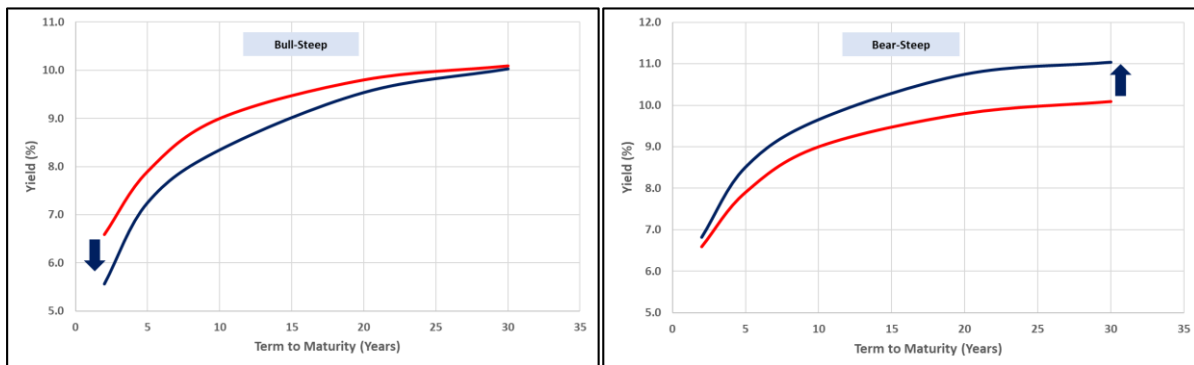
## 2.2 Graphical Depictions

For ease of interpretation, Figure 7 provides graphical depictions of the 2nd and 3rd order curve scenarios. Note the below depictions are extreme curve movements and in reality, milder versions are expected.

## Curve Twists



## Curve Steepening



## Curve Flattening

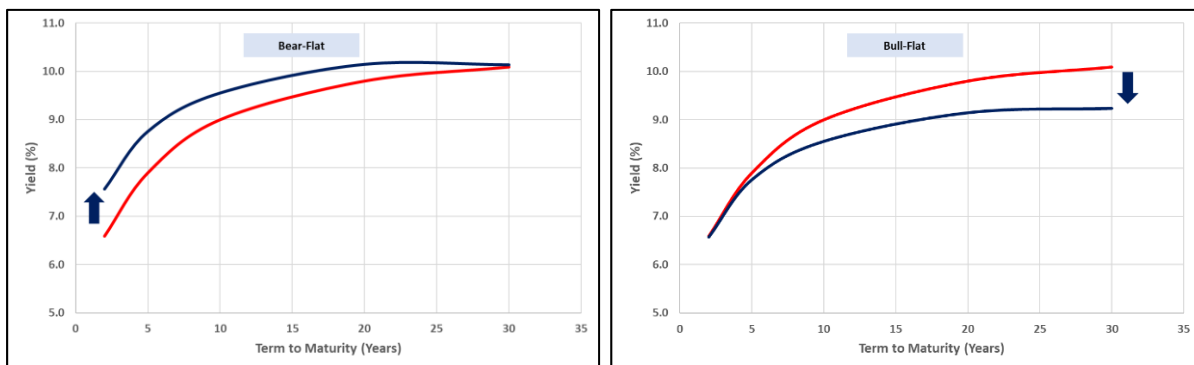


Figure 7 – Graphical depictions of the 2nd and 3rd order curve scenarios that are given in Table 1. These are extreme curve movements and in reality, milder versions of these curve changes are expected.

## 2.3 Butterfly Strategies vs. Curve Scenarios

Table 3 describes the typical curve scenarios that will benefit long and short butterfly strategies. Note the below outcomes are theoretical and should hold over the long-term but in practice, there could be instances when the long or short butterfly strategies do not perform accordingly due to non-uniform or uncharacteristic curve changes. An example could be during a bull steepening curve scenario, where short, medium and long-term bond yields change by -75, -50 and -60 basis points respectively. Thus, a cash and duration neutral long butterfly strategy (which is long the body and short the wings) will underperform, as the medium-term bond yield (body) has decreased by only 50bps whilst the short- and long-term bond yields (wings) have decreased by 75 and 60 basis points respectively, resulting in relatively greater returns. Thus, the cash and duration neutral long butterfly strategy underperforms as the returns from the body is less than the wings.

Strategy	Outperforming Scenarios	Underperforming Scenarios
<b>Long Butterfly</b> Outperforms when curvature decreases (except for flat twists)	<ul style="list-style-type: none"> <li>• Positive Twist</li> <li>• Steep Twist</li> <li>• Bull Flattening</li> <li>• Bear Flattening</li> </ul>	<ul style="list-style-type: none"> <li>• Negative Twist</li> <li>• Flat Twist</li> <li>• Bull Steepening</li> <li>• Bear Steepening</li> </ul>
<b>Short Butterfly</b> Outperforms when curvature increases (except for steep twists)	<ul style="list-style-type: none"> <li>• Negative Twist</li> <li>• Flat Twist</li> <li>• Bull Steepening</li> <li>• Bear Steepening</li> </ul>	<ul style="list-style-type: none"> <li>• Positive Twist</li> <li>• Steep Twist</li> <li>• Bull Flattening</li> <li>• Bear Flattening</li> </ul>

**Table 3** – Summary of curve scenarios that indicate when long and short butterfly strategies outperform and underperform. The long (short) butterfly outperforms when curvature decreases (increases) except during flat (steep) twists.

## 2.4 Curve Scenario and Rate Cycle Frequencies for EM and DM Regions

Next, we compare the frequency of interest rate cycles, including 1st, 2nd and 3rd order curve changes for emerging and developed markets from June 2007 to July 2024, these are shown in Table 4 and Table 5 respectively. We define an interest rate cycle from the first hike (cut) to the first cut (hike). For example if a central bank pauses a hiking cycle for several months but continues thereafter, it is still assumed to be in the same interest rate cycle. Only when the central bank changes direction, a cut in this instance will we conclude the interest rate cycle. We see that EM countries have experienced more cutting cycles than hiking cycles over the period, with IDR, PLN and CNY experiencing the most accommodative interest rate cycle with cuts occurring 66%, 70% and 83% of the time respectively. Looking at 1st order changes, there have been more parallel down shifts compared to parallel up shifts as inflation has drifted lower for most EM countries. Bull flattening and bear steepening have been the most common 2nd

order shifts for SA, MEX, BRA and POL. IDR, INR and CNY have experienced more bull steepening. TRL experienced more flat and steep twists (24% and 19% respectively), whilst INR realised more bull steepening and bear flattening (20% and 23% respectively). 3rd order shifts are generally evenly split between positive and negative convexity, with SA and INR having slightly more positive than negative convexity shifts.

For DM countries there have been substantially more cutting cycles than hiking cycles over the period, with JPN experiencing accommodative policies 92% of the time, European nations between 70-79% and the US and AUS at 66% and 69% respectively. Canada has experienced more hiking than cutting cycles (58% vs. 42%). Looking at 1st order changes, parallel down shifts have been a common occurrence throughout the DM countries with the US and CAN being balanced between parallel up and down. Similar to EM, bull flattening and bear steepening have been the most common 2nd order shifts with the UK undergoing more bull steepening. Positive convexity has been the common 3rd order scenario amongst DM countries.

EM Scenarios	IDR	SA	MEX	INR	CNY	TRL	BRA	PLN
<b>Rates Cycle</b>								
Hike	34%	48%	44%	43%	17%	36%	48%	30%
Cut	66%	52%	56%	57%	83%	64%	52%	70%
<b>1st Order</b>								
Parallel Up	44%	51%	52%	47%	48%	48%	49%	47%
Parallel Down	56%	49%	48%	53%	52%	52%	51%	53%
<b>2nd Order</b>								
Bull Steep	20%	12%	11%	20%	20%	14%	14%	15%
Bull Flat	23%	25%	25%	17%	19%	13%	27%	23%
Bear Steep	18%	25%	26%	14%	14%	13%	23%	19%
Bear Flat	15%	12%	15%	23%	16%	16%	15%	14%
Flat Twist	15%	15%	12%	12%	11%	24%	11%	16%
Steep Twist	7%	11%	10%	13%	19%	19%	9%	13%
<b>3rd Order</b>								
Pos Convex	49%	54%	51%	55%	50%	49%	49%	50%
Neg Convex	51%	46%	49%	45%	50%	51%	51%	50%

**Table 4** – Summarises the frequency of interest rate cycles, including 1st, 2nd and 3rd order curve changes for emerging markets from June 2007 to July 2024. Source Data: IRESS and Bloomberg.

DM Scenarios	FRA	GER	JPN	UK	CAN	US	AUS	ITL
<b>Rates Cycle</b>								
Hike	21%	21%	8%	30%	58%	34%	31%	21%
Cut	79%	79%	92%	70%	42%	66%	69%	79%
<b>1st Order</b>								
Parallel Up	46%	44%	44%	45%	50%	51%	46%	45%
Parallel Down	54%	56%	56%	55%	50%	49%	54%	55%
<b>2nd Order</b>								
Bull Steep	12%	11%	6%	26%	12%	11%	15%	16%
Bull Flat	33%	30%	32%	22%	24%	28%	30%	30%
Bear Steep	24%	22%	22%	21%	25%	24%	19%	17%
Bear Flat	13%	11%	8%	19%	15%	15%	17%	17%
Flat Twist	9%	12%	17%	6%	9%	11%	11%	11%
Steep Twist	9%	13%	15%	4%	13%	10%	7%	8%
<b>3rd Order</b>								
Pos Convex	52%	56%	55%	51%	51%	54%	52%	54%
Neg Convex	48%	44%	45%	49%	49%	46%	48%	46%

**Table 5** – Summarises the frequency of interest rate cycles, including 1st, 2nd and 3rd order curve changes for developing markets from June 2007 to July 2024. Source Data: IRESS and Bloomberg.

The key takeaway over the period is that inflation has drifted lower resulting in a greater proportion of bullish interest rate scenarios for both emerging and developed markets. Ha et al. (2019) confirm the decline in inflation rates across EM and DM over the last two decades attributing the disinflation to increased international trade, financial integration and resilient monetary policy frameworks such as central bank transparency and independence. According to our research there have been several steepening and flattening occurrences, thus in the next chapter we quantify the effects of slope and curvature changes on EM and DM long butterfly returns.

#### Conclusion:

1. Provided descriptive and graphical representations of 1st, 2nd, and 3rd-order yield curve scenarios that highlighted changes in short-medium- and long-term yields.
2. Provided a summary of outperforming and underperforming 2nd, and 3rd-order curve scenarios for long and short butterfly strategies.
3. EM and DM countries have experienced more cutting cycles than hiking cycles as inflation has drifted lower over the period due to improved globalisation and monetary policy, Ha et al. (2019).
4. Lower inflation has led to an increased occurrence of bullish curve scenarios such as parallel down, bull flattening, flat twists and positive convexity.



## Chapter 3



### Chapter 3 - EM and DM Butterfly Analysis

*"Developed markets offer stability, but emerging markets offer growth. The challenge lies in balancing the two."*

– Mohamed El-Erian (Former CEO of PIMCO)

#### Objectives:

- Evaluate the return prospects of a cash and duration-neutral long butterfly strategy in EM and DM countries using zero-coupon sovereign bonds.
- Analyse strategy performance with monthly rebalancing and zero trade costs.
- Present performance data for EM and DM long butterfly strategies, emphasising key factors influencing returns.
- Highlight the relationship between steeper slopes, positive curvature, volatility, and higher butterfly return potential.

The work in this chapter is based on the below publications:

- The Journal of Risk and Financial Management - Hariparsad, S. and Maré, E. (2024.2).

### 3.1 Long Butterfly Methodology

This chapter assesses the return prospects of a long butterfly strategy on each of the EM and DM countries. A butterfly strategy consists of a short-, medium- and long-dated sovereign bond. As a recap the long butterfly strategy purchases the medium-dated sovereign bond and sells the short- and long-dated sovereign bonds in a cash and duration neutral manner. Being duration neutral allows the strategy to be immunised against parallel shifts but exposed to non-parallel shifts (such as slope and curvature changes). Cash neutrality is employed to allow for operational efficiency, so no cash surpluses/shortfalls are invested or borrowed. Trade costs are ignored for now as we want to determine the pure effects of slope and curvature changes on a long butterfly strategy (trade costs are discussed in chapters 5.8 Incorporating Trade Costs into the Butterfly Weight Scheme Strategies, 6.3 Describing Butterfly Trade Costs and Chapter

8 - Rebalancing Frequencies). To ensure a profitable butterfly strategy, trade costs from rebalancing frequencies are an important consideration and must be practically managed.

As we do not have the actual sovereign bonds, we use generic zero-coupon sovereign bonds with maturity sectors: 1-3 years, 3-7 years, 7-12 years and 12+ years. Each of these maturity sectors contain an equally weighted amount of zero-coupon sovereign bonds, e.g. the 3-7 year maturity bucket will contain equal amounts of the 4-,5-,6-, and 7-year zero-coupon sovereign bonds. Each month we assume new zero-coupon sovereign bonds are issued. The long butterfly strategy purchases the 3-7 year maturity bucket, and sells the 1-3 year and 7-12 year maturity buckets in a cash and duration neutral manner. This mimics a 2v5v10 long butterfly that purchases the 5-year bond and sells the 2-year and 10-year bond (cash and duration neutral). We opted to use the maturity buckets rather than individual sovereign bonds to eliminate concentration risk by diversifying amongst several sovereign bonds. The maturity bucket (diversified) approach is much stricter than the individual (concentrated) approach, so if positive (negative) returns emerge, we have greater confidence that the long butterfly strategy is profitable (loss-making). The downside of our diversified approach is that some zero coupon bonds may be hypothetical so implementation will be difficult. However, this downside can be minimised by buying coupon bonds, structuring and stripping the coupons with an investment bank to create a series of zero coupon bonds to match exact maturities. Swaps would be better suited in this diversified approach as custom maturities can be created but not all EM's have liquid and tradeable swap markets.

The long butterfly strategy invests in the maturity buckets (cash and duration neutral which is the preferred weighting methodology as explained in Chapter 5 - Butterfly Weight Schemes) at the beginning of the month and closes the positions at month-end. This monthly rebalancing process is continued from June 2007 to July 2024 with zero trade costs assumed so that we can determine the strategy's effectiveness for each country.

### 3.2 Long Butterfly Performance Summary

Table 6 and Table 7 highlight the performance statistics of the EM and DM long butterfly strategies respectively. Amongst the EM countries SA has the highest performance at 0.36% p.a. followed by INR, CNY and BRA at 0.16%, 0.12% and 0.1% p.a. TRL is the underperformer at -0.47% p.a. given its volatile yield environment. Out of the DM countries, ITL is the outperformer at 0.29% p.a. followed by the US, GER, FRA and UK between 0.14%

and 0.19%. JPN has zero performance given its relatively flat yield curve and low yield volatility market. To understand the performance of these long butterfly strategies we will compare the returns to their slope and curvature, level and volatility. The slope is defined as the 7-12 year yield less the 1-3 year yield and the curvature is defined as the 3-7 year yield less the average of the 1-3 year yield and 7-12 year yield.

EM Long Butterfly	IDR	SA	MEX	INR	CNY	TRL	BRA	PLN
Index (Start = 100)	100.82	106.14	100.16	102.77	102.11	92.44	101.65	100.71
Tot Ret (pa)	0.05%	0.36%	0.01%	0.16%	0.12%	-0.47%	0.10%	0.04%
Ret SD (pa)	1.2%	1.4%	1.3%	1.1%	1.3%	4.6%	2.5%	1.4%
Avg Spread Dur	4.1	4.1	4.2	4.1	4.6	3.6	3.8	4.5
Spread Vol (pa)	39%	48%	48%	38%	57%	161%	54%	59%

**Table 6** – Summarises the performance statistics of the EM long butterfly strategy from June 2007 to July 2024. SA has the highest returns due to its steep slope, whilst TRL has the lowest returns from an inverted/flat slope. Source Data: IRESS, The World Bank and Bloomberg.

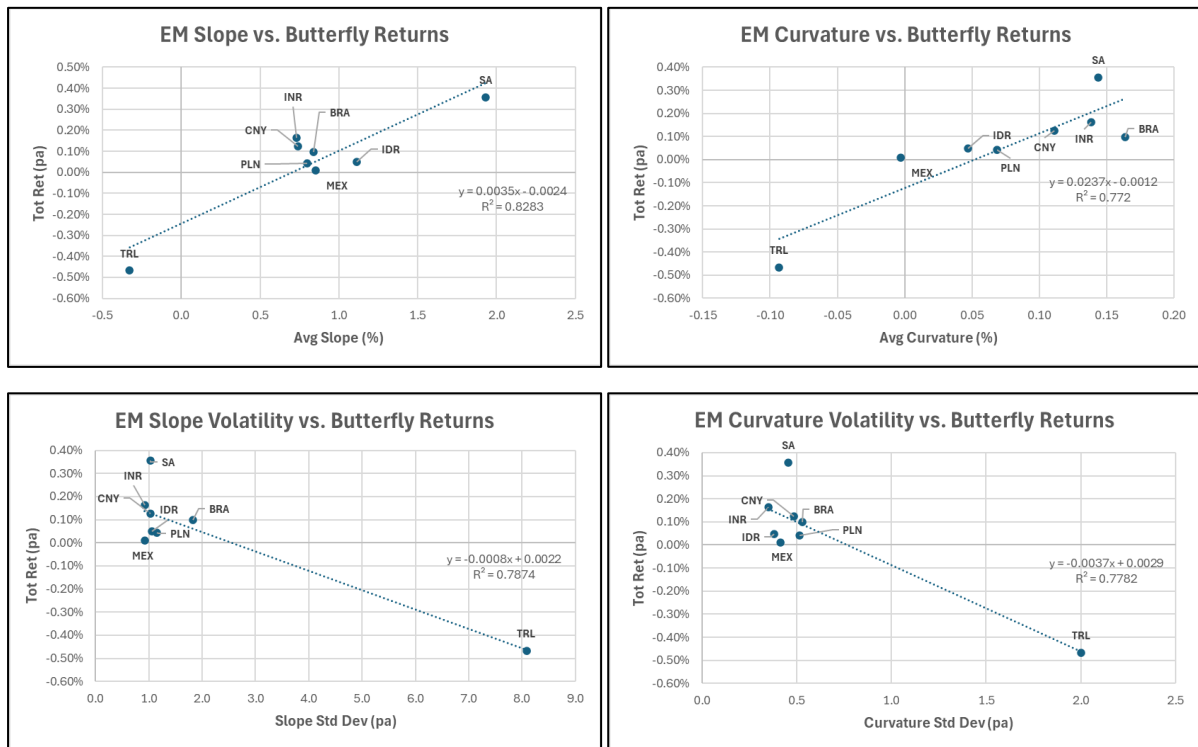
DM Long Butterfly	FRA	GER	JPN	UK	CAN	US	AUS	ITL
Index (Start = 100)	102.72	103.26	99.99	102.37	101.75	103.21	101.71	104.94
Tot Ret (pa)	0.16%	0.19%	0.00%	0.14%	0.10%	0.19%	0.10%	0.29%
Ret SD (pa)	0.8%	1.0%	0.3%	0.4%	0.7%	1.1%	0.8%	1.2%
Avg Spread Dur	4.8	4.8	5.0	4.7	4.7	4.7	4.6	4.7
Spread Vol (pa)	21%	31%	8%	7%	20%	36%	26%	29%

**Table 7** – Summarises the performance statistics of the DM long butterfly strategy from June 2007 to July 2024. ITL has the highest returns from a relatively steep slope, followed by the US and GER, whilst JPN has the zero returns due to a flat slope and low volatility. Source Data: IRESS, The World Bank and Bloomberg.

### 3.3 Long Butterfly Returns vs. Slope and Curvature Characteristics

Figure 8 and Figure 9 show the average EM and DM slope level, curvature level, slope volatility and curvature volatility relative to the long butterfly returns respectively (we will refer to long butterfly returns as returns for ease of reference). There is a positive relationship with EM slopes/curvature and returns in that steeper slopes and/or increased curvature imply higher returns. SA has a relatively steep slope and positive curvature resulting in high returns, conversely TRL has an inverted slope and negative curvature leading to negative returns. We also find that increased slope and curvature volatility leads to lower returns, this is demonstrated by TRL who have succumbed to political interference in their central banking policies leading to extreme moves in their exchange rate, inflation and interest rate levels. Thus, a short butterfly strategy (selling the 3-7 year maturity bucket and purchasing the 1-3 year and 7-12 year maturity buckets in a cash and duration neutral manner) which is the opposite of the long butterfly strategy will be profitable in a volatile interest rate environment with inverted curves and low curvature as in TRL.

SA has experienced similar slope and curvature volatility to the other EM countries but have relatively higher returns due to steeper slopes and increased curvature. This is because SA has undergone a decade of below trend growth due to poor infrastructure investment, reduced power generation, rising unemployment and social inequality. Thus, government has had to increase its debt levels and fiscal deficit to maintain spending levels. Investors require higher risk premiums for increased debt loads resulting in a steeper slope and curvature.

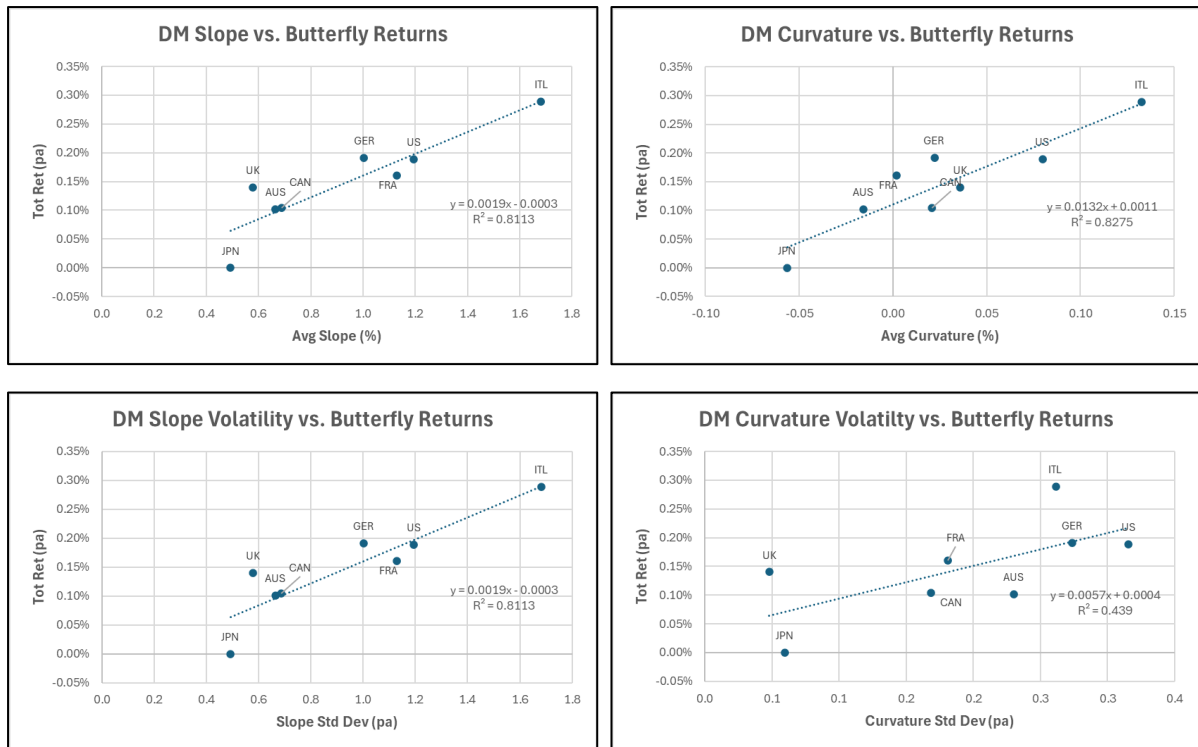


**Figure 8** – Illustrates EM long butterfly returns versus average slope level, average curvature level, slope volatility and curvature volatility respectively. Steep slopes, high curvature, and low slope and curvature volatility result in increased long butterfly returns. Source Data: IRESS, The World Bank and Bloomberg.

Observing Figure 9, a similar pattern transpires for the DM long butterfly strategies, in that steeper slopes and/or increased curvature imply higher returns. Of the DM countries, ITL on average has the steepest slope and greatest curvature, translating into the greatest returns. JPN has the flattest slope and lowest curvature leading to the lowest returns at zero. This is because the Japanese government incorporates large stimulus measures to suppress long-term bond yields whilst the Bank of Japan has for many years, maintained an accommodative monetary policy stance resulting in a flat government yield curve with reduced volatility.

In the DM space, we see that volatile slope and curvature changes imply greater returns which is the opposite of what occurs with EM countries in that increased volatility results in lower returns. A possible reason is that with increased volatility in DM countries we have increased

opportunities to capture non-parallel risk premia with the added insurance of DM fiscal stimulus which can control yield curve shapes. This is evident with ITL, US, and GER who have increased volatility and high returns due to their ability to control yield curves by utilising fiscal stimulus measures. JPN has relatively muted slope and curvature changes resulting in fewer return opportunities and lower returns. The UK is interesting in that it also has relatively muted slope and curvature volatility, but steeper slopes and positive curvature allow for increased return potential.



**Figure 9** – Illustrates DM long butterfly returns versus average slope level, average curvature level, slope volatility and curvature volatility respectively. Steep slopes, high curvature, and high slope and curvature volatility result in increased long butterfly returns. Source Data: IRESS, The World Bank and Bloomberg.

### 3.4 Long Butterfly Returns vs. Inflation Volatility

Figure 10 illustrates the long butterfly returns versus inflation volatility in both EM and DM countries. If we exclude the EM outliers of SA (high slope and curvature levels) and TRL (low slope and curvature levels), we can see that increased inflation volatility leads to higher returns. This pattern continues for the DM countries with JPN being a slight outlier (flat slope and low curvature) but still following this relationship. Volatile inflation requires extreme monetary policy and possible fiscal intervention to moderate current and future inflation expectations within central bank targets. Increased inflation volatility translates into an increased occurrence of non-parallel curve changes, risk-premia and amplified returns.



**Figure 10** – Illustrates EM and DM long butterfly returns versus inflation volatility in both EM and DM countries. If we exclude the EM outliers of SA (high slope and curvature levels) and TRL (low slope and curvature levels), we can see that increased inflation volatility leads to higher returns. Source Data: IRESS, The World Bank and Bloomberg.

### 3.5 Monetary and Fiscal Policy Categorisation

This means that long butterfly strategies are advantageous in countries with credible central banks that are disciplined at managing inflation volatility and expectations, but also have above average fiscal risk or term premia resulting in steep yields and increased curvature like SA and ITL. Short butterfly strategies are profitable when countries experience inverted curves with low curvature and increased inflation volatility which could occur when unconventional monetary and fiscal policies are applied as in the case of TRL. When we have loose monetary and fiscal policy like JPN, where flat curves with low curvature and inflation volatility are evident then neither a long or short butterfly strategy will be profitable. During tight monetary and loose fiscal policy as is common in many DM countries (like the US, UK, GER, FRA, AUS and CAN due to the large amount of quantitative easing and stimulus programs), long butterfly strategies are still profitable (albeit to a lesser degree) but tactically switching between long and short butterflies during curve normalisations and inversions would be beneficial to maximise returns. Table 8 summarises the successful strategies given the monetary and fiscal policy regime.

Fiscal Policy	Monetary Policy	
	Loose	Tight
<b>Loose</b> Optimal Strategy	JPN None	SA, ITL Long Butterfly
<b>Tight</b> Optimal Strategy	TRL Short Butterfly	US, UK, GER, FRA, AUS, CAN Tactical Long/Short Butterfly

**Table 8** - The above table summarises the findings of which monetary and fiscal policy regime is profitable for a given long or short butterfly strategy and the countries in our analysis that possess these policies. Source Data: IRESS, The World Bank and Bloomberg.

Next, we use a quantitative approach to determine if the type of monetary and fiscal policy of each EM and DM country does in fact follow Table 8.

Conclusion:

1. Explained the long butterfly methodology that was applied and back-tested to select EM and DM countries.
2. Our results indicate that steeper slopes and greater curvature tend to generate higher long butterfly returns. Additionally, increased volatility in slope and curvature further enhances these returns.
3. Among EM and DM countries, SA and ITL offered the highest potential for long butterfly returns due to their steep slopes and high curvature. In contrast, JPN had the least potential due to its flat yield curves, while TRL was better suited for a short butterfly strategy due to its unconventional policies.



## Chapter 4



### Chapter 4 - Monetary and Fiscal Scores

*"Monetary policy provides the oxygen, but fiscal policy determines how the oxygen is used." – Adair Turner  
(Former Chairman of the UK Financial Services Authority)*

#### Objectives:

- Provide an overview of the transition from the gold standard to the fiat currency system and its effects on inflation and debt.
- Analyse how monetary and fiscal policies influence the profitability of butterfly strategies using a quantitative approach and economic indicators
- Highlight South Africa's suitability for butterfly strategies due to its: tight monetary and loose fiscal policies, high absolute yields, sensitivity to risk-off events, and a cyclical economy dependent on commodity exports.

The work in this chapter is based on the below publications:

- Investments Analysts Journal - Hariparsad, S. and Maré, E. (2023.1),
- The South African Journal of Economic and Management Sciences - Hariparsad, S. & Maré, E. (2024.1),
- The Journal of Risk and Financial Management - Hariparsad, S. and Maré, E. (2024.2).

#### 4.1 Background of the Fiat Currency System

The abandonment of the gold standard in the early 1970s represented a transformative moment in global economic policy, with significant ramifications for monetary and fiscal policies as well as bond markets. Under the gold standard, a nation's currency was directly linked to a specific quantity of gold, which effectively restricted the money supply to the amount of gold reserves held by the country. While this system was initially designed to promote economic stability and control inflation, it ultimately constrained governments during economic crises by preventing them from expanding the money supply freely.

The definitive end of the gold standard occurred on August 15, 1971, when U.S. President Richard Nixon announced that the United States would no longer exchange dollars for gold with foreign governments. This decision effectively dismantled the Bretton Woods system and signalled the global shift to fiat currency systems. As Bordo (1984) notes, the transition away from the gold standard provided nations with greater flexibility in monetary policy, enabling more effective responses to economic downturns. Although inflationary risks emerged as a concern, expectations of strong economic growth and productivity gains were anticipated to offset these risks.

In the absence of the gold standard, central banks gained enhanced control over monetary policy, primarily through tools such as interest rate adjustments and open market operations. Fiat currency systems allow central banks to modify the money supply as needed, unencumbered by gold reserve limitations as mentioned in Autor (2021) and Cachanosky (2021). This newfound flexibility empowered policymakers to combat inflation and stimulate economic growth in ways that were previously unattainable. Furthermore, fiscal policy became more expansive, as governments could sustain larger deficits without the immediate need to maintain a specific gold reserve ratio. This flexibility allowed for greater stimulus spending during recessions and more effective inflation control during economic expansions.

The shift to a fiat currency system also had profound effects on bond markets. In a fiat regime, inflation expectations play a crucial role in determining bond yields. Anticipation of higher inflation, often driven by expansive monetary or fiscal policies, typically leads to higher bond yields as investors demand greater returns to compensate for the erosion of purchasing power. This dynamic was particularly evident during the high-inflation era of the 1970s, when bond yields rose sharply. Conversely, during periods of low inflation in recent decades, bond yields have remained relatively low, even as governments have run substantial deficits.

Moreover, the departure from the gold standard has enabled central banks to implement policies such as quantitative easing (QE), which involves purchasing government bonds and other assets to reduce interest rates and stimulate economic activity. Such policies would have been unfeasible under a gold-backed system due to constraints on money creation. QE has significantly influenced bond markets by suppressing yields and encouraging borrowing, investment, and consumption. However, its long-term use raises concerns about debt sustainability, potential inflationary pressures, and the diminished value of bonds.

The transition to a fiat system has provided governments and central banks with greater flexibility to address economic challenges, but it has also introduced new complexities. Inflation expectations now exert a direct influence on bond yields, tying bond markets closely to fiscal discipline and confidence in monetary policy. This interdependence contributes to heightened price volatility and creates opportunities along the yield curve, particularly in the form of risk premia as suggested by Cochrane (2017) and Cochrane and Piazzesi (2005).

## 4.2 Methodology to Quantify Monetary and Fiscal Policies

To quantify the extent of monetary and fiscal policies in each country, we used several indicators to determine the extent of policy tightness or looseness and followed the approach by Hariparsad and Maré (2024.2). Data was obtained from Bloomberg and the World Bank. The indicators are given in Table 9 together with the rationale for using them and the data frequency used. We ranked and scored monetary and fiscal policies on a scale of -1 (very loose policy) to +1 (very tight policy) with 0 being neutral policy, for all the DM and EM countries on a relative basis.

The rank and scoring methodology entailed finding the minimum and maximum values of each indicator so we could rescale the indicator data from -1 to +1. This provided a simple and effective way to quantify the relative value of each indicator and compare the score for each country. As an example, if we have the following list of indicator values [-3, -1, +4, +7, +11] and we want to rescale between -1 and +1, we will take each list value, subtract the minimum list value, and divide by the difference between the maximum and minimum list value. The first list value would be transformed as  $(-3 - (-3)) / (11 - (-3)) = 0$ , and the second list value would be transformed as  $(-1 - (-3)) / (11 - (-3)) = 0.14$ , and so on. We would then rescale these list values between -1 and +1 by subtracting 0.5 and multiplying the result by 2, e.g., the first transformed value would be  $(0 - 0.5) * 2 = -1$ , the second transformed value would be  $(0.14 - 0.5) * 2 = -0.7$ , and so on. This is continued for each indicator so that we can find an average score for each country for relative comparison purposes.

	Variable	Rational	Data Frequency
Fiscal Policy Measures	Budget to GDP <sup>1</sup> ratio	Greater budget deficit = increased funding and bond supply = increased term premia and steeper curves	Annual data from Jan 2007 to Dec 2023
	Volatility of budget to GDP ratio	Increased budget volatility = uncertainty in government finances = increased term premia and steeper curves	Annual data from Jan 2007 to Dec 2023
	Average gross debt to GDP	High debt to GDP = leveraged economy that is dependent on investor demand for debt and susceptible to high interest rates.	Annual data from Jan 2007 to Dec 2023
	Gross debt to GDP volatility	Increased debt volatility = uncertainty in government finances and susceptible to global growth cycle = increased term premia and steeper curves	Annual data from Jan 2007 to Dec 2023
	Average net borrowing requirement to GDP	Increased borrowing requirements = increased bond supply = increased term premia and steeper curves	Annual data from Jan 2007 to Dec 2023
	Volatility of average net borrowing requirement to GDP	Increased volatility of borrowing requirements = uncertainty in bond supply, financing costs and susceptible to global growth cycle = increased term premia and steeper curves	Annual data from Jan 2007 to Dec 2023
	Average difference between real GDP and the long-term real yield	Smaller difference = negative impact on government finances as will find it difficult to service debt, not generating sufficient growth to repay debt = increased term premia and steeper curves	Quarterly data from Jan 2007 to Mar 2024
	Variable	Rational	Data Frequency
Monetary Policy Measures	Inflation volatility	Greater inflation volatility = increased central bank intervention and volatile central bank rates = volatile short-term rates with extreme steepening and flattening.	Monthly data from June 2007 to July 2024
	Real effective exchange rate volatility	Greater currency volatility = increased inflation passthrough and volatility = greater central bank intervention required = volatile short-term rates with extreme steepening and flattening.	Monthly data from June 2007 to July 2024
	Average real central bank rate	Higher real central bank rates = greater incentive to save and invest rather than spend and consume = lower demand-pull inflation and inflation volatility.	Monthly data from June 2007 to July 2024
	Average long-term real yields	Higher long-term real rates = greater incentive to invest, attracting foreign investment flows, capital flows > consumption flows = increased productivity = lower structural inflation and volatility.	Monthly data from June 2007 to July 2024

**Table 9** - Ranks and scores monetary and fiscal policies of EM and DM countries on a scale of -1 (very loose policy) to +1 (very tight policy) with 0 being neutral policy, on a relative basis. The rational for using them and the data frequency is also provided.

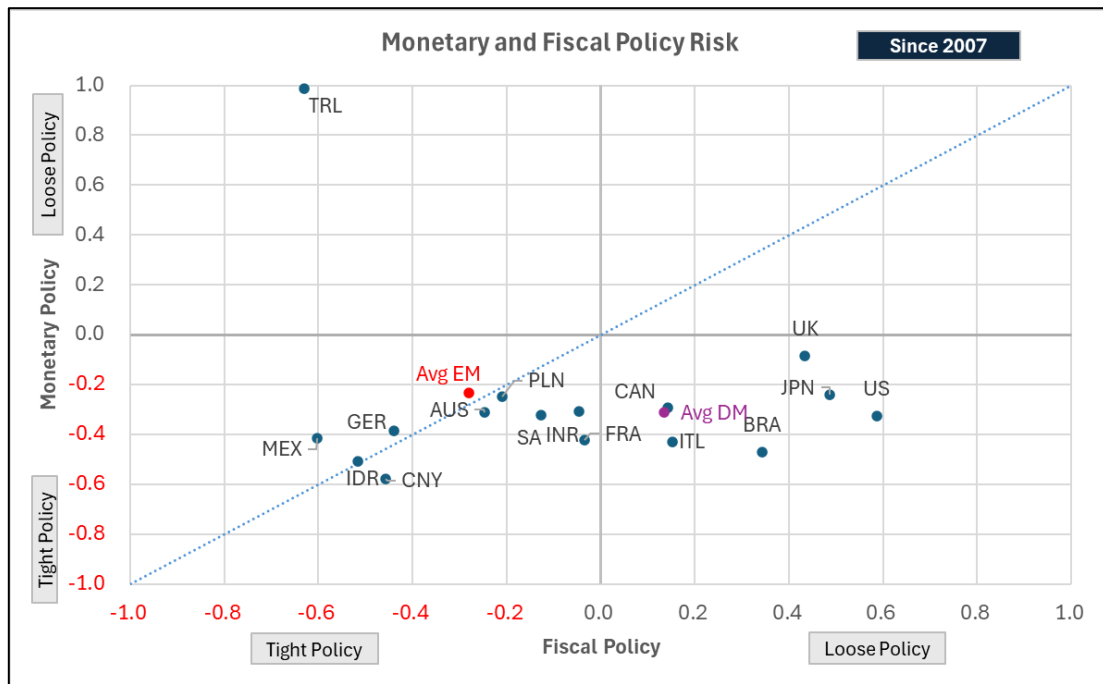
### 4.3 Analysing Policies for EM and DM Regions

The 45-degree dotted line in Figure 11 to Figure 14 represents a country that has relatively balanced monetary and fiscal policy. Using data from 2007 we see that TRL had very loose monetary policy caused by volatile inflation, currency, and relatively low real central bank rates and real yields. On the contrary, this translated into a weak currency and increased TRL exports which helped fund the fiscal deficit resulting in a tighter fiscal position. Of the DM countries, we saw that the UK, US, JPN, CAN and ITL had loose monetary and fiscal policies enabled by quantitative easing and stimulus programs respectively. These programs aim to suppress long-dated interest rates and term premia, resulting in flatter yield curves that would otherwise occur. Term premia is the excess yield that investors demand for holding a longer-term bond compared to a series of shorter-term bonds. Term premia compensate investors for risks (such as interest rate, reinvestment and inflation risk) associated with investing in long-term bonds rather than investing in a series of short-term bonds for the entire holding period. Term premia varies over time based on economic conditions e.g. during severe risk-off events like the great financial crisis and COVID-19 pandemic, many DM countries experienced negative term premia due to the large quantitative easing programs implemented in their domestic bond markets whilst EM countries had increased term premia due to heightened fiscal

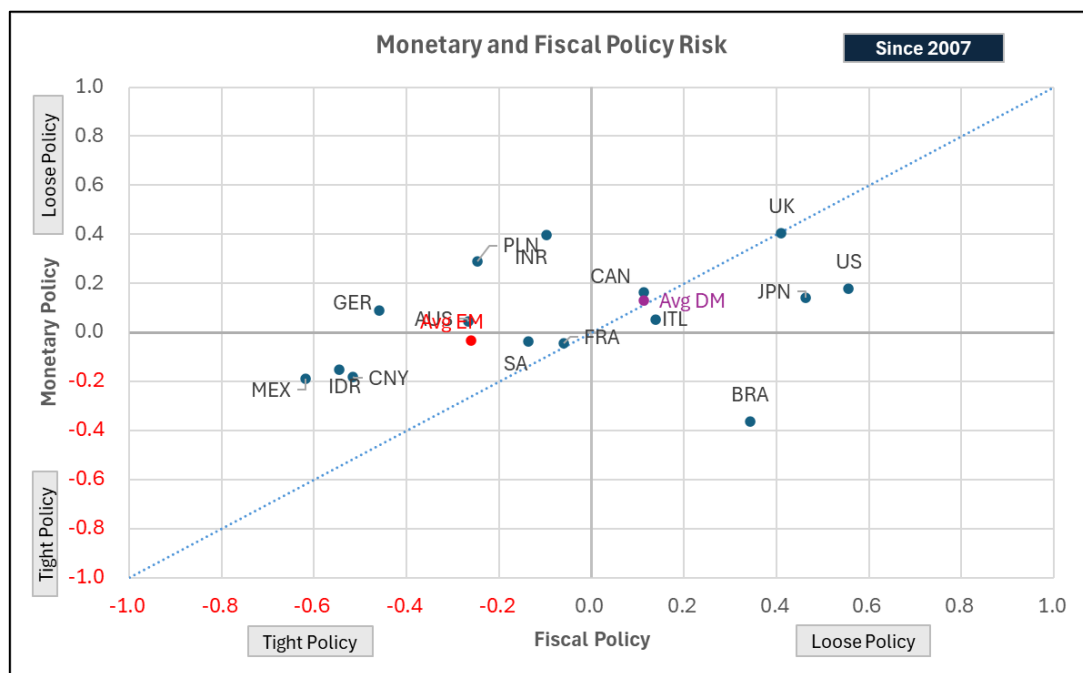
<sup>1</sup> Gross Domestic Product in local currency

risk. With a negative term premium, investors are not compensated for holding long-dated government bonds, this was intentional as DM governments encouraged businesses and consumers to spend rather than save. FRA had neutral fiscal policies and relatively tight monetary policies brought about by a stable Euro currency and inflation environment. Out of the DM countries, GER and AUS had the tightest fiscal policies as they controlled their budget deficits and did not allow them to get out of hand with excessive borrowing.

Since 2007, EM on average has relatively tighter fiscal policies than DM, however DM has marginally tighter monetary policy relative to EM (mainly due to the extremely loose TRL monetary policy). If we remove the TRL outlier, we can see that EM has tighter monetary and fiscal policies relative to DM which resulted in a larger proportion of parallel down shifts as illustrated in Table 4. MEX, IDR and CNY have the tightest fiscal and monetary policies as they maintain high real central bank rates. INR and PLN have similar monetary and fiscal policies whilst BRA has relatively tight monetary policy but loose fiscal policy. SA and FRA have similar monetary policy with SA having slightly tighter fiscal policy due to lower overall debt levels. GER and AUS have the tightest fiscal policies out of the DM countries owing to their lower debt levels and budget deficits. The UK, US and JPN have loose monetary and fiscal policies caused by large budget deficits, borrowing requirements and low real central rates. Despite utilising their reserve currency statuses to increase government debt at low interest rates, DM countries still have relatively loose fiscal policies. If it were not for the government intervention to suppress long-dated interest rates, DM countries would have much steeper yield curves leading to greater long butterfly returns. Since the GFC, term premia in the U.S. and Europe have declined and become negative in some instances. This trend is attributed to shifts in expected short-term rates rather than changes in term premia themselves and can be observed using the Board of Governors of the Federal Reserve System (US) who apply the Kim and Wright (2005) term premium approach. Cohen, Hördahl and Xia (2018) also find that the term premia in US and Europe have been negative post the GFC.



**Figure 11** – The chart shows the extent of monetary and fiscal policy for each of the DM and EM countries from June 2007 to July 2024. A score of -1 = tight policy, 0 = neutral policy and +1 = loose policy. The 45-degree dotted line represents a balanced proxy between monetary and fiscal policies. TRL has ultra loose monetary policy relative to the other markets. EM on average has tighter fiscal policy relative to DM countries. Source Data: IRESS, The World Bank and Bloomberg.

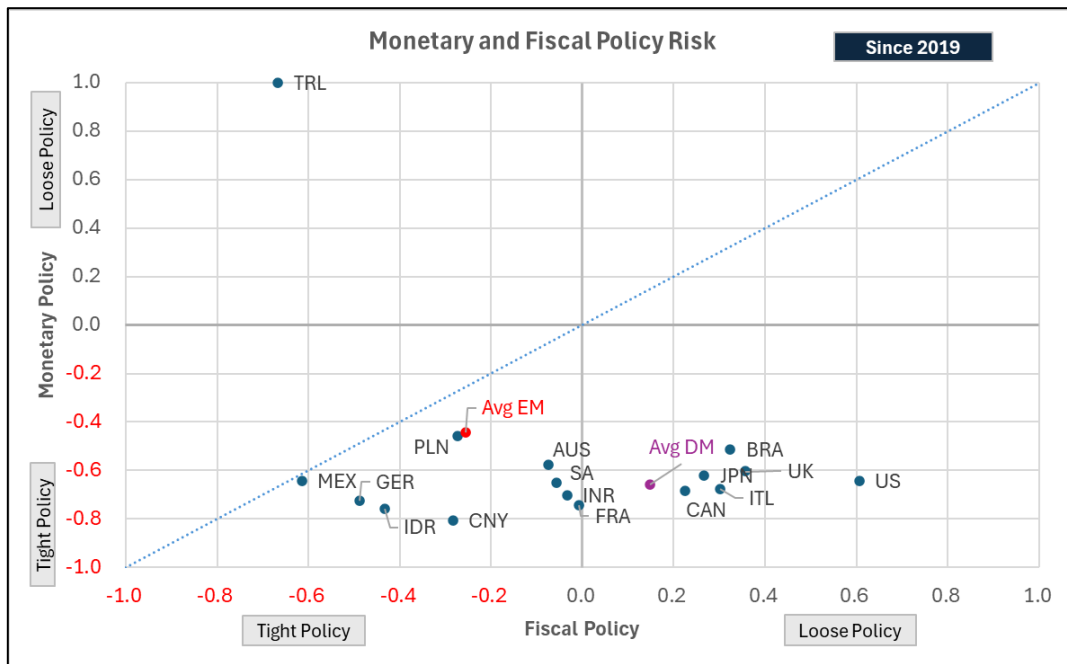


**Figure 12** – The above chart excludes TRL as it is distorting the monetary policy regimes given its ultra loose stance. Thus, the chart shows the extent of monetary and fiscal policy for each of the DM and EM countries from June 2007 to July 2024. A score of -1 = tight policy, 0 = neutral policy and +1 = loose policy. The 45-degree dotted line represents a balanced proxy between monetary and fiscal policies. EM on average has tighter monetary and fiscal policies relative to DM countries. Source Data: IRESS, The World Bank and Bloomberg.

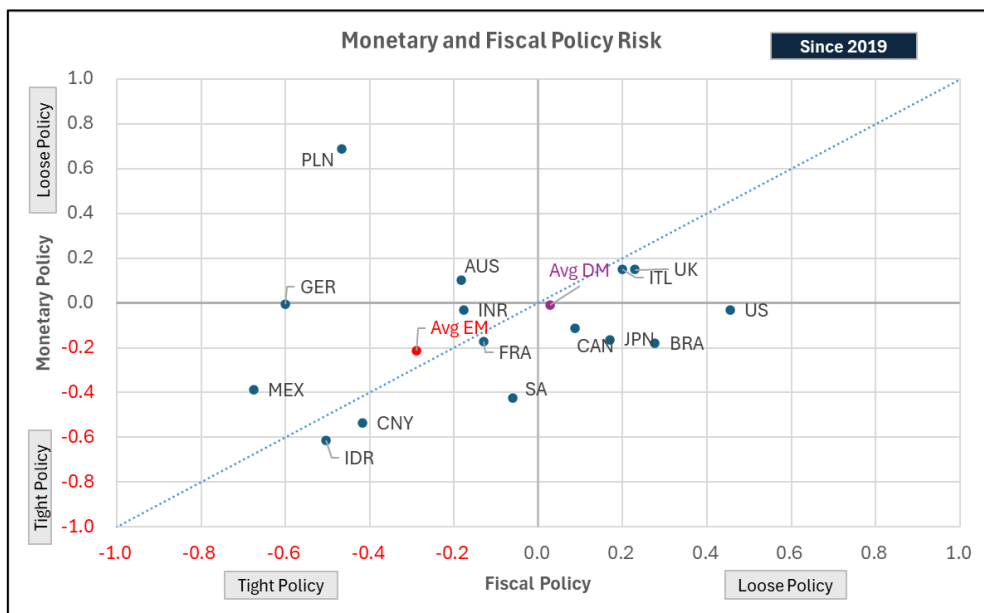
Looking at the same chart in Figure 13 from the Dec 2019 to Mar 2024 (which can be described as the coincidental and post COVID-19 era) illustrates similar fiscal policies but tighter

monetary policies for both EM and DM. If we exclude TRL as in Figure 14 we can see that EM has tighter monetary policy relative to DM countries, even tighter than using data from June 2007. Inflation surged following the COVID-19 pandemic period as massive stimulus was introduced by DM countries. The rebound in growth and consumer demand, together with supply chain disruptions were underestimated. EM central banks responded quickly to the sharp inflation increase by hiking interest rates with DM central banks were slow to react. Thus, cost-push inflation in DM countries far exceeded their inflation targets requiring relatively large interest rate increases which disrupted financial markets especially long-term interest rates. Once again MEX, IDR and CNY had the tightest fiscal and monetary policies given their high real central bank rates, low debt levels and borrowing requirements. SA and INR had tighter monetary policy, POL had much looser monetary policy but tighter fiscal policy, and BRA had looser monetary policy with similar fiscal policy. Out of the DM countries AUS and ITL had looser monetary and fiscal policies post Dec 2019 compared to the whole period. Tighter monetary policy was observed in FRA, GER, JPN, CAN, UK and the US with little change in fiscal policies.

From the above, we see that large QE measures from DM countries suppress long term interest rates resulting in flat or inverted yield curves and lower long butterfly returns. Thus, we find that the appropriate policies to increase long butterfly returns are countries that have relatively tight monetary policies and neutral to slightly loose fiscal policies. From our analysis, countries that fall into this category are SA, BRA, ITL and FRA but ITL and FRA are DM countries that can stimulate and artificially suppress long term interest rates. Therefore, SA and BRA have the most appropriate monetary and fiscal policies to maximise long butterfly returns. If we reverse this argument, we find that TRL which has loose monetary policy and tight fiscal policy favours a short butterfly strategy due to its volatile inflation and currency regime. Countries with relatively balanced monetary and fiscal policies will still be able to generate attractive butterfly returns but will require tactical switches between long and short butterfly strategies for significant returns.



**Figure 13** – The above chart shows the extent of monetary and fiscal policy for each of the DM and EM countries from Dec 2019 to Mar 2024, used to represent the COVID and post COVID era. A score of -1 = tight policy, 0 = neutral policy and +1 = loose policy. The 45-degree dotted line represents a balanced proxy between monetary and fiscal policies. DM monetary policy has been tighter relative to history and EM, with the US having a very loose fiscal stance. Source Data: IRESS, The World Bank and Bloomberg.



**Figure 14** – The above chart excludes TRL as it is distorting the monetary policy regimes given its ultra loose stance. Thus, the chart shows the extent of monetary and fiscal policy for each of the DM and EM countries from Dec 2019 to Mar 2024, used to represent the COVID and post COVID era. A score of -1 = tight policy, 0 = neutral policy and +1 = loose policy. The 45-degree dotted line represents a balanced proxy between monetary and fiscal policies. EM on average has tighter monetary and fiscal policies relative to DM countries. Source Data: IRESS, The World Bank and Bloomberg.

From the above analysis we see that South Africa offers the best potential for butterfly strategies given that it has contrary policies (tight monetary policy and loose fiscal policy),

high absolute yields, elevated sensitivity to risk-off events and a highly cyclical economy given its dependency on commodity exports. We will focus on the SA sovereign bond and interest rate swap market in the next few chapters.

Conclusion:

- Explained the transition from the gold standard to the fiat currency system which resulted in increased sovereign debt and inflation over the past few decades.
- Quantified monetary and fiscal policies using several economic variables and concluded that SA was the most suitable candidate for non-parallel risk premia given its contrary policies of tight monetary policy and loose fiscal policy.
- TRL was also a candidate but was rejected given its volatile political climate and unconventional monetary and fiscal policies.

## Chapter 5 - Butterfly Weight Schemes

*"In finance, the greatest risks are often those that aren't immediately visible. Higher-order risk involves recognising patterns and anomalies that emerge from deeper analysis." – Nassim Nicholas Taleb (Author of The Black Swan)*

### Objectives:

- Introduce five butterfly weight schemes adapted from Hariparsad and Maré (2023.2) and Martellini et.al (2002).
- Explain various approaches to weighting short and long-dated points in a fixed income butterfly strategy.
- Define slope durations with a sensitivity example.
- Apply back-test methodologies using South African swap and bond markets to determine the appropriate butterfly weight scheme for non-parallel risk premia.

The work in this chapter is based on the below publications:

- Investments Analysts Journal - Hariparsad, S. and Maré, E (2023.1),
- The South African Journal of Economic and Management Sciences - Hariparsad, S. & Maré, E. (2024.1), and
- Currently submitted and under review - Hariparsad, Sanveer and Maré, Eben, (2023.2)

The methodologies in this chapter have been adapted from Martellini et.al (2002) and will explain the various approaches to weighting the short and long-dated points in a fixed income butterfly strategy. The weighting schemes we employ are the cash and duration neutral weighting (CN+DN), the fifty-fifty weighting (50/50), the regression weighting (REG), the maturity weighting (MAT) and the high convexity weighting (HCVX). Choosing one will depend on risk tolerances which can amplify or suppress returns. These are described in detail below:

## 5.1 Cash and Duration-Neutral Weights

For the CN+DN weights we define the equations below:

Equation 9 : CN+DN Weights and Duration

$$q_S D_S + q_L D_L + \alpha D_M = 0,$$

Equation 10 : CN+DN Weights and Price

$$q_S P_S + q_L P_L + \alpha P_M = 0,$$

where  $q_S$ ,  $\alpha$  and  $q_L$  are defined as the nominal quantities to be held in the short-, medium- and long-dated bond/swap respectively.  $D_S$ ,  $D_M$  and  $D_L$  are defined as the present value per basis point (PV01) of the short-, medium- and long-dated bonds/swaps, similarly  $P_S$ ,  $P_M$  and  $P_L$  are defined as the all-in prices of the short-, medium- and long-dated bonds/swaps respectively. Equation 9 and Equation 10 calculate the quantities of the short- and long-dated bonds/swaps respectively so that their modified durations and all-in prices match the medium-dated bond/swap. Thus, we solved the system of linear equations to arrive with:

Equation 11 : CN+DN Linear Equations

$$\begin{pmatrix} q_S \\ q_L \end{pmatrix} = \begin{pmatrix} D_S & D_L \\ P_S & P_L \end{pmatrix}^{-1} \times \begin{pmatrix} -\alpha D_M \\ -\alpha P_M \end{pmatrix},$$

which gives us  $q_S$  and  $q_L$  nominal quantities of the short- and long-dated bonds/swaps for  $\alpha$  nominal amount of the medium-dated bond/swap.

## 5.2 Fifty-Fifty Weights

Equation 12 : Fifty-Fifty Weight Solution

$$q_S D_S = q_L D_L = -\alpha D_M / 2,$$

With fifty-fifty weights we must ensure that the PV01 on each wing is equivalent which is effectively what Equation 12 is stating (i.e. equally share the PV01 of the medium-dated bond so that the short- and long-dated bonds have the same PV01). The 50/50 weighting scheme will be immune to small steepening or flattening scenarios.

## 5.3 Regression and Maturity Weights

Equation 13 : Regression Beta Solution

$$q_S D_S \times 1/\beta = q_L D_L, \text{ thus}$$

$$\beta = (q_S D_S) / (q_L D_L) .$$

Short-term yields are generally more volatile than long-term yields due to active monetary policy and tactical, investor sentiment shifts, whereas long-term yields are concerned about strategic growth, inflation and business cycles. With regression weights the sensitivity of long-term yields to short-term yields is calculated and represented by the  $\beta$  coefficient in Equation 13. The  $\beta$  coefficient is sensitive to the data frequency and period used (e.g. if the  $\beta = 0.2$  then a 10bps move in the short-bond yield would result in a 2bp move in the long-bond yield). The 50/50 weighting scheme is given by setting  $\beta = 1$ .

For the maturity weights we set the  $\beta$  coefficient to Equation 14, which gives us a ratio of the distance (in years) of the medium-bond to the short-bond, relative to the distance of the long-bond to the medium-bond.

Equation 14 : Maturity Beta Solution

$$\beta = (M_m - M_S)/(M_L - M_m),$$

with  $M_L$ ,  $M_m$  and  $M_S$  being the maturity of the long-, medium- and short-dated bond respectively.

## 5.4 High Convexity Weights

HCVX is a duration-neutral weighting scheme with a significant long-dated bond allocation and a  $\beta$  coefficient generally set above 1. Additional cash is required to purchase the long body which means that interest costs are incurred.

The HCVX and DN+CN weight schemes have positive slope durations whilst the MAT, 50/50 and REG weight schemes have negative slope durations. So, if we experience curve flattening then weight schemes with a positive (negative) slope duration will outperform (underperform). The opposite occurs during curve steepening, weight schemes with negative (positive) slope duration outperform (underperform).

## 5.5 Back-Test Methodology for the Weight Schemes

To demonstrate the effects of the various butterfly weight methodologies we use the South African Best Decency (SABD) bond curve and swap rates obtained from Bloomberg to apply the above weight schemes. The SABD curve is derived from the South African Perfect Fit (SAPF) bond curve which prices all SA government bonds in the government bond index perfectly, hence the name, but the SABD curve strikes a balance between pricing accuracy and curve smoothness, Ririe and Dugmore (2007). The interest rate swaps involve fixed-for-floating swaps with quarterly coupons and a floating leg based on 3-month JIBAR.

Total returns on a hypothetical, constant maturity, zero-coupon SA government bond are calculated, with interest accruing over the period. Monthly rebalancing is used with beginning of month data which meant that the SA zero-coupon government bonds priced at par but changed at month-end as the zero-coupon yields changed. For each bond butterfly strategy, interest earned and paid on borrowed amounts are set to the beginning of month overnight cash

rate, adjusted by a 0.5% per annum margin spread (e.g. if the overnight cash rate is 7%, additional proceeds will earn 6.5% per annum and borrowed amounts will pay interest of 7.5% per annum). Monthly data from January 2002 to July 2024 is used for back-testing, with trade costs initially excluded, but discussed in chapters 5.8 Incorporating Trade Costs into the Butterfly Weight Scheme Strategies, 6.3 Describing Butterfly Trade Costs and Chapter 8 - Rebalancing Frequencies.

There is no excess or shortfall of proceeds with interest rate swaps as these are derivatives with no physical cash transfers, only mark-to-market adjustments. In the later chapters we use data starting from January 2001 but for this back-test we required an initial regression period for the REG weight scheme, hence we adjusted the start period to January 2002 instead of January 2001.

Three long butterfly strategies (2v5v10, 5v10v20, and 10v20v30, which will represent a short-, medium- and long-dated butterfly respectively) are back-tested, each using five weighting schemes. The passive approach maintains a long butterfly strategy throughout the period whilst a tactical approach switches between a long or short butterfly strategy depending on the interest rate cycle and slope duration. The tactical approach follows the below technical signal in Table 10.

Tactical Approach	Slope Duration of Weight Scheme	
	Positive	Negative
<b>Hiking Cycle</b> (Flattening Anticipated)	Short Butterfly	Long Butterfly
<b>Cutting Cycle</b> (Steepening Anticipated)	Long Butterfly	Short Butterfly

**Table 10** – Describes the technical rule that will be used for the tactical approach. Depending on the interest rate cycle and slope duration of the chosen weight scheme, a long or short butterfly strategy will be implemented.

To explain the tactical approach, if a weight scheme has a positive (negative) slope duration, and:

- If interest rate cuts are anticipated, steepening is more likely as short-dated yields fall more than long-dated yields, thus a long (short) butterfly strategy is preferred.
- If interest rate hikes are anticipated, flattening is more likely as short-dated yields rise more than long-dated yields, thus a short (long) butterfly strategy is preferred.

To determine the interest rate cycle we observe the change in the central bank rate or from a South African perspective, the change in the South African Reserve Bank Repo Rate and follow the below technical rule:

Equation 15 : Tactical Approach

$$\text{If } Repo\ Rate_{t-1} - Repo\ Rate_{t-2} = \begin{cases} < 0, & \text{Cutting Cycle} = \text{Steeper Curves} \Rightarrow \text{Long Butterfly Strategy} \\ > 0, & \text{Hiking Cycle} = \text{Flatter Curves} \Rightarrow \text{Short Butterfly Strategy} \\ = 0, & \text{Current Cycle Continues} \Rightarrow \text{Maintain Previous Butterfly Strategy} \end{cases} ,$$

where  $Repo\ Rate_{t-1}$  is the SA repo rate one-month ago and  $Repo\ Rate_{t-2}$  is the SA repo rate two-months ago. Equation 15 provides clarity on how the tactical approach works in that a negative (positive) monthly change in the SA repo rate equates to a cutting (hiking) cycle, steeper (flatter) curve and long (short) butterfly strategy to maximise returns. Whilst an unchanged SA repo rate means that we maintain the previous months strategy (i.e. if a short butterfly strategy was held during the prior month, then we continue to hold the short butterfly strategy in the upcoming month).

The slope durations are a critical component of the tactical approach, and we need to determine if they are positive or negative for each of the five weight schemes, this will be expanded upon in the next section.

## 5.6 Slope Durations

As described in the preamble, duration is a form of risk premia that compensates investors for interest rate risk associated with holding bonds of longer maturities. Duration generally refers to taking on risk associated with parallel yield curve shifts, in that all yields across the yield curve move by similar amounts. Slope duration refers to risk-taking associated with non-parallel yield curve shifts, where all maturities increase or decrease by different amounts. For example, if a bond has a duration risk of 5 and the yield curve immediately shifts up (down) by 1% in a parallel fashion, the bond will experience a 5% capital loss (gain). Similarly, if a 2v5v10 long butterfly strategy has a slope duration of 2 and the 10-year less 2-year spread

steepens (flattens) by 1% then the 2v5v10 long butterfly strategy will experience a 2% capital loss (gain).

To illustrate the slope duration of the various long butterfly weight schemes we will provide a hypothetical example. Assume we have three bonds (2-,5- and 10-year bond) with which to construct a 2v5v10 long butterfly strategy with characteristics given in Table 11 below.

Position	Bond Maturities	Bond Price (par 100)	Bond Yield (%)	Convexity	Modified Duration	PV01 per R1m nominal
Short Wings	2y	102.0	8.5	4.6	1.8	187
Long Body	5y	105.0	9.2	25.1	4.6	479
Short Wings	10y	108.0	10.8	94.2	9.0	969

**Table 11** – An example of 2-,5- and 10-yr bond which will be used to construct a 2v5v10 long butterfly strategy. The bond prices are shown per 100 par value, PV01 is known as the present value per basis point move and is the rand amount that will be gained (lost) if the bond yield decreases (increases) by 1bp, the bond yield, convexity and modified duration are also provided. A short position in the 2- and 10-year bonds will be used for the wings whilst a long position will be applied to the 5-year bond referred to as the body.

The bond weights and long butterfly statistics for each of the 2v5v10 weight schemes are provided in Table 12. The PV01 is zero for all the weight schemes which implies a duration neutral strategy.

Position	Bond Maturities	HCVX	CN+DN	MAT	50/50	REG
Short Wings	2-year	-30%	-63%	-96%	-128%	-147%
Long Body	5-year	100%	100%	100%	100%	100%
Short Wings	10-year	-44%	-37%	-31%	-25%	-21%
Long Butterfly Statistics		HCVX	CN+DN	MAT	50/50	REG
Net PV01		0	0	0	0	0
A - Butterfly Yield (pa)		1.9%	-0.1%	-2.3%	-4.3%	-5.5%
B - Interest income/costs (pa)		2.0%	0.1%	-1.7%	-3.4%	-4.4%
Net Butterfly Yield (pa) = A-B		-0.1%	-0.2%	-0.6%	-0.9%	-1.1%
Net Convexity		-17	-13	-8	-4	-1
Slope Duration		0.7	0.4	0.1	-0.1	-0.3
Curvature Duration		0.2	0.2	0.3	0.3	0.3

**Table 12** – Weights of the 2-,5- and 10-year bonds that will be used for the five weight schemes (HCVX, CN+DN, MT, 50/50, REG). A negative weight = short position whilst a positive weight = long position. All the weight schemes are duration neutral with a PV01 = 0. The long butterfly statistics show the butterfly yield (including an excluding interest income and costs), net convexity, slope duration and curvature duration.

The weight scheme differentiation can be identified by the weight allocation between the 2- and 10-year bonds. The HCVX, CN+DN and MAT weight schemes allocate less than 100% to the 2-year bond whilst the 50/50 and REG weight schemes allocate more than 100% to the 2-year bond. The butterfly yield is the annual yield we would earn on the long butterfly strategy according to the bond allocations and is calculated as below:

Equation 16 : Long Butterfly Yield

$$\text{Long Butterfly Yield} = \text{Weight}_{\text{Body}} \text{Yield}_{\text{Body}} - (\text{Weight}_{\text{Wing1}} \text{Yield}_{\text{Wing1}} + \text{Weight}_{\text{Wing2}} \text{Yield}_{\text{Wing2}}).$$

In this example, the HCVX butterfly yield is calculated as below:

$$\text{Butterfly Yield}_{\text{HCVX}} = 100\% (9.2\%) - [-30\% (8.5\%) - 44\% (10.8\%)] = 1.9\%$$

And we continue for each of the other weight schemes. The HCVX, MAT, 50/50 and MAT weight schemes are duration but not cash neutral so there will be interest income or costs incurred. We assume an interest expense of 7.5% per annum on borrowed funds and interest income of 6.5% per annum on excess proceeds that we receive. The net butterfly yield accounts for the interest income and expenses that are associated with the cash proceeds of the butterfly strategy. We see that the HCVX weight scheme has the highest net butterfly yield at -0.1% per annum with the REG weight scheme having the lowest net butterfly yield at -1.1% per annum. A higher net butterfly yield is preferred as this is the annual return one would earn on the 2v5v10 strategy assuming an unchanged bond yield curve.

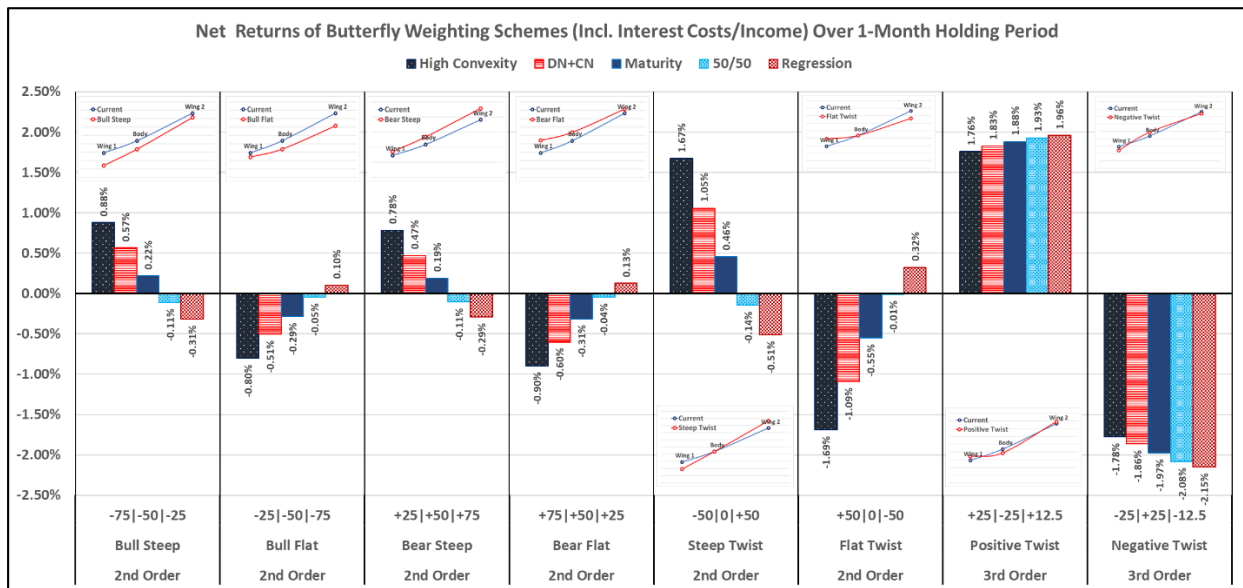
The HCVX, CN+DN and MAT weight schemes have positive slope duration whilst the 50/50 and REG weight schemes have negative slope durations. Assuming long butterfly strategies, weight schemes with positive slope duration (HCVX, CN+DN and MAT) outperform during curve steepening due to the relatively higher allocation to the long-dated bond which underperforms resulting in the wings underperforming the body in a long butterfly strategy. Weight schemes with negative slope duration (50/50 and REG) underperform during curve steepening as they hold relatively less of the long-dated bond which is the biggest underperformer during steepening scenarios as the body underperforms the wings assuming a long butterfly strategy. The opposite holds true for curve flattening scenarios in that negative

slope duration strategies outperform relative to positive slope duration strategies as the relatively lower long-dated bond allocation does not hinder the returns. A summary of this is provided in Table 13.

Long Butterfly Relative Performance		
Slope Duration	Curve Steepening	Curve Flattening
<b>Positive</b> (HCVX, CN+DN and MAT)	Outperformance	Underperformance
<b>Negative</b> (50/50 and REG)	Underperformance	Outperformance
Short Butterfly Relative Performance		
Slope Duration	Curve Steepening	Curve Flattening
<b>Positive</b> (HCVX, CN+DN and MAT)	Underperformance	Outperformance
<b>Negative</b> (50/50 and REG)	Outperformance	Underperformance

**Table 13** – Summary of the relative performances of the various butterfly weight schemes that consist of positive and negative slope durations. For a long butterfly strategy, positive slope duration weight schemes (HCVX, CN+DN and MAT) prefer curve steepening, whilst negative slope duration weight schemes (50/50 and REG) prefer curve flattening. For a short butterfly strategy, positive slope duration weight schemes (HCVX, CN+DN and MAT) prefer curve flattening, whilst negative slope duration weight schemes (50/50 and REG) prefer curve steepening. Source Data: IRESS and Bloomberg.

To confirm this we use our above example over a one-month holding period with 2nd order curve scenarios (bull steepening and flattening, and bear steepening and flattening) and 3rd order curve scenarios (positive and negative twists). Figure 15 illustrates the net returns (including the interest income and costs) of the various weight schemes over a one-month holding period.



**Figure 15-** shows the net returns (including the interest income and costs) of the various weight schemes over a one-month holding period using several 2nd and 3rd order curve scenarios. Curve scenario images are also provided to depict the curve changes and make it easier for the reader to visualise. The x-axis denotes the yield change of each of the bonds (e.g. -75|-50|-25 equates to the 2-year bond yield changing by -75 basis points, the 5-year bond yield changing by -50 basis points and 10-year bond yield changing by -25 basis points which is a bull steepening scenario). The HCVX, CN+DN and MAT weight schemes outperform during curve steepening whilst the MAT and 50/50 weight schemes outperform during curve flattening. Source Data: IRESS and Bloomberg.

The x-axis describes the change in yield of each of the bonds (e.g. -75|-50|-25 equates to the 2-year bond yield changing by -75 basis points, the 5-year bond yield changing by -50 basis points and 10-year bond yield changing by -25 basis points which is a bull steepening scenario). For the steepening scenarios (bull steepening, bear steepening and steep twist) we see the HCVX, CN+DN and MAT weight schemes delivering positive performance whilst the 50/50 and REG weight schemes had negative performance which confirms the summary in Table 13. For flattening scenarios (bull flattening, bear flattening and flat twist) we notice the positive returns of the REG weight scheme followed by the MAT weight scheme with returns close to zero. The HCVX, CN+DN and MAT weight schemes produce negative returns with the HCVX being the laggard as it has the largest short position in the long-dated 10-year bond.

For the 3rd order scenarios (positive and negative twists) we see that the returns for all the weight schemes are positive during the positive twist scenario and all negative during the negative twist scenario but there are subtle differences. For the positive twist scenario the 2-year and 10-year bond yields shift higher (+25 and +12.5 basis points respectively) whilst the 5-year bond yield shifts lower by 25 basis points resulting in curve flattening. Thus, the curve flattening benefitted the negative slope duration weight schemes (50/50 and REG) relative to positive slope duration weight schemes (HCVX, CN+DN and MAT). The opposite occurs

during the negative twist scenario in that the 2-year and 10-year bond yields shift lower (-25 and -12.5 basis points respectively) whilst the 5-year bond yield shifts higher by 25 basis points resulting in curve steepening. Thus, the curve steepening resulted in the positive slope duration weight schemes (HCVX, CN+DN and MAT) outperforming the negative slope duration weight schemes (50/50 and REG). We must also take note of the relative net convexities of the weight schemes as the HCVX and CN+DN weight schemes have relatively lower net convexity compared to the MAT, 50/50 and REG weight schemes (0.2 versus 0.3 in an absolute sense). During the positive (negative) twist scenario the curvature decreased (increased) which resulted in the higher convexity weight schemes outperforming (underperforming) the lower convexity weight schemes.

The above example is over a one-month holding period, if we increase the holding period to three or six months, we notice that weight schemes with borrowed funds underperform those that have excess funds or are cash neutral. Thus, the MAT, 50/50 and REG weight schemes have borrowed funds and will likely underperform the HCVX and CN+DN weights schemes as the holding period increases since the interest cost on the borrowed funds will wipeout the returns generated by the MAT, 50/50 and REG weight schemes. For the MAT, 50/50 and REG weight schemes to be profitable over a long holding period, the yield curve will have to experience very large curve flattening. This is an important point because duration neutral weight schemes that require borrowed funds are relatively riskier than duration neutral weight schemes that have excess funds or are cash neutral. This is because if curve flattening does not materialise in a timely fashion, the opportunity cost of holding the duration neutral weight schemes with borrowed funds increases exponentially as the interest costs are compounded. We can conclude that weight schemes with excess or cash neutral funds are lower risk compared to those with borrowed funds as they are less dependent on the holding period but can underperform during quick flattening scenarios relative to the borrowed fund weight schemes.

It must be noted that these are only a handful of curve scenarios, in reality there are many curve variations with different outcomes for the long butterfly weight schemes. Knowing which curve scenarios are likely will assist in selecting the appropriate butterfly strategy and weight scheme.

In the next section we will back-test three butterfly strategies in the SA interest rate markets using the methodologies described in chapter 5.5 Back-Test Methodology for the Weight Schemes.

## 5.7 Back-Test Results

To determine the viability of the weight schemes, we back-test three butterfly strategies in the SA interest rate markets using a passive and tactical approach, using the methodologies described in chapter 5.5 Back-Test Methodology for the Weight Schemes. The three butterfly strategies we back-test are a 2v5v10, 5v10v20 and 10v20v30 which will cover the entire curve and represent a short, medium and long-dated butterfly strategy respectively. For each of the three butterfly strategies we will also test the five weight schemes (HCVX, CN+DN, MAT, 50/50 and REG).

The results of the passive and tactical swap and bond butterfly strategies are presented in Table 14 and Table 15 respectively. For the swap butterfly strategies in Table 14, the passive approach shows positive performance for all the weight schemes of the 2v5v10 and 5v10v20 butterflies. The 10v20v30 butterfly has negative returns for all the weight schemes (except the HCVX weight scheme) due to relatively greater slope duration which compromised returns as there was a higher proportion of negative twists which favoured the wings over the belly. Over the period the swap slope has increased which negatively impacted high spread duration butterflies as in the case of the 10v20v30 butterfly strategy. The omega ratios for the 2v5v10 and 5v10v20 passive butterflies are relatively higher than the passive 10v20v20 butterfly suggesting a more attractive risk/return profile and a favourable upside to downside return ratio. The kurtosis is relatively higher for the 2v5v10 and 5v10v20 passive butterflies which suggests large outperformance periods. This is confirmed by the back-test as we notice high returns for the 2v5v10 and 5v10v20 passive butterflies during the 2008 global financial crisis and 2020 COVID pandemic where central banks cut interest rates to spur economic growth which favoured the short- and medium-dated butterflies.

Tactical swap butterfly strategies show that the 50/50, REG and MAT weight schemes are the outperformers with gross annualised returns between 0.1% and 0.2% for the 2v5v10 and 0.4% each for the 10v20v30 butterfly strategies. However, the 50/50, REG and MAT weight schemes underperform for the tactical 5v10v20 butterfly strategy with gross annualised returns between -0.6% and -0.4% and the outperformers being the HCVX and CN+DN weight schemes with gross annualised returns of 0.8% and 0.6% respectively.

Passive		2v5v10					5v10v20					10v20v30				
Swap Butterfly	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	
Index	100.8	102.3	101.5	103.6	106.1	105.2	103.7	102.7	102.8	104.0	100.5	99.3	96.4	96.3	96.4	
Ret (pa)	0.04%	0.10%	0.07%	0.16%	0.26%	0.23%	0.16%	0.12%	0.12%	0.17%	0.02%	-0.03%	-0.16%	-0.17%	-0.16%	
Std Dev (pa)	1.2%	0.8%	0.9%	0.8%	0.8%	1.5%	1.2%	1.2%	1.2%	1.2%	1.0%	0.9%	1.2%	1.1%	1.2%	
Ret/SD	0.03	0.13	0.07	0.20	0.31	0.15	0.13	0.10	0.10	0.15	0.02	-0.04	-0.14	-0.15	-0.14	
Skew	1.6	0.3	0.9	-0.4	0.1	0.1	-0.5	-1.9	-1.1	-0.7	-0.1	-0.1	-0.1	-0.2	-0.1	
Kurtosis	16.7	5.5	10.4	1.0	5.8	2.1	6.8	20.2	16.3	8.5	4.4	4.0	1.5	1.5	1.5	
Omega	0.96	1.04	0.99	1.09	1.12	1.12	1.06	1.01	1.01	1.07	0.97	0.93	0.88	0.87	0.88	
Max DD	4.5%	3.1%	3.7%	2.2%	2.5%	4.1%	3.6%	4.0%	4.5%	3.5%	3.2%	3.8%	7.5%	7.7%	7.5%	
CVaR 1%	-1.3%	-1.0%	-1.1%	-1.0%	-1.5%	-1.1%	-1.5%	-2.4%	-2.3%	-1.6%	-1.4%	-1.3%	-1.3%	-1.3%	-1.3%	

Tactical		2v5v10					5v10v20					10v20v30				
Swap Butterfly	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	
Index	100.9	99.4	104.0	102.7	102.2	118.4	114.0	91.6	91.4	87.6	103.8	102.8	109.4	109.2	109.4	
Ret (pa)	0.04%	-0.03%	0.17%	0.12%	0.10%	0.75%	0.59%	-0.39%	-0.40%	-0.59%	0.17%	0.12%	0.40%	0.39%	0.40%	
Std Dev (pa)	0.4%	0.9%	0.8%	0.8%	0.7%	0.4%	1.2%	1.2%	1.2%	1.2%	0.3%	0.9%	1.2%	1.1%	1.2%	
Ret/SD	0.09	-0.03	0.22	0.14	0.13	2.12	0.49	-0.34	-0.33	-0.50	0.51	0.13	0.35	0.34	0.35	
Skew	1.7	0.9	-0.4	0.1	-0.2	0.2	-0.5	-1.9	-1.1	-0.7	-0.5	-0.1	-0.1	-0.2	-0.1	
Kurtosis	16.7	10.4	1.0	5.8	2.1	2.1	6.8	20.2	16.3	8.5	4.5	4.0	1.5	1.5	1.5	
Omega	0.96	0.93	1.10	1.02	1.04	1.59	1.43	0.73	0.73	0.62	1.09	1.05	1.25	1.24	1.25	
Max DD	4.3%	4.1%	3.2%	4.5%	3.2%	3.0%	2.2%	11.3%	11.7%	14.7%	3.3%	3.2%	3.2%	3.2%	3.2%	
CVaR 1%	-1.3%	-1.1%	-0.8%	-1.7%	-1.0%	-1.1%	-1.5%	-1.5%	-1.9%	-1.3%	-1.6%	-1.5%	-1.2%	-1.2%	-1.2%	

**Table 14** - Summarises the back-tested gross annualised returns and risk statistics of 2v5v10, 5v10v20 and 10v20v30 swap butterfly strategies using the South African Best Decency Zero Curve from January 2002 to July 2024. Five weighting schemes are tested, high convexity (HCVX), fifty/fifty (50/50), regression (REG), maturity (MAT) and cash and duration neutral (CN+DN). The passive approach assumes a constant long butterfly strategy whilst the tactical approach adjusts between a long or short butterfly strategy depending on the interest rate cycle and slope duration. The HCVX, CN+DN and 50/50 weight schemes outperform for the 5v10v20 passive butterfly whilst the MAT and REG weight schemes outperform for the 2v5v10 passive butterfly. The REG and MAT weight schemes outperform for the 2v5v10 and 10v20v30 tactical butterflies whilst the HCVX, CN+DN and 50/50 weight schemes outperform for the 5v10v20 tactical fly strategy. Source Data: IRESS and Bloomberg.

For the bond butterfly strategies in Table 15 the passive approach shows a similar pattern to the passive swap butterfly strategies in that a positive gross performance is observed for all the weight schemes of the 2v5v10 and 5v10v20 butterflies with gross negative returns across most of the 10v20v30 butterfly weight schemes (except the HCVX weight scheme that is marginally positive with 0.01% gross return). The gross negative returns of the 10v20v30 butterfly weight schemes are once again due to its relatively greater spread duration and is exacerbated by bond curve steepening over the period. The omega ratios, positive skew and maximum drawdowns for the passive 2v5v10 and 5v10v20 butterflies are relatively higher than the passive 10v20v30 butterfly suggesting a more attractive risk/return profile and a favourable upside to downside return ratio.

Tactical bond butterfly strategies show that the 50/50, REG and MAT weight schemes for the tactical 2v5v10 and 5v10v20 butterfly strategies are the outperformers with gross annualised returns between -0.04% and 0.45%, with the HCVX and CN+DN weight schemes delivering gross annualised returns between -0.44% and -0.12%. For the 10v20v30 tactical butterfly we see that the HCVX and CN+DN weight schemes are the outperformers with gross annualised returns of 0.23% and 0.31% respectively whilst the 50/50, REG and MAT weight schemes are the underperformers with gross annualised returns between -0.63% and -0.52%. Amongst all

the tactical butterfly strategies, the tactical HCVX weight scheme is the underperformer with gross annualised returns between -0.44% and 0.23%, followed by the tactical CN+DN weight scheme with gross annualised returns between -0.34% and 0.25%. The high omega ratios and low maximum drawdowns for the tactical 50/50, REG and MAT weight schemes amongst all the tactical butterfly strategies suggest that these weight schemes produce attractive risk-adjusted returns, that respond well to the technical signal.

Passive	2v5v10					5v10v20					10v20v30				
	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT
<b>Index</b>	105.6	108.7	102.3	104.7	105.5	115.2	110.3	100.0	105.8	110.2	100.2	95.8	78.8	78.3	78.8
<b>Ret (pa)</b>	0.24%	0.37%	0.10%	0.20%	0.24%	0.63%	0.43%	0.00%	0.25%	0.43%	0.01%	-0.19%	-1.05%	-1.08%	-1.05%
<b>Std Dev (pa)</b>	1.8%	1.4%	1.6%	1.9%	1.4%	2.5%	1.6%	1.6%	1.9%	1.7%	3.0%	2.8%	3.2%	3.3%	3.2%
<b>Ret/SD</b>	0.14	0.26	0.06	0.11	0.17	0.25	0.26	-0.00	0.13	0.26	0.00	-0.07	-0.32	-0.33	-0.32
<b>Skew</b>	0.2	0.1	-0.5	-0.8	-0.2	-0.3	0.0	0.5	0.7	0.0	-4.6	-3.2	0.2	0.2	0.2
<b>Kurtosis</b>	5.3	4.1	4.6	7.4	3.6	7.6	12.2	12.3	8.6	12.0	57.7	42.2	9.9	10.4	9.9
<b>Omega</b>	1.07	1.14	1.01	1.03	1.07	1.15	1.11	0.94	1.04	1.11	0.92	0.87	0.75	0.74	0.75
<b>Max DD</b>	6.2%	5.5%	6.5%	6.9%	5.4%	7.5%	5.3%	7.5%	5.8%	5.4%	14.6%	13.9%	31.6%	32.2%	31.6%
<b>CVaR 1%</b>	-2.0%	-1.8%	-2.5%	-3.0%	-1.9%	-3.4%	-2.7%	-2.6%	-2.4%	-2.7%	-4.5%	-4.3%	-4.7%	-4.6%	-4.7%

Tactical	2v5v10					5v10v20					10v20v30				
	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT
<b>Index</b>	97.4	95.7	107.2	110.6	105.5	90.6	92.8	104.4	99.2	106.3	105.2	107.3	86.7	88.9	86.7
<b>Ret (pa)</b>	-0.12%	-0.19%	0.31%	0.45%	0.24%	-0.44%	-0.33%	0.19%	-0.04%	0.27%	0.23%	0.31%	-0.63%	-0.52%	-0.63%
<b>Std Dev (pa)</b>	0.6%	1.4%	1.6%	1.9%	1.4%	0.9%	1.6%	1.6%	1.9%	1.7%	1.1%	2.8%	3.2%	3.3%	3.2%
<b>Ret/SD</b>	-0.20	-0.14	0.20	0.24	0.17	-0.51	-0.20	0.12	-0.02	0.16	0.22	0.11	-0.19	-0.16	-0.19
<b>Skew</b>	0.3	0.1	-0.5	-0.8	-0.2	-0.4	0.0	0.5	0.7	0.0	-4.7	-3.2	0.2	0.2	0.2
<b>Kurtosis</b>	5.3	4.1	4.6	7.4	3.6	7.4	12.2	12.3	8.6	12.0	58.1	42.2	9.9	10.4	9.9
<b>Omega</b>	0.91	0.88	1.10	1.14	1.07	0.84	0.83	1.01	0.94	1.04	0.98	1.01	0.82	0.84	0.82
<b>Max DD</b>	9.0%	10.0%	9.5%	11.0%	8.7%	19.1%	14.1%	8.5%	8.6%	12.0%	14.2%	12.7%	21.5%	19.4%	21.5%
<b>CVaR 1%</b>	-2.0%	-1.8%	-1.8%	-1.9%	-1.8%	-3.4%	-2.7%	-2.4%	-2.9%	-2.1%	-4.6%	-4.3%	-4.4%	-4.6%	-4.4%

**Table 15** - Summarises the back-tested gross annualised returns and risk statistics of 2v5v10, 5v10v20 and 10v20v30 bond butterfly strategies using the South African Best Decency Zero Curve from January 2002 to July 2024. Five weighting schemes are tested, high convexity (HCVX), fifty/fifty (50/50), regression (REG), maturity (MAT) and cash and duration neutral (CN+DN). The passive approach assumes a constant long butterfly strategy whilst the tactical approach adjusts between a long or short butterfly strategy depending on the interest rate cycle and slope duration. The HCVX, CN+DN and MAT weight schemes outperform for the 2v5v10 and 5v10v20 passive butterflies. The HCVX and CN+DN weight scheme outperforms for the 10v20v30 tactical butterfly strategy whilst the 50/50, REG and MAT weight schemes outperform for the 2v5v10 and 5v10v20 tactical butterfly strategies. Source Data: IRESS and Bloomberg.

## 5.8 Incorporating Trade Costs into the Butterfly Weight Scheme Strategies

Trade costs can be a significant detractor from the above butterfly returns if not managed pragmatically. Table 16 summarises the net returns for each of the swap and bond butterfly strategies and weight schemes. We assumed roundtrip trade costs of 1bp of spread duration, with monthly rebalancing. Roundtrip trade costs for the swap butterfly strategies are 0.4%, 0.7% and 1.0% for the 2v5v10, 5v10v20 and 10v20v30 weights schemes respectively and 0.5%, 1.1% and 2.1% for the 2v5v10, 5v10v20 and 10v20v30 bond butterfly weights schemes respectively. The bond butterfly trade costs are greater than the swap butterfly trade costs since we have assumed the bond butterfly strategies are zero coupon which implies higher spread duration and trade costs relative to the swap butterflies that have quarterly interest payments.

As can be seen, monthly rebalancing is very costly resulting in negative net annualised returns across all the swap and bond butterfly strategies and weight schemes. Thus a pragmatic rebalancing policy is required to ensure the swap and bond butterfly strategies are profitable. Pragmatic rebalancing strategies are discussed in more detail in Chapter 6 - Exploiting Non-Parallel Risk Premia and Chapter 8 - Rebalancing Frequencies.

Swap Butterfly		2v5v10					5v10v20					10v20v30				
Passive	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	
Gross Ret (pa)	0.04%	0.07%	0.16%	0.26%	0.12%	0.23%	0.16%	0.12%	0.12%	0.17%	0.02%	-0.03%	-0.16%	-0.17%	-0.16%	
Trade Costs (pa)	0.43%	0.43%	0.43%	0.43%	0.43%	0.71%	0.71%	0.71%	0.71%	0.71%	1.02%	1.02%	1.02%	1.02%	1.02%	
Net Ret (pa)	-0.39%	-0.37%	-0.28%	-0.17%	-0.31%	-0.48%	-0.55%	-0.59%	-0.59%	-0.54%	-1.00%	-1.05%	-1.18%	-1.19%	-1.18%	
Tactical	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	
Gross Ret (pa)	0.04%	0.07%	0.16%	0.26%	0.12%	0.23%	0.16%	0.12%	0.12%	0.17%	0.02%	-0.03%	-0.16%	-0.17%	-0.16%	
Trade Costs (pa)	0.43%	0.43%	0.43%	0.43%	0.43%	0.71%	0.71%	0.71%	0.71%	0.71%	1.02%	1.02%	1.02%	1.02%	1.02%	
Net Ret (pa)	-0.39%	-0.37%	-0.28%	-0.17%	-0.31%	-0.48%	-0.55%	-0.59%	-0.59%	-0.54%	-1.00%	-1.05%	-1.18%	-1.19%	-1.18%	

Bond Butterfly		2v5v10					5v10v20					10v20v30				
Passive	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	
Gross Ret (pa)	0.24%	0.37%	0.10%	0.20%	0.24%	0.63%	0.43%	0.00%	0.25%	0.43%	0.01%	-0.19%	-1.05%	-1.08%	-1.05%	
Trade Costs (pa)	0.53%	0.53%	0.53%	0.53%	0.53%	1.06%	1.06%	1.06%	1.06%	1.06%	2.12%	2.12%	2.12%	2.12%	2.12%	
Net Ret (pa)	-0.29%	-0.16%	-0.43%	-0.33%	-0.30%	-0.43%	-0.62%	-1.06%	-0.81%	-0.63%	-2.11%	-2.31%	-3.17%	-3.20%	-3.17%	
Tactical	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	HCVX	CN+DN	50/50	REG	MAT	
Gross Ret (pa)	-0.12%	-0.19%	0.31%	0.45%	0.24%	-0.44%	-0.33%	0.19%	-0.04%	0.27%	0.23%	0.31%	-0.63%	-0.52%	-0.63%	
Trade Costs (pa)	0.53%	0.53%	0.53%	0.53%	0.53%	1.06%	1.06%	1.06%	1.06%	1.06%	2.12%	2.12%	2.12%	2.12%	2.12%	
Net Ret (pa)	-0.65%	-0.73%	-0.22%	-0.08%	-0.30%	-1.49%	-1.39%	-0.87%	-1.09%	-0.79%	-1.89%	-1.81%	-2.75%	-2.64%	-2.75%	

**Table 16** – Summarises the gross and net performances of the passive and tactical swap and bond butterfly strategies across the various weight schemes. Roundtrip trade costs of 1bp of spread duration, with monthly rebalancing is assumed. Bond butterfly strategies have higher trade costs relative to the swap butterfly strategies as zero coupon bonds were assumed which have higher spread duration relative to the swap butterfly strategies which have regular interest payments. As can be seen, monthly rebalancing is very costly resulting in negative net annualised returns across all the swap and bond butterfly strategies and weight schemes, thus a pragmatic rebalancing policy is required. Source Data: IRESS and Bloomberg.

## 5.9 Butterfly Weight Scheme Selection

To determine the most attractive weight schemes we compare the average gross annualised returns for all the passive and tactical strategies of the swap and bond butterflies (i.e. the average of the three butterfly strategies and five weight schemes) which is presented in Table 17. Amongst all the weight schemes and butterfly strategies, the HCVX and CN+DN weight schemes are the outperformers with average gross annualised returns of 0.21% and 0.15% for the swap butterfly strategies respectively, and average gross annualised returns of 0.09% and 0.07% for the bond butterfly strategies respectively. This was due to their due to their relatively higher tactical swap butterfly and passive bond butterfly returns. The high omega ratios and low maximum drawdowns for the HCVX and CN+DN weight schemes amongst all the butterfly strategies suggest that these weight schemes produce the most attractive risk-adjusted returns and that they respond well to both tactical and passive approaches.

Average Swap Butterfly Gross Annualised Returns	HCVX	DN+CN	50/50	REG	MAT
Passive Swap Fly	0.09%	0.06%	0.04%	0.07%	0.04%
Tactical Swap Fly	0.32%	0.23%	0.06%	0.04%	-0.03%
Overall Average	0.21%	0.15%	0.05%	0.06%	0.01%

Average Bond Butterfly Gross Annualised Returns	HCVX	DN+CN	50/50	REG	MAT
Passive Bond Fly	0.29%	0.20%	-0.32%	-0.21%	-0.13%
Tactical Bond Fly	-0.11%	-0.07%	-0.04%	-0.04%	-0.04%
Overall Average	0.09%	0.07%	-0.18%	-0.12%	-0.08%

**Table 17** – Summarises the average gross annualised returns for all the passive and tactical strategies of the swap and bond butterflies (i.e. the average of the three butterfly strategies and five weight schemes). Overall, the HCVX and CN+DN weights schemes outperform the 50/50, REG and MAT weight schemes due to their relatively higher tactical swap butterfly returns and passive bond butterfly returns. Source Data: IRESS and Bloomberg.

Comparing the HCVX and CN+DN weight schemes we notice that the HCVX weight scheme does produce slightly higher gross annualised returns but comes at the expense of higher drawdowns and lower CVaR's at the 1% confidence level. There is also the administrative burden of the HCVX strategy not being cash neutral implying that cash shortfalls or excess cash proceeds need to be borrowed or invested in a timely manner to reduce return drag. With this in mind the CN+DN weight schemes is the appropriate choice for exploiting non-parallel risk premia and is the weight scheme we use for the rest of this thesis, beginning in the next chapter.

#### Conclusion:

1. Defined and back-tested five butterfly weight schemes on three butterfly strategies using the SA swap and bond curves.
2. Trade costs were analysed to show their impact on net returns. Butterfly strategies with high slope duration incurred the highest trade costs, reinforcing the need for a practical rebalancing approach.
3. A sensitivity example and table using a butterfly strategy was presented that analysed performance and slope duration of the five butterfly weight schemes.
4. Assessed these five butterfly weight schemes and determined that the cash and duration neutral weight scheme to be the most appropriate given its attractive risk-adjusted returns and robust performance under both passive and tactical approaches.



## Chapter 6



### Chapter 6 - Exploiting Non-Parallel Risk Premia

*"The financial world is full of higher-order risks—complicated systems that no one fully understands until they break. It's the unmeasurable complexities that present the biggest threats." – Michael Lewis (Author of "The Big Short")*

#### Objectives:

- Introduce the methodology for exploiting non-parallel risk premia.
- Introduce ten swap and bond butterfly factors.
- Describe the process of selecting butterfly strategies based on these factors.
- Rank the butterfly strategies based on month-end values to choose the top and bottom three for analysis.

The work in this chapter is based on the below publications:

- Investments Analysts Journal - Hariparsad, S. and Maré, E (2023.1),
- The South African Journal of Economic and Management Sciences - Hariparsad, S. & Maré, E. (2024.1).

### 6.1 Background and Literature on Non-Parallel Fixed Income Factors

There is a vast amount of research decomposing bond yields/returns into various factors, Litterman and Scheinkman (1991) estimate a linear five-factor model that explains 96% of international bond returns in the United States, Japan and Germany using level and steepness changes, and spread changes between the United States and German/Japanese bond yields. Their study also revealed that reduced residual, and profit and loss differences could be achieved by incorporating level, slope and curvature rather than duration-only (parallel) based hedging. Maitland (2002) showed that the variability of SA government bond yields using zero coupon curves were explained by only absolute yield levels and yield changes. Hautsch and Ou (2008) decompose the US yield curve using a Nelson Siegel model and find the slope and curvature factors as important determinants of future excess returns with yield level and volatility being closely connected to economic activity, inflation, monetary policy and

employment growth. The Nelson and Siegel (1987) model is extensively used by academia, central banks, monetary policy makers and portfolio managers due to its' tractability and factor interpretation of the term structure of interest rates. Thomas (2008) tested the SA swap curve using a PCA method and found four significant factors over the 2000 to 2007 period. Phoa (2000) applied a PCA approach to US treasuries which produced similar results with the level factor explaining 90% of the variation in yields followed by the slope and curvature factors. It was interesting to note that the coefficients and significance of the level and slope factor remained mostly the same, but the curvature coefficient decreased in importance.

Attempts have been made to relate the level, slope and curvature factors to macroeconomic indicators. Tracey (2009) suggested that inflation expectations describe the parallel/level factor, changes in long-term inflation expectations or market risk premiums affect the slope factor whilst changes in interest rate volatility impact the curvature. Morita and Bueno (2008) found inflation and GDP growth to be correlated to the level and slope factors, they also found coefficients to be smoother during periods of economic stability, but they became erratic during high volatile periods (e.g. during the great financial crisis of 2007/2008).

Patel, Mohamed and van Vuuren (2018) analysed US and SA swap rates and found that monetary policy shocks significantly impacted slope and curvature changes and also found that volatile market and economic conditions significantly distorted the shape, smoothness and explained variation of swap rates. On comparing the two markets, Patel et al (2018) emphasised that SA level shifts were largely driven by US level shifts during the great financial crisis of 2008 with an  $R^2$  of 54%, in fact the USD/ZAR exchange rate affected level changes in SA swap rates to a greater degree over the long-term relative to other economic variables. SA slope and curvature factors were seen to exhibit greater volatility relative to their US counterparts from emerging market risks, namely political and monetary policy instability, and volatile interest rate expectations.

Thiagarajan et al. (2016) studied US treasury and credit indices and decomposed the returns according to rates, growth, and volatility factors. The rates factor was shown to influence US treasury returns more than credit returns whilst the growth and volatility factors influenced credit returns more than US treasury returns. This makes economic sense as growth and volatility affect corporates to a greater degree than the general level of interest rates.

Cochrane and Piazzesi (2005) show that a combination of lagged forward rates were able to forecast bond returns with  $R^2$  of up to 44%. Their research suggested that the level, slope,

curvature and other variables are at play when determining bond returns and disproved the pure expectations hypothesis that long-term interest rates represent expectations of future short-term interest rates. Sarno et al. (2016) also use statistical methods based on a combination of past bond returns and yields. Their statistical models predict excess returns with improved (inferior) accuracy over economic models during periods of high (low) macroeconomic uncertainty. This implies that bond returns and yields are a combination of statistical forward rates and economic variables.

As can be seen, identifying, and understanding the drivers of yield curves is a well-researched area. Our research can be seen as an extension of this work and attempts to exploit opportunities based on non-parallel yield curve moves by utilising butterfly strategies. Pal (2007) tested butterfly strategies on the Australian bond market using two butterfly strategies: duration neutral (exposed to slope and curvature risk) and duration and slope neutral (exposed only to curvature risk). The yield pickup of all the butterfly pairs were predicted using a vector autoregressive (VAR) model. The butterfly pairs with the highest expected returns based on the predicted yield pickup changes were held and rebalanced over various holding periods with positions being closed if expected returns were achieved. Pal's (2007) strategy was based on mean reversion and efficient markets, in that market participants would trade the appropriate maturities moving the yield curve towards fair value.

Results were positive in that the duration neutral and duration and slope neutral strategies achieved net excess average annual returns of 1.2% and 0.72% respectively. While the results were positive the period tested was very short (Jan 2004 to May 2005) and did not incorporate a full interest rate cycle. Key takeaways were that returns and volatility were higher for the duration neutral butterflies relative to the duration and slope neutral butterflies, and upward sloping curves delivered greater returns relative to downward sloping curves.

Pal's (2007) results were consistent with Fabozzi, Martellini and Priaulet (2005) who assessed five duration neutral butterfly strategies on the US swap market over a nine-year period and selected them based on swap curve predictions using a similar VAR process (lags determined using the Schwartz Information Criterion), a NSS (Nelson, Siegel, and Svensson) model (Svensson (1994)) and several economic variables. Little predictability was found with the level factor over monthly forecast horizons, but the slope and curvature factors demonstrated better forecast results and higher hit rates, with bets on the slope factor being greater than the curvature factor as suggested by other researchers.

Next we define the swap and bond butterfly factors/risk premia in more detail by allowing many more duration neutral butterflies on the SA swap and bond curves. No curve predictions were used but we attempt to understand how the various butterfly risk premia perform under several curve scenarios and monetary policy cycles.

## 6.2 Butterfly Methodology and Risk Premia Definitions

To understand the magnitude of butterfly risk premia, monthly SA nominal bond and swap data from January 2001 until July 2024 sourced from Bloomberg and IRESS were compiled. Several fixed-rate government bonds with maturities exceeding one year and interest rate swaps with maturities of 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20, 25 and 30-year were used as these are liquid and regularly quoted by major SA banks (the 11, 13, 14, 16, 17, 18, 19, 21, 22, 23, 24, 26, 27, 28 and 29-year points were linearly interpolated). SA vanilla interest rate swaps (fixed for floating rates) are compounded quarterly (interest is reset and paid every three-months) so spreads and yield differences had to be converted to ensure like-for-like comparisons (e.g. semi-annual bond yields to semi-annual swap rates). The SA swap data uses average end-of-day, mid swap rates from the major banks in SA, bid-offer spreads on swaps can vary depending on banks liquidity, risk appetite and counterparty relationship and is known as trade costs which is discussed in chapter 6.3 Describing Butterfly Trade Costs. For the bonds, end of day, mid yields from JSE closing values are used.

Data for SA nominal interest rate swaps, SA real interest rate swaps, US treasuries and US nominal interest rate swaps were obtained monthly from Bloomberg using mid, end-of-day rates. We checked the data for any anomalies/outliers and ensured the shape of the swap/bond curves were realistic (i.e. no irregular and extreme hump shapes, and if there were humps these were within an acceptable tolerance of the surrounding points). To quantitatively test for outliers and anomalies we applied a Z-Score to each data series based on its' last six observations. If the Z-Score was within a  $[-2.5$  to  $+2.5]$  interval it was assumed acceptable. If the data series fell outside this range, we inspected the data series and related series to determine if it was an unacceptable outlier or acceptable anomaly.

To address missing data, we employed linear interpolation to estimate values between the corresponding points (e.g., interpolating between the 12-year and 15-year bond yields to estimate the 14-year bond yield). Additionally, we utilised a simple linear regression model with correlated variables to evaluate the accuracy of the interpolated value (e.g. regressing the

USDZAR exchange rate against the 14-year bond yield to determine its sensitivity and expected value).

Butterfly strategies are selected on a cash and duration neutral basis (as this is most appropriate weight scheme that is confirmed in chapter 5.9 Butterfly Weight Scheme Selection) according to ten factors, these bond and swap factors, together with descriptions are given in Table 18 and Table 19 respectively.

The ten swap and bond butterfly factors are an addition to the common absolute spread factor as we have observed differences in performances within butterfly strategies that have similar absolute spreads. For example, two butterfly strategies could have the same absolute spread but behave differently given a non-parallel curve scenario. As an example, a butterfly at the short-end of the yield curve could have the same absolute spread as a butterfly at the long-end of the curve, however these two butterflies are exposed to different risk characteristics. The short-end butterfly will have lower duration, convexity, and other risk premia relative to the long-end butterfly. This is the intuition that led us to define the various butterfly factors other than the typical absolute spread factor. The other nine butterfly factors were developed based on current, tradeable market data which makes them timeous and pragmatic relative to factors based on stale economic data. Defining the ten butterfly factors as we have is comprehensive, intuitive and allows us more insight into how these butterfly factors perform under various non-parallel curve movements.

Bond Butterfly Risk Factors	Short Name	Description
<b>Bond Spread Duration</b>	BSD	<ul style="list-style-type: none"> <li>Spread duration of the bond butterfly is determined and is the same as the modified duration of the middle-dated bond.</li> <li>Assuming a long bond butterfly spread duration of 5, if the long butterfly spread increases (decreases) by 1%, then a 5% capital loss (profit) will result.</li> </ul>
<b>Bond Absolute Spread</b>	BAS	<ul style="list-style-type: none"> <li>The long bond butterfly absolute spread is calculated using the cash and duration neutral weights. It is applied to the three points on the long bond butterfly to arrive at an absolute spread.</li> <li>If the absolute bond spread is positive (negative), the long bond butterfly will earn (deduct) interest over time.</li> </ul>
<b>Bond Term Spread</b>	BTS	<ul style="list-style-type: none"> <li>The net term to maturity of the long bond butterfly using the cash and duration neutral weights. A positive (negative) term spread implies that the middle bond of the butterfly is closer to long-point (short-point).</li> </ul>
<b>Bond Risk Premium</b>	BRP	<ul style="list-style-type: none"> <li>BRP is defined as SA Government Bond yield in USD - US Treasury yield both with the same term to maturity. The BRP is akin to a CDS spread but also incorporates a liquidity and currency risk premium. The BRP is calculated for each of the three points of the long bond butterfly and the net BRP is found by using the cash and duration neutral weights.</li> </ul>
<b>Bond Carry and Roll</b>	B/C+R	<ul style="list-style-type: none"> <li>Carry is defined as the yield earned from holding a government bond for one-month. Roll is defined as the capital gain as the bond rolls down the curve over one-month as it approaches maturity (assuming an unchanged, upward sloping bond curve). The Carry and Roll is calculated for each of the three bonds of the long bond butterfly and the net C+R is found by using the cash and duration neutral weights.</li> </ul>
<b>Bond Convexity</b>	BCVX	<ul style="list-style-type: none"> <li>The convexity of the three bonds on the long bond butterfly is identified. The BCVX is calculated as the net convexity of the long bond butterfly using the cash and duration neutral weights.</li> </ul>
<b>Bond Nelson Siegel Svensson</b>	BNSS	<ul style="list-style-type: none"> <li>The NSS uses a Nelson-Siegel-Svensson 3 factor model to fit a smooth curve to the actual nominal government bond curve.</li> <li>Deviations between the fitted NSS curve and the actual nominal government bond curve are computed for each of the three bonds on the long bond butterfly. The BNSS is defined as the net deviation of the three bonds on the long bond butterfly using the cash and duration neutral weights.</li> </ul>
<b>SA Swap less SA Bond Spread</b>	SBS	<ul style="list-style-type: none"> <li>The difference between the SA swap rate and nominal government bond yield of the same term to maturity is computed for each of the three bonds on the long bond butterfly.</li> <li>The net SA swap less SA bond spread difference is calculated using the cash and duration neutral weights of the long swap butterfly and encapsulates the net SA bank credit and liquidity risk.</li> </ul>
<b>Break-Even Inflation</b>	BEI	<ul style="list-style-type: none"> <li>For each of the three bonds in the long bond butterfly, the difference between SA nominal and inflation-linked government bonds of the same term to maturity is computed. This spread is commonly known as break-even inflation and can be viewed as investors inflation expectations.</li> <li>The net difference of the SA nominal and inflation-linked government bonds is then calculated using the cash and duration neutral weights of the long bond butterfly.</li> <li>The BEI accounts for the net inflation risk premium of the long bond butterfly.</li> </ul>
<b>Bond Reversion</b>	BRev	<ul style="list-style-type: none"> <li>Compares all the long bond butterfly returns over the previous month and selects the underperformers.</li> <li>This is a reversion strategy and based on the assumption that the underperforming long bond butterfly strategies will revert to their long-term average and outperform in the upcoming month.</li> </ul>

Table 18 – Describes the ten bond butterfly factors that will be used for the analysis and back-test.

Swap Butterfly Risk Factors	Short Name	Description
Swap Spread Duration	SSD	<ul style="list-style-type: none"> <li>Spread duration of the swap butterfly is determined and is the same as the modified duration of the mid swap point.</li> <li>Assuming a long swap butterfly spread duration of 5, if the long butterfly spread increases (decreases) by 1%, then a 5% capital loss (profit) will result.</li> </ul>
Swap Absolute Spread	SAS	<ul style="list-style-type: none"> <li>The long butterfly swap spread is calculated using the cash and duration neutral weights and applied to the three positions on the swap butterfly.</li> <li>If the absolute swap spread is positive (negative), the long swap butterfly will earn (deduct) interest over time.</li> </ul>
Swap Term Spread	STS	<ul style="list-style-type: none"> <li>The net term to maturity of the long swap butterfly using the cash and duration neutral weights. A positive (negative) term spread implies a mid-point of the butterfly that is closer to long-point (short-point).</li> </ul>
Swap Risk Premium	SRP	<ul style="list-style-type: none"> <li>SRP is defined as SA Nominal swap yield - US Treasury yield both with the same term to maturity. The SRP is akin to a CDS spread but also incorporates a liquidity and bank credit premium. The SRP is calculated for each of the three points of the long swap butterfly and the net SRP is found by using the cash and duration neutral weights.</li> </ul>
Swap Carry and Roll	S/C+R	<ul style="list-style-type: none"> <li>Carry is defined as the yield earned from holding a swap for 1-month. Roll is defined as the capital gain earned as the swap rolls down the curve over 1-month as it approaches maturity (assuming an unchanged, upward sloping swap curve).</li> <li>The Carry and Roll is calculated for each of the three points of the long swap butterfly and the net C+R is found by using the cash and duration neutral weights.</li> </ul>
Swap Convexity	SCVX	<ul style="list-style-type: none"> <li>The convexity of the three positions on the swap butterfly is identified. The SCVX is calculated as the net convexity of the long swap butterfly using the cash and duration neutral weights.</li> </ul>
Swap Nelson Siegel Svensson	SNSS	<ul style="list-style-type: none"> <li>The NSS uses a Nelson-Siegel-Svensson 3 factor model to fit a smooth curve to the actual nominal swap rates.</li> <li>Deviations between the fitted NSS curve and the actual nominal swap rates are computed for each of the three points of the long swap butterfly.</li> <li>The SNSS is defined as the net deviation of the three swap points using the cash and duration neutral weights.</li> </ul>
SA less US Swap Spread	SA-US	<ul style="list-style-type: none"> <li>The difference between the SA and US nominal swap rate of the same term to maturity is computed for each of the three swap butterfly points.</li> <li>The net SA-US difference is calculated using the cash and duration neutral weights of the long swap butterfly.</li> <li>The SA-US swap spread encapsulates the net SA liquidity and sovereign risk relative to the US.</li> </ul>
Real Swap Rates	RSR	<ul style="list-style-type: none"> <li>For each of the three swap butterfly points, the difference between SA nominal and real swap rates of the same term to maturity is computed.</li> <li>The net difference of the SA nominal and real swap rates is then calculated using the cash and duration neutral weights of the long swap butterfly.</li> <li>The RSR accounts for the net inflation risk premium of the long swap butterfly.</li> </ul>
Swap Reversion	SRev	<ul style="list-style-type: none"> <li>Compares all the long swap butterfly returns over the previous month and selects the underperformers.</li> <li>This is a reversion strategy and based on the assumption that the worst long swap butterfly performers will revert to their long-term average and outperform in the upcoming month.</li> </ul>

Table 19 – Describes the ten swap butterfly factors that will be used for the analysis and back-test.

There are approximately 220 bond and 3654 swap butterfly strategies. 29 available points on the swap curve with 3 selection points on each swap butterfly, so by using COMBINATION (29,3) we have 3654, similarly on average, there are 12 government bonds, so COMBINATION (12,3) would provide 220 bond butterfly combinations. We arranged the butterfly strategies in ascending order, from the lowest factor value to the highest factor value. As an example, the SAS factor arranged 3654 swap butterflies using previous month-end data from the lowest absolute spread to the highest absolute spread. The top three swap butterflies contained the highest absolute spreads, likewise the bottom three swap butterflies contained

the lowest absolute spreads. This was continued for the other swap and bond butterfly factors and continued for each successive month. For pragmatic reasons we only selected the top and bottom three swap and bond butterfly strategies from each factor.

The reason for only selecting the top and bottom three bond and swap butterfly strategies was because:

- Bond yields and swap rates across the curve are highly correlated as illustrated in Table 20 (ranging between +0.3 and +0.9) so increasing the number of swap and bond butterfly strategies does not significantly improve diversification. In fact, including more butterfly strategies will likely duplicate risk exposures and potentially dilute expected returns.
- In South Africa, interest rate swaps have been treated as OTC instruments. However, this changed in early 2023 and has moved to daily margining. This change, reduced counterparty risk and provided updated pricing. The downside of this change is that there will be some additional costs when trading interest rate swaps which will have to be managed and minimised by incorporating efficient trading, valuation and liquidity systems. Thus, managing fewer butterfly positions with increased size might result in relatively lower trade costs.

Bond Maturity (Yrs)	SA Nominal Bond Yields Correlation Matrix									
	1	2	3	5	7	10	12	15	20	30
1	1.00	0.92	0.86	0.74	0.66	0.54	0.48	0.42	0.35	0.27
2	0.92	1.00	0.97	0.86	0.78	0.67	0.61	0.54	0.46	0.38
3	0.86	0.97	1.00	0.94	0.87	0.78	0.72	0.65	0.57	0.49
5	0.74	0.86	0.94	1.00	0.98	0.91	0.87	0.81	0.74	0.66
7	0.66	0.78	0.87	0.98	1.00	0.97	0.95	0.91	0.85	0.79
10	0.54	0.67	0.78	0.91	0.97	1.00	0.99	0.98	0.94	0.90
12	0.48	0.61	0.72	0.87	0.95	0.99	1.00	0.99	0.97	0.93
15	0.42	0.54	0.65	0.81	0.91	0.98	0.99	1.00	0.99	0.97
20	0.35	0.46	0.57	0.74	0.85	0.94	0.97	0.99	1.00	0.99
30	0.27	0.38	0.49	0.66	0.79	0.90	0.93	0.97	0.99	1.00

Swap Maturity (Yrs)	SA Nominal Swap Rates Correlation Matrix									
	1	2	3	5	7	10	12	15	20	30
1	1.00	0.93	0.85	0.74	0.64	0.57	0.54	0.53	0.52	0.50
2	0.93	1.00	0.98	0.90	0.83	0.76	0.74	0.72	0.71	0.70
3	0.85	0.98	1.00	0.97	0.91	0.85	0.83	0.81	0.80	0.80
5	0.74	0.90	0.97	1.00	0.98	0.95	0.93	0.91	0.91	0.90
7	0.64	0.83	0.91	0.98	1.00	0.99	0.98	0.96	0.95	0.95
10	0.57	0.76	0.85	0.95	0.99	1.00	1.00	0.98	0.97	0.98
12	0.54	0.74	0.83	0.93	0.98	1.00	1.00	0.98	0.98	0.98
15	0.53	0.72	0.81	0.91	0.96	0.98	0.98	1.00	1.00	0.98
20	0.52	0.71	0.80	0.91	0.95	0.97	0.98	1.00	1.00	0.98
30	0.50	0.70	0.80	0.90	0.95	0.98	0.98	0.98	0.98	1.00

**Table 20** – Correlation matrix of SA nominal bond yields and swap rates. Bonds and swaps with maturities close together are highly correlated with correlations ranging from 0.3 to 0.9 for the bonds and 0.5 to 0.9 for the swaps. Source Data: IRESS and Bloomberg.

We also introduced an All-Factor Rank (AFR) that incorporated all ten individual swap and bond butterfly factors (referred so as S-AFR and B-AFR respectively). To calculate the AFRs we ranked the individual swap and bond butterfly strategies from 1 to 3654 for the swaps and 1 to 220 for the bonds and averaged across each of the ten swap and bond butterfly factors respectively. As an example, the 2v5v10 swap butterfly may rank 10 under the SAS factor, 35 under the S/C+R factor, 82 under STS factor and so on. The arithmetic average rank for the 2v5v10 butterfly strategy is obtained and this is continued for the remaining 3653 swap butterfly strategies. The top and bottom three swap butterfly strategies based on their average rank was selected for the S-AFR. The same methodology was applied to the bond butterfly factors to arrive at the B-AFR.

The swap and bond butterfly strategies were selected using the previous month-end values and rebalanced at the end of every month. We used a long butterfly strategy (recall this involved purchasing the medium dated swap or bond and selling the short- and long-dated swap or bond in a cash and duration neutral manner exposed only to slope and curvature changes and immune

to parallel curve shifts). Note that swaps trade at par when rebalancing with new positions whilst the fixed rate government bonds will differ from par, thus cash neutrality will be maintained by default when rebalancing interest rate swaps. When dealing with fixed rate bonds we will be using off-the run bonds (i.e. previously issued bonds) resulting in bond values deviating from par during their term, thus cash neutral constraints are important.

### 6.3 Describing Butterfly Trade Costs

Monthly rebalancing is a trade-off between maintaining duration neutral butterfly strategies whilst balancing trade costs. Ideally, it would make sense to rebalance intra-month especially if there have been large non-parallel curve shifts but for the purposes of this analysis a consistent one-month rebalance frequency will be maintained.

We find that, a one month rebalance frequency doesn't allow the net duration position to drift too far from zero, allows for sufficient time for the butterfly strategy to realise a profit, and allows for a profitable strategy by limiting excessive trading costs. In practice, the investor may decide to rebalance more or less than one month intervals depending on their risk appetite, but only if it makes sense on an after-cost basis. Market conditions and relationships will also determine the extent of trade costs. High risk, volatile environments will increase trade costs due to risk aversion and price maker uncertainty. Respectable relationships between clients and market makers will generally result in favourable pricing as there will be honest and candid communication, legacy, and potential for repeat business.

A reasonable cost would be 1bps in absolute spread (0.5bps on entry and 0.5bps on exit), which equates to annualised trade costs of 84bps assuming monthly rebalancing and a spread duration of 7 years ( $0.01\% \times 7 \times 12$ ). Table 21 gives a summary of the annual potential trade costs for various spread durations and monthly rebalancing. For trade costs above 1bps, monthly rebalancing becomes relatively expensive, and the trade position will have to be rebalanced less frequently which exposes it to duration risk and will require a higher success rate in tactically allocating between swap factors which is a difficult exercise.

Roundtrip Trade Costs (bps)	Annualised Trade Costs (Monthly Rebalancing)				
	Spread Duration (Years)				
	4	5	6	7	8
0.5	0.24%	0.30%	0.36%	0.42%	0.48%
1.0	0.48%	0.60%	0.72%	0.84%	0.96%
1.5	0.72%	0.90%	1.08%	1.26%	1.44%
2.0	0.96%	1.20%	1.44%	1.68%	1.92%

**Table 21** – Shows the annualised trade costs of rebalancing a swap or bond butterfly strategy based on several roundtrip trade costs and spread durations. Higher spread duration and roundtrip costs will lead to higher annualised trade costs and reduced net returns from swap or bond butterfly strategies.

### Conclusion:

1. Provided the methodology to analyse and prepare bond and swap data, selecting the number of butterflies and the process for detecting outliers and anomalies in the data.
2. Illustrated that bond yields and swap rates across the curve are highly correlated, especially maturities that are close together.
3. Defined the ten swap and bond butterfly factors that will be used for back-testing investment strategies, including the All-Factor Rank that combines all the factors.
4. Illustrated the effect of trade costs on butterfly strategies, recommending a one month rebalance frequency assuming a roundtrip trade cost of one basis point of absolute spread.

## Chapter 7 - Performance and Risk Statistics of Swap and Bond Butterfly Factors

*"The financial markets are always in a state of uncertainty and flux, and money is made by discounting the obvious and betting on the unexpected." – George Soros (Investor and Philosopher)*

### Objectives:

- Present the performance and risk statistics for selected swap and bond butterfly factors.
- Highlight the key characteristics of top-performing factors, including high absolute spreads, risk premiums, positive NSS differences, strong carry and roll metrics, wide break-even inflation spreads, and low swap spreads.
- Introduce the concept of dominant and defensive factors, grouping them based on risk and return profiles.
- Identify dominant factors such as those with higher returns but greater volatility and drawdowns.
- Identify defensive factors such as those with lower returns and volatility, acting as a hedge with reduced drawdowns.

The work in this chapter is based on the below publications:

- Investments Analysts Journal - Hariparsad, S. and Maré, E. (2023.1),
- The South African Journal of Economic and Management Sciences - Hariparsad, S. & Maré, E. (2024.1).

### 7.1 Swap Butterfly Factor Performance

Table 22 illustrates the performance statistics of the top and bottom swap butterfly factors, we see that the top SAS, SRP, SNSS, RSR, S/C+R, SA-US and SRev factors have the highest annualised returns (between 1.0% and 1.6%) with standard deviation between 1.4% and 1.7% per annum, and a return to standard deviation (Ret/SD) ratio between 0.7 and 1.1. The corresponding bottom swap butterfly factors have annualised returns between -0.1% and -

1.3%, standard deviation between 0.8% and 1.9% per annum, and a return to standard deviation (Ret/SD) ratio between -1.0 and -0.2. The widest differences between top and bottom returns are for the SAS, S/C+R and SA-US factors with an almost 3% difference, followed by the SNSS and SRP factors with 2.1% and 1.8% respectively. The reason for highlighting the widest differences between the top and bottom swap butterfly factors is to identify a clear distinction on whether there are benefits to investing in a factor or if it is a coincidence.

Swap Butterfly Factors		Short Name	Index		Ret (pa)		Std Dev (pa)		Ret/SD	
			Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top
Dominant Factors	Swap Absolute Spread	SAS	74.5	142.2	-1.2%**	1.5%*	1.3%	1.6%	-1.0	0.9
	Swap Risk Premium	SRP	89.7	137.8	-0.5%	1.4%*	0.8%	1.7%	-0.6	0.8
	Swap Nelson Siegel Svensson	SNSS	83.3	136.2	-0.8%	1.3%*	1.8%	1.6%	-0.4	0.8
	Swap Carry and Roll	S/C+R	73.8	141.7	-1.3%**	1.5%*	1.3%	1.6%	-1.0	0.9
	SA less US Swap Spread	SA-US	73.1	146.2	-1.3%**	1.6%*	1.5%	1.5%	-0.9	1.1
	Real Swap Rates <sup>2</sup>	RSR	97.7	118.4	-0.1%	1.0%	0.9%	1.4%	-0.2	0.7
	Swap Reversion	SRev	82.0	143.6	-0.8%	1.6%*	1.9%	1.5%	-0.4	1.1
Defensive Factors	Swap Term Spread	STS	112.9	106.2	0.5%	0.3%	1.8%	0.6%	0.3	0.4
	Swap Convexity	SCVX	119.1	104.2	0.8%	0.2%	1.6%	0.6%	0.5	0.3
	Swap Spread Duration	SSD	100.4	100.7	0.0%	0.0%	0.7%	0.2%	0.0	0.2
Average		Avg	82.0	138.0	-0.9%**	1.4%*	1.3%	1.6%	-0.4	0.7
Dominant Factors		S-DOM	80.3	141.5	-0.9%	1.5%	1.2%	1.2%	-0.8	1.2
Defensive Factors		S-DEF	110.6	104.4	0.4%	0.2%	1.1%	0.4%	0.4	0.4
All Factor Rank		S-AFR	70.7	150.9	-1.5%**	1.8%*	1.4%	1.3%	-1.0	1.4

**Table 22** – Gross annualised factor returns and standard deviation for the top and bottom swap butterfly risk factors from January 2001 until July 2024. \* Denotes greater than zero mean at 1% significance level. \*\* Denotes less than zero mean at 1% significance level. The top SAS, SRP, SNSS, RSR, S/C+R, SA-US and SRev factors have the highest annualised gross returns (between 1.3% and 1.7%), whilst the corresponding bottom factors have the lowest annualised gross returns (between -1.3% and -0.5%). The top and bottom STS, SCVX and SSD factors have relatively consistent, positive gross annualised returns (between 0% and 0.8%). Source Data: IRESS and Bloomberg.

<sup>2</sup> Real swap rate data began in June 2007 so performance statistics are from that start date.

Risk Statistics		Short Name	Max DD		Omega		Skew		Kurtosis		CVaR 1%	
Swap Butterfly Factors			Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top
Dominant Factors	Swap Absolute Spread	SAS	25.6%	4.2%	0.2	2.2	-5.9	1.1	77.5	8.7	-3.0%	-1.6%
	Swap Risk Premium	SRP	10.3%	3.9%	0.5	2.2	-0.3	3.1	6.9	29.0	-1.1%	-1.4%
	Swap Nelson Siegel Svensson	SNSS	19.1%	3.7%	0.5	2.1	0.4	1.0	45.6	21.8	-3.0%	-2.2%
	Swap Carry and Roll	S/C+R	26.4%	4.7%	0.2	2.2	-5.8	1.1	75.5	8.4	-2.9%	-1.6%
	SA less US Swap Spread	SA-US	27.0%	2.8%	0.3	2.8	-5.1	2.2	57.3	17.1	-3.1%	-1.2%
	Real Swap Rates	RSR	4.1%	4.9%	0.7	2.6	-1.2	1.7	4.8	6.6	-0.9%	-0.8%
	Swap Reversion	SRev	20.1%	2.0%	0.5	2.7	-1.2	3.0	43.8	25.8	-4.0%	-1.1%
Defensive Factors	Swap Spread Duration	STS	7.5%	0.4%	1.2	7.8	-1.3	15.4	12.2	249.1	-2.7%	-0.1%
	Swap Convexity	SCVX	5.3%	0.1%	1.4	6.4	0.2	16.4	2.4	272.8	-1.6%	-0.1%
	Swap Term Spread	SSD	2.5%	0.5%	1.0	0.9	1.5	-0.3	17.1	5.6	-0.7%	-0.2%
Average		Avg	18.9%	3.7%	0.4	2.4	-2.7	1.9	44.5	16.8	-2.6%	-1.4%
Dominant Swap Factors		S-DOM	19.8%	2.7%	0.3	2.9	-11.8	2.5	272.4	25.8	-1.1%	-0.8%
Defensive Swap Factors		S-DEF	4.1%	0.1%	1.3	3.1	0.6	29.0	14.6	888.0	-0.8%	-0.1%
Swap All Factor Rank		S-AFR	29.5%	1.8%	0.3	3.4	-5.0	1.4	56.2	17.4	-3.0%	-1.4%

**Table 23** – Swap factor risk statistics (maximum drawdown, omega ratio, skewness, kurtosis and CVaR at 1% level) for the top and bottom three swap butterfly risk factors from January 2001 until July 2024. The Omega ratio for the top S-DOM factors is impressive with values above 2 whilst the bottom S-DOM have values much lower than 1. The Max DD and CVaR of the bottom S-DOM and S-DEF factors are lower than that of their corresponding top S-DOM and S-DEF factors. This means that extreme negative returns are slightly larger for the top factors relative to the bottom factors. The S-AFR has improved risk statistics relative to the individual swap butterfly risk factors. Source Data: IRESS and Bloomberg.

For the STS, SCVX and SSD factors, the annualised returns for the bottom factors are greater than the top factors (ranging between 0% to 0.8% for the bottom three versus 0% to 0.3% for the top three). Having a lower net term spread, convexity or spread duration equates to swap butterfly points that are relatively close together, have higher correlations, lower risk and expected returns. From the results, over the long-term, swap butterflies with lower net term spreads, convexity and spread durations produce greater returns relative to swap butterflies with higher net term, convexity and spread durations.

For ease of reference, we group the SAS, SRP, SNSS, RSR, S/C + R, SA-US and SRev factors together and call them the dominant swap butterfly factors (S-DOM), whilst the STS, SCVX and SSD factors are grouped and called the defensive swap butterfly factors (S-DEF). These names identify the key characteristics of the individual swap butterfly factors as dominant factors will generally deliver greater returns at the expense of high volatility and large drawdowns. The defensive factors will be the opposite in that they will diversify portfolio risk, providing a hedge and limit large drawdown during risk off periods but will likely underperform relative to the dominant factors over the long-term. We discuss some of their risk statistics in Table 23.

The omega ratios for the top S-DOM and S-DEF factors are impressive with values close to 3 mainly due to the low standard deviations of the individual swap butterfly factors. The omega ratio of the bottom S-DEF factors is close to zero due to the relatively higher standard deviations. The bottom S-DEF factors have a moderate omega ratio above 1 due to a marginal return improvement but greater standard deviations whilst the top S-DEF factors have higher omega ratios given their much lower standard deviations.

The skew of the top S-DOM and S-DEF factors are positive but significantly more for the STS and SCVX factors given their low risk and frequent occurrences of small positive returns. The skew of the bottom S-DOM factors are negative except for the SNSS factor which is slightly positive at 0.4 and indicates the general underperformance of the bottom S-DOM factors. The skew of the bottom S-DEF factors are close to zero and the closest to a normal distribution.

The kurtosis of the bottom S-DOM and top S-DEF factors produce very high kurtosis (much greater than that of a normal distribution of 3) which highlights the occurrence of large, positive and negative monthly returns, but also returns clustered around a mean which in this case is at or below zero. As a comparison, the kurtosis of the bottom S-DEF and top S-DOM factors are relatively lower but still much greater than a normal distribution with positive mean returns and skew which suggests a greater proportion of positive relative to negative returns over the period.

The conditional value at risk (CVaR) at the 1% level is below -1% for the top S-DOM and bottom S-DEF factors highlighting the low downside risk. The top B-DEF factors have relatively less downside risk with a CVaR at -0.1%, however this is due to the very low returns and return volatility.

The maximum drawdown (Max DD) of the bottom S-DOM and S-DEF factors is larger than the corresponding top S-DOM and S-DEF factors. This means that extreme negative returns are slightly larger for the bottom factors relative to the top factors. This is due to the top factors having relatively higher omega ratios which implies a greater proportion and magnitude of positive returns relative to negative returns.

Overall we find that the top S-DOM and S-DEF factors have the most attractive risk-adjusted attributes: low drawdowns, value at risk, standard deviations, a positive distribution skew, low kurtosis, and high omega scores which implies a greater upside to downside return ratio. Despite the additional risk, the top S-DOM and S-DEF factors deliver improved returns on an absolute and risk-adjusted basis relative to the bottom S-DOM and S-DEF factors.

We see that the top S-AFR has improved risk statistics relative to the top S-DOM and S-DEF factors. The top S-AFR had a low Max DD of 1.8%, high omega ratio of 3.4, slight positive skew of 1.4, and low kurtosis of 17.3 and CVaR of -1.4%. The bottom S-AFR had the opposite risk statistics relative to the top S-AFR with a large Max DD of 29.5%, low omega ratio of 0.3 and skew of -5.0, and a high kurtosis of 56.2 and CVaR of -3.0%. The polarised differences between the top and bottom S-AFR illustrates that there is a clear distinction between factor selection. The S-AFR selection process is also superior as the results show an improvement over just taking the average of the individual swap factors. The S-AFR incorporates both the dominant and defensive swap factors which diversifies risk resulting in much improved absolute and risk-adjusted returns.

## 7.2 Bond Butterfly Factor Performance

In Table 24 we see the performance statistics of the top and bottom bond butterfly factors. The top BAS, BNSS, B/C+R, BEI, and BRev factors deliver the highest annualised returns between 1% and 1.4%, with the BRP and SBS factors delivering 0.5% and 0.7% respectively. Like the dominant swap factors (S-DOM) we will refer to BAS, BNSS, B/C+R, BEI, BRev, BRP and SBS factors as the dominant bond factors (B-DOM). The top B-DOM factors have standard deviations between 1.6% and 1.8% and return to standard deviation (Ret/SD) ratios between 0.3 to 0.7. Conversely, the bottom B-DOM factors display annualised returns between -0.9% and 0%, standard deviations ranging from 1.2% to 2.0% and Ret/SD ratios between -0.7 and 0. The most noteworthy disparities in annualised returns are observed in BAS, B/C+R, and BNSS factors, with differences between the top and bottom B-DOM factors exceeding 1.6%, followed by BEI and BRev with differences of 1.5% and 1.4%, respectively. These wide divergences in returns between the top and bottom BAS, BNSS, B/C+R, BEI, and BRev factors show that there is merit in these bond butterfly factors.

Reviewing the Bond All-Factor Rank (B-AFR) which aggregates all ten bond factors by averaging the rank of each bond butterfly factor based on their respective month-end values, we see that the top and bottom B-AFR factors return 1.5% and -0.7% per annum, with Ret/SD ratios of 1.2 and -0.4, respectively. Thus, the B-AFR provides a diversified approach and enhances both absolute and risk-adjusted performance.

Defining the BTS, BCVX, and BSD factors as the defensive bond factors (B-DEF), we see that the bottom B-DEF factors have annualised returns ranging between 0.2% and 0.4% whilst the

top B-DEF factors deliver annualised returns between -0.2% and 0.2%. Analysing the B-DEF factors reveals that lower net term spreads, convexity, and spread durations result in bond butterflies with points that are relatively close together which leads to higher correlations, lower risk and expected returns.

Analysing the additional risk statistics in Table 25 shows us that the top B-DOM factors have greater absolute and risk-adjusted performance relative to the bottom B-DOM factors. The omega ratio for each of the top B-DOM factors exceeds 1.3, whilst each of the bottom B-DOM factors fall at or below 1.1, which suggests relatively better upside to downside risk metrics for the top B-DOM factors. The bottom B-DEF factors have greater absolute returns relative to the top B-DEF factors, however the top B-DEF factors provide improved risk statistics with lower max drawdowns, CVaR and kurtosis. The relatively high skew and kurtosis for the top B-DOM and bottom B-DEF factors indicate episodes of high positive returns, particularly during cutting cycles as shown in the next chapter. From a risk-adjusted standpoint the top B-DOM and B-DEF factors are the preferred factors which is why the top B-AFR provides superior absolute and risk-adjusted returns over the bottom B-AFR.

We find that top performing bond factors share distinct characteristics such as, high absolute spreads and bond risk premiums, large positive NSS (Nelson Siegel Svensson) differences, strong carry and roll metrics, wide break-even inflation spreads, and low swap spreads (SA bonds less swaps). Mean-reversion is also an effective factor as bond butterflies that have underperformed over the past month, are likely to outperform the following month.

Just like the above outperforming bond factors, outperforming swap factors possess the following characteristics: high absolute spreads and risk premiums, large positive NSS (Nelson Siegel Svensson) differences, high carry and roll, high spreads over US swaps and have recent underperformance over the past month. Identifying these attributes allows for a long/short strategy, where investors take a long position in the top and a short position in the bottom factors.

This showcases an important investing concept, to achieve outperformance some risk is required. Identifying the most efficient risk factors, when and how much to invest in is the key to successful investing. Markowitz (1952) and Sharpe (1964) were the pioneers in establishing the trade-off between risk and expected return, the concept of efficient portfolios and laying the groundwork for modern portfolio theory. Analysing the above bond and swap butterfly risk premia in several risk dimensions will greatly assist in developing an effective investment

strategy. As such scenario analysis in Chapter 9 - Scenario Analysis will assist in identifying additional risk dimensions.

Bond Butterfly Factors		Short Name	Index		Ret (pa)		Std Dev (pa)		Ret/SD	
			Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top
Dominant Factors	Bond Absolute Spread	BAS	78.6	142.5	-0.9%**	1.4%*	1.3%	1.9%	-0.7	0.7
	Bond Risk Premium	BRP	100.1	113.7	0.0%	0.5%	1.7%	1.7%	0.0	0.3
	Bond Nelson Siegel Svensson	BNSS	88.0	132.3	-0.5%	1.1%*	1.6%	1.7%	-0.3	0.7
	Bond Carry and Roll	B/C+R	81.4	130.2	-0.8%**	1.0%*	1.2%	1.8%	-0.7	0.6
	SA Swap less SA Bond Spread	SBS	98.2	115.9	-0.1%	0.7%	2.0%	1.6%	-0.0	0.4
	Break-Even Inflation	BEI	95.9	134.4	-0.2%	1.3%*	1.8%	1.7%	-0.1	0.7
	Bond Reversion	BRev	92.5	127.7	-0.3%	1.1%*	1.8%	1.8%	-0.2	0.6
Defensive Factors	Bond Term Spread	BTS	111.7	105.0	0.4%	0.2%	2.2%	1.1%	0.2	0.2
	Bond Convexity	BCVX	103.8	99.6	0.2%	-0.0%	2.4%	1.0%	0.1	-0.0
	Bond Spread Duration	BSD	109.8	95.8	0.4%	-0.2%	1.5%	1.5%	0.2	-0.1
Average		Avg	94.6	118.9	-0.2%	0.7%*	1.2%	1.0%	-0.2	0.7
Dominant Bond Factors		B-DOM	88.7	129.3	-0.5%	1.0%*	1.1%	1.2%	-0.4	0.9
Defensive Bond Factors		B-DEF	108.6	100.2	0.3%	0.0%	1.7%	0.7%	0.2	0.0
Bond All Factor Rank		B-AFR	83.8	145.5	-0.7%**	1.5%*	1.2%	1.7%	-0.4	1.2

**Table 24** – Gross annualised factor returns and standard deviation for the top and bottom bond butterfly risk factors from January 2001 until July 2024. \* Denotes greater than zero mean at 1% significance level. \*\* Denotes less than zero mean at 1% significance level. The BAS, BRP, BNSS, BEI, S/C+R, SBS and BRev factors have the highest annualised gross returns (between 1.2% and 2.0%), whilst the corresponding bottom three factors have the lowest annualised gross returns (between -0.9% and -0.1%). The top and bottom BTS, BCVX and BSD factors have relatively consistent, positive gross annualised returns (between -0.2% and 0.4%). Source Data: IRESS and Bloomberg.

Risk Statistics		Short Name	Max DD		Omega		Skew		Kurtosis		CVaR 1%	
Bond Butterfly Factors			Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top
Dominant Factors	Bond Absolute Spread	BAS	20.7%	5.2%	0.5	2.0	-0.2	1.5	5.6	12.9	-1.6%	-1.6%
	Bond Risk Premium	BRP	6.9%	6.2%	0.9	1.3	0.6	1.3	13.2	14.1	-2.3%	-1.8%
	Bond Nelson Siegel Svensson	BNSS	14.2%	4.3%	0.7	1.5	1.1	0.5	15.6	3.8	-1.9%	-1.4%
	Bond Carry and Roll	B/C+R	18.3%	3.5%	0.6	1.6	-1.0	1.4	5.7	18.3	-1.8%	-2.0%
	SA Swap less SA Bond Spread	SBS	7.4%	3.6%	1.0	1.3	-0.4	1.3	3.5	16.7	-2.2%	-1.8%
	Break-Even Inflation	BEI	7.0%	3.5%	1.0	1.8	-1.0	2.5	4.5	23.7	-2.2%	-1.2%
	Bond Reversion	BRev	17.0%	4.5%	0.8	1.5	0.1	1.2	2.6	9.0	-1.8%	-1.5%
Defensive Factors	Bond Term Spread	BTS	5.8%	3.4%	1.1	1.0	0.7	-1.0	4.5	5.2	-1.7%	-1.3%
	Bond Convexity	BCVX	10.0%	5.8%	1.0	0.8	0.0	-0.2	4.0	12.8	-2.6%	-1.3%
	Bond Spread Duration	BSD	4.6%	7.5%	1.2	0.9	2.6	0.8	26.1	5.2	-1.5%	-1.4%
Average		Avg	6.4%	3.1%	0.7	3.3	-0.2	1.7	3.2	15.2	-1.3%	-0.9%
Dominant Bond Factors		B-DOM	11.9%	3.1%	0.7	2.0	-1.0	1.4	3.6	11.8	-1.3%	-1.0%
Defensive Bond Factors		B-DEF	5.9%	3.5%	1.1	1.0	1.1	-0.2	12.6	2.5	-1.4%	-0.8%
Bond All Factor Rank		B-AFR	16.8%	1.9%	0.7	2.8	-0.7	0.2	3.9	4.1	-2.1%	-1.2%

**Table 25** – Bond factor risk statistics (maximum drawdown, omega ratio, skewness, kurtosis and CVaR at 1% level) for the top and bottom bond butterfly risk factors from January 2001 until July 2024. The Omega ratio for the top B-DOM factors is impressive with values above 2 whilst the bottom B-DOM factors have values much lower than 1. The Max DD and CVaR of the bottom B-DOM and B-DEF factors are lower than that of the corresponding top B-DOM and B-DEF factors. This means that extreme negative returns are larger for the top factors relative to the bottom factors. The B-AFR has improved risk statistics relative to the individual bond butterfly risk factors. Source Data: IRESS and Bloomberg.

## Conclusion:

1. The top S-DOM, S-DEF, B-DOM and B-DEF factors deliver improved returns on an absolute and risk-adjusted basis relative to the bottom S-DOM and S-DEF factors.
2. Top performing swap and bond factors share distinct characteristics such as, high absolute spreads and bond risk premiums, large positive NSS differences, strong carry and roll metrics, wide break-even inflation spreads, recent underperformance over the past month, low swap spreads (SA bonds less swaps) for bond factors and high spreads over US swaps for swap factors.
3. Top factors can incur large drawdowns relative to bottom factors but to achieve outperformance some risk is required. Identifying the most efficient risk factors, when and how much to invest in is the key to successful investing. Establishing efficient and diversified portfolios is essential for successful investing, Markowitz (1952) and Sharpe (1964).



# Chapter 8



## Chapter 8 - Rebalancing Frequencies

*"The market can remain irrational longer than you can remain solvent." – John Maynard Keynes (Economist)*

### Objectives:

- Explore the impact of different rebalancing frequencies on butterfly strategy performance.
- Compare monthly and quarterly rebalancing frequencies, considering trade costs.
- Show that monthly rebalancing generally yields higher gross returns but incurs greater trading costs.
- Emphasise that the choice of rebalancing frequency depends on the specific factors and strategies employed.

The work in this chapter is based on the below publications:

- Investments Analysts Journal - Hariparsad, S. and Maré, E (2023.1),
- The South African Journal of Economic and Management Sciences - Hariparsad, S. & Maré, E. (2024.1).

In our analysis we have assumed a consistent one-month rebalancing frequency as we wanted to avoid duration drift (i.e. when the long butterfly strategy loses its duration neutrality and becomes exposed to both parallel and non-parallel shifts, instead of only non-parallel shifts). Rebalancing costs and frequencies were mentioned in chapters 5.8 Incorporating Trade Costs into the Butterfly Weight Scheme Strategies and 6.3 Describing Butterfly Trade Costs which indicated how significant trading costs can be, especially if the butterfly strategy has high spread duration.

### 8.1 Rebalancing Frequency of Swap Butterfly Factors

In this chapter we elaborate on trade costs and repeat our swap and bond butterfly factor strategy as above with quarterly instead of monthly rebalancing and an assumed roundtrip trade

cost of 1bp of spread duration (i.e. 0.5 bps to close a trade and 0.5 bps to enter a new trade) to assess the differences. Table 26 and Table 27 illustrate the gross and net returns of the swap butterfly factors using both monthly and quarterly rebalancing frequencies respectively. We see that monthly rebalancing results in higher gross returns relative to the returns using quarterly rebalancing. However, when we compare the net returns we see that average annualised rebalancing costs of the monthly strategy is 1% and 0.7% for the top and bottom swap factors respectively, whilst the quarterly rebalancing strategy has average annualised rebalancing costs of 0.3% and 0.2% for the top and bottom swap factors respectively.

Thus, average annualised cost saving using the quarterly rebalancing strategy is 0.7% and 0.5% for the top and bottom swap factors respectively which is a significant amount. In fact, when we compare the net returns of the monthly and quarterly rebalancing returns we find that top S-DOM and S-AFR factors had equal returns whilst the quarterly rebalancing outperformed the monthly rebalancing of the top S-DEF factor by 0.7% per annum. The quarterly rebalancing strategy outperformed the monthly rebalancing strategy for all the bottom swap factors by an average of 1.1% per annum. Next, we compare the differences between monthly and quarterly rebalancing of the bond butterfly factors.

Swap Butterfly Factors			Monthly Rebalancing						
			Short Name	Gross Returns (pa)		Net Returns (pa)		Gross – Net Returns (pa)	
				Bottom	Top	Bottom	Top	Bottom	Top
Dominant Factors	Swap Absolute Spread	SAS	-1.2%**	1.5%*	-1.9%**	0.6%	0.6%	0.9%	
	Swap Risk Premium	SRP	-0.5%	1.4%*	-1.3%**	0.4%	0.8%	0.9%	
	Swap Nelson Siegel Svensson	SNSS	-0.8%	1.3%*	-1.5%**	0.5%	0.7%	0.9%	
	Swap Carry and Roll	S/C+R	-1.3%**	1.5%*	-1.9%**	0.6%	0.6%	0.9%	
	SA less US Swap Spread	SA-US	-1.3%**	1.6%*	-2.0%**	0.8%	0.7%	0.8%	
	Real Swap Rates <sup>3</sup>	RSR	-0.1%	1.0%	-0.7%	0.1%	0.6%	0.9%	
	Swap Reversion	SRev	-0.8%	1.6%*	-1.6%**	0.7%	0.8%	0.9%	
Defensive Factors	Swap Term Spread	STS	0.5%	0.3%	-0.5%	-0.8%	0.9%	1.1%	
	Swap Convexity	SCVX	0.8%	0.2%	-0.1%	-1.0%**	0.8%	1.2%	
	Swap Spread Duration	SSD	0.0%	0.0%	-0.3%	-1.3%**	0.3%	1.3%	
Average		Avg	-0.9%**	1.4%*	-1.2%**	0.1%	0.7%	1.0%	
Dominant Swap Factors		S-DOM	-0.9%	1.5%	-1.5%**	0.6%	0.7%	0.9%	
Defensive Swap Factors		S-DEF	0.4%	0.2%	-0.3%	-1.0%**	0.7%	1.2%	
Swap All Factor Rank		S-AFR	-1.5%**	1.8%*	-2.2%**	0.8%	0.7%	1.0%	

**Table 26** – Annualised gross and net returns of top and bottom swap butterfly factors from January 2001 until July 2024 using monthly rebalancing and 1bps of spread duration trade cost (0.5bps to close trade and 0.5bps to enter new trade). \* Denotes greater than zero mean at 1% significance level. \*\* Denotes less than zero mean at 1% significance level. Monthly rebalancing incurs annualised cost of 0.9% for the top S-DOM factors, 1.2% for the top S-DEF factors and 1.0% for top S-AFR factors. The bottom S-DOM, S-DEF and S-AFR factors have annualised costs a little lower at 0.7%. Source Data: IRESS and Bloomberg.

Swap Butterfly Factors			Quarterly Rebalancing						
			Short Name	Gross Returns (pa)		Net Returns (pa)		Gross – Net Returns (pa)	
				Bottom	Top	Bottom	Top	Bottom	Top
Dominant Factors	Swap Absolute Spread	SAS	-0.6%	1.1%*	-0.8%	0.9%	0.2%	0.3%	
	Swap Risk Premium	SRP	-0.1%	1.0%*	-0.4%	0.7%	0.3%	0.3%	
	Swap Nelson Siegel Svensson	SNSS	0.1%	0.8%	-0.1%	0.5%	0.2%	0.3%	
	Swap Carry and Roll	S/C+R	0.0%	1.0%*	-0.2%	0.7%	0.2%	0.3%	
	SA less US Swap Spread	SA-US	-0.2%	1.1%*	-0.4%	0.8%	0.2%	0.3%	
	Real Swap Rates <sup>4</sup>	RSR	0.2%	0.7%	0.0%	0.4%	0.2%	0.3%	
	Swap Reversion	SRev	0.8%	0.1%	0.5%	-0.2%	0.3%	0.3%	
Defensive Factors	Swap Term Spread	STS	0.5%	0.2%	0.2%	-0.2%	0.3%	0.4%	
	Swap Convexity	SCVX	0.7%	0.0%	0.4%	-0.4%	0.3%	0.4%	
	Swap Spread Duration	SSD	0.1%	0.0%	0.0%	-0.4%	0.1%	0.4%	
Average		Avg	0.2%	0.6%	-0.1%	0.3%	0.2%	0.3%	
Dominant Swap Factors		S-DOM	0.0%	0.8%	-0.2%	0.6%	0.2%	0.3%	
Defensive Swap Factors		S-DEF	0.4%	0.1%	0.2%	-0.3%	0.2%	0.4%	
Swap All Factor Rank		S-AFR	-0.7%	1.1%*	-1.0%**	0.8%	0.2%	0.3%	

**Table 27** – Annualised gross and net returns of top and bottom swap butterfly factors from January 2001 until July 2024 using quarterly rebalancing and 1bps of spread duration trade cost (0.5bps to close trade and 0.5bps to enter new trade). \* Denotes greater than zero mean at 1% significance level. \*\* Denotes less than zero mean at 1% significance level. Quarterly rebalancing incurs annualised cost of 0.3% for the top S-DOM factors, 0.4% for the top S-DEF factors and 0.3% for top S-AFR factors. The bottom S-DOM, S-DEF and S-AFR factors have annualised costs a little lower at 0.2%. Source Data: IRESS and Bloomberg.

<sup>3</sup> Real swap rate data began in June 2007 so performance statistics are from that start date.

<sup>4</sup> Real swap rate data began in June 2007 so performance statistics are from that start date.

## 8.2 Rebalancing Frequency of Bond Butterfly Factors

Table 28 and Table 29 compare the gross and net returns of the bond butterfly factors using both monthly and quarterly rebalancing frequencies respectively. We see a similar pattern emerge in that the gross returns of the monthly rebalancing strategy outperform those of the quarterly rebalancing strategy by an average of 0.3% and 0.1% for the top and bottom bond factors respectively. However, when we compare the net returns we find that the top B-DOM and B-AFR have similar annualised net returns for monthly and quarterly rebalancing but the top B-DEF factor is 0.5% per annum greater by using the quarterly as opposed to the monthly rebalancing strategy. For the bottom bond factors, the quarterly rebalancing strategy of the bottom B-DOM, B-DEF and B-AFR factors are relatively better than the monthly rebalancing strategy by 1.1%, 0.4% and 1.3% per annum respectively.

What we observe from the above rebalancing strategies is that monthly rebalancing leads to greater gross returns because the factors are:

- Exposed to recent rather than stale swap and bond factors, especially when large non-parallel curve movements have occurred, and
- Monthly rebalancing will reduce duration drift, resulting in more non-parallel risk premia and less parallel risk premia relative to quarterly rebalancing.

On the other hand, due to the high rebalance costs, frequent rebalancing will likely diminish returns, so much so that it offsets the benefits of maximising swap and bond factor attributes and exposure to non-parallel risk premia. This is what occurred in that the additional trade costs of monthly rebalancing resulted in lower net returns relative to using quarterly rebalancing. Also, if roundtrip trade costs are greater than the assumed 1bp then net returns using monthly rebalancing would be hampered even more. In practice, a fine balance must be struck on when to rebalance so that trade costs can be minimised. This implies some subjectivity into the swap and bond factor strategies but with suitable non-parallel risk measures and curve monitoring, these quantitative tools can assist on appropriate rebalancing frequencies. Other techniques as mentioned by Engle and Russell (2012) and Perold (1988) to reduce trade costs include optimising trade sizes and timing, algorithmic trading, limit orders, smart order routing and actively managing implementation shortfall risk. In the next chapter we will analyse the performance of the swap and bond factors under various curve, interest rate and risk-off scenarios.

Bond Butterfly Factors			Monthly Rebalancing						
			Short Name	Gross Returns (pa)		Net Returns (pa)		Gross – Net Returns (pa)	
				Bottom	Top	Bottom	Top	Bottom	Top
Dominant Factors	Bond Absolute Spread	BAS	-0.7%	1.7%*	-1.3%**	0.9%	0.6%	0.7%	
	Bond Risk Premium	BRP	0.2%	0.7%	-0.4%	-0.1%	0.6%	0.8%	
	Bond Nelson Siegel Svensson	BNSS	-0.4%	0.9%	-1.0%**	0.2%	0.5%	0.7%	
	Bond Carry and Roll	B/C+R	-0.6%	0.9%	-1.2%**	0.3%	0.6%	0.6%	
	SA Swap less SA Bond Spread	SBS	0.1%	0.7%	-0.7%	-0.1%	0.7%	0.8%	
	Break-Even Inflation	BEI	0.0%	1.3%*	-0.7%	0.6%	0.7%	0.7%	
	Bond Reversion	BRev	-0.6%	1.0%*	-1.3%**	0.3%	0.7%	0.8%	
Defensive Factors	Bond Term Spread	BTS	0.5%	0.0%	-0.4%	-0.8%	0.9%	0.9%	
	Bond Convexity	BCVX	0.6%	-0.1%	-0.2%	-0.9%	0.8%	0.8%	
	Bond Spread Duration	BSD	0.4%	0.0%	0.1%	-1.0%**	0.3%	1.0%	
Average		Avg	0.0%	0.7%	-0.7%	-0.1%	0.7%	0.8%	
Dominant Bond Factors		B-DOM	-0.3%	1.0%*	-0.9%	0.3%	0.7%	0.7%	
Defensive Bond Factors		B-DEF	0.5%	0.0%	-0.2%	-0.9%	0.7%	0.9%	
Bond All Factor Rank		B-AFR	-0.4%	1.2%*	-1.1%**	0.4%	0.6%	0.8%	

**Table 28** – Annualised gross and net returns of top and bottom bond butterfly factors from January 2001 until July 2024 using monthly rebalancing and 1bps of spread duration trade cost (0.5bps to close trade and 0.5bps to enter new trade). \* Denotes greater than zero mean at 1% significance level. \*\* Denotes less than zero mean at 1% significance level. Monthly rebalancing incurs annualised cost of 0.7% for the top B-DOM factors, 0.9% for the top B-DEF factors and 0.8% for top B-AFR factors. The bottom B-DOM and B-DEF factors have annualised costs a little lower at 0.7% with the bottom B-AFR factors at 0.6%. Source Data: IRESS and Bloomberg.

Bond Butterfly Factors			Quarterly Rebalancing						
			Short Name	Gross Returns (pa)		Net Returns (pa)		Gross – Net Returns (pa)	
				Bottom	Top	Bottom	Top	Bottom	Top
Dominant Factors	Bond Absolute Spread	BAS	-0.5%	1.4%*	-0.7%	1.1%*	0.2%	0.2%	
	Bond Risk Premium	BRP	0.5%	0.3%	0.3%	0.0%	0.2%	0.3%	
	Bond Nelson Siegel Svensson	BNSS	-0.2%	0.6%	-0.4%	0.4%	0.2%	0.2%	
	Bond Carry and Roll	B/C+R	-0.2%	0.9%	-0.4%	0.7%	0.2%	0.2%	
	SA Swap less SA Bond Spread	SBS	-0.1%	0.2%	-0.4%	-0.3%	0.2%	0.3%	
	Break-Even Inflation	BEI	0.1%	0.7%	-0.1%	-0.4%	0.2%	0.2%	
	Bond Reversion	BRev	0.3%	0.1%	0.1%	-0.5%	0.3%	0.3%	
Defensive Factors	Bond Term Spread	BTS	0.6%	-0.1%	0.3%	-0.3%	0.3%	0.3%	
	Bond Convexity	BCVX	0.7%	-0.1%	0.4%	-0.4%	0.3%	0.3%	
	Bond Spread Duration	BSD	0.3%	-0.1%	0.2%	-0.5%	0.1%	0.3%	
Average		Avg	0.1%	0.4%	-0.1%	0.1%	0.2%	0.3%	
Dominant Bond Factors		B-DOM	0.0%	0.6%	-0.2%	0.3%	0.2%	0.2%	
Defensive Bond Factors		B-DEF	0.5%	-0.1%	0.3%	-0.4%	0.2%	0.3%	
Bond All Factor Rank		B-AFR	-0.5%	1.4%*	-0.7%	1.1%*	0.2%	0.3%	

**Table 29** – Annualised gross and net returns of top and bottom bond butterfly factors from January 2001 until July 2024 using quarterly rebalancing and 1bps of spread duration trade cost (0.5bps to close trade and 0.5bps to enter new trade). \* Denotes greater than zero mean at 1% significance level. \*\* Denotes less than zero mean at 1% significance level. Quarterly rebalancing incurs annualised cost of 0.2% for the top B-DOM factors, 0.3% for the top B-DEF factors and 0.3% for top B-AFR factors. The bottom B-DOM, B-DEF and B-AFR factors have similar annualised costs at 0.2%. Source Data: IRESS and Bloomberg.

### Conclusion:

1. Due to the high rebalance costs, frequent rebalancing will likely diminish butterfly returns, to the extent that it offsets the benefits of maximising swap and bond butterfly returns.
2. Rebalancing frequency should aim to minimise trade costs whilst maintaining factor effectiveness. Non-parallel risk measures and curve monitoring help determine optimal rebalancing frequency.
3. Techniques to reduce trade costs include optimising trade sizes, algorithmic trading, limit orders, smart order routing, and managing implementation shortfall risk (Engle and Russell, 2012; Perold, 1988).



## Chapter 9



### Chapter 9 - Scenario Analysis

*"The biggest mistake most investors make is to believe that what happened in the past is going to happen in the future." - Ray Dalio (Founder of Bridgewater Associates)*

#### Objectives:

- Analyse the performance of swap and bond butterfly factors under various curve scenarios, interest rate cycles, and risk-off events.
- Identify that cutting cycles have occurred more frequently than hiking cycles in South Africa due to declining and stable inflation, a hawkish central bank, and below-trend growth post the 2008 global financial crisis.
- Highlight common scenarios during interest rate cuts: bull steepening, bear steepening, and bull flattening.
- Explain that during interest rate hikes, short-dated rates rise more than long-dated rates, leading to curve flattening, with expected scenarios including bear flattening, bull flattening, and flat twists.
- Examine average gross monthly returns under different scenarios (parallel shifts, bull/bear steepening/flattening, twists, and global risk-off events).
- Provide insights into the performance characteristics of dominant and defensive factors across these scenarios, highlighting strengths and weaknesses.
- Emphasise the importance of understanding the behaviour of different factors in diverse market environments for effective tactical asset allocation.

The work in this chapter is based on the below publications:

- Investments Analysts Journal - Hariparsad, S. and Maré, E (2023.1),
- The South African Journal of Economic and Management Sciences - Hariparsad, S. & Maré, E. (2024.1).

Understanding the risk/return metrics of each swap and bond butterfly factor provides an intuitive perspective on their performance. Analysing the performance in this way provides

great insight into which swap and bond butterfly factors are the best and worst performers under a given curve scenario.

## 9.1 South African Interest Rate Cycles and Curve Scenarios

Table 30 shows the frequency of 1st, 2nd and 3rd order curve scenarios under South African interest rate hiking and cutting cycles for both the bond and swap curves. Amongst the 1st order changes, parallel down is being favoured over parallel up (53% and 51% for parallel down scenarios for swap and bond curves respectively). For swap and bond curves the most common 2nd order changes are bull/bear flattening, and bull/bear steepening which cumulatively occur 79% and 75% of the time, whilst steep and flat twists occur the remaining 21% and 25% of the time respectively. It seems bull flattening and bear steepening are the common denominators during 2nd order curve scenarios under both hiking and cutting cycles. This highlights the binary risk of SA swaps and bonds in that they can have strong performance during bull flattening but also weak performance during bear steepening brought about by changes in fiscal risk premium. Another way to describe this is by using duration and slope risk. Duration risk measures the price sensitivity of a bond (or a portfolio) to parallel shifts in the yield curve. A 1% rise in interest rates leads to a proportional decline in bond prices, with longer-duration bonds experiencing larger losses. Slope risk, by contrast, captures the risk of changes in the relative difference between short-term and long-term yields, meaning only parts of the yield curve move rather than all maturities shifting together. Slope risk generally results in less extreme price moves because it implies a rotation (some parts of the curve move more than others), meaning losses in one part of the portfolio can be offset by gains in another. Thus, investors can expect volatility when dealing with duration risk whilst higher order (slope and curvature) risk via butterfly strategies offer a lower risk alternative.

Cutting cycles have occurred more frequently relative to hiking cycles owing to declining and relatively stable inflation in SA due to a hawkish central bank and below trend growth post the 2008 global financial crisis. This allowed for accommodative monetary policy to spur economic growth which favoured interest rate cuts. The most common types of scenarios under interest rate cuts are bull steepening, bear steepening and bull flattening. During interest rate hikes short-dated rates rise more than long-dated rates leading to curve flattening, thus bear flattening, bull flattening, and flat twists would be expected. Chen (2017) confirms this by classifying yield curve shapes and their transitions in response to macroeconomic and monetary

policy changes. Diebold and Rudebusch (2013) find similar relations by using the dynamic Nelson Siegel model to understand yield curve behaviour and monetary policy changes.

Analysing 3rd order changes (negative and positive twists) we see that they occur relatively evenly over the period for both swap and bond curves. If we rescale, we find that positive twists occur relatively more during interest rate hikes whilst negative twists are more prevalent during interest rate cuts.

Frequency of Curve Changes during Interest Rate Hikes and Cuts										
Curve Scenarios	Swap Curve Frequencies			Bond Curve Frequencies						
1 <sup>st</sup> Order Changes	Hike	Cut	Total	Rescale Hike	Rescale Cut	Hike	Cut	Total	Rescale Hike	Rescale Cut
Parallel Up	21%	26%	47%	48%	46%	23%	26%	49%	50%	47%
Parallel Down	23%	30%	53%	52%	54%	22%	29%	51%	50%	53%
<b>Total</b>	<b>44%</b>	<b>56%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>45%</b>	<b>55%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>
2 <sup>nd</sup> Order Changes	Hike	Cut	Total	Rescale Hike	Rescale Cut	Hike	Cut	Total	Rescale Hike	Rescale Cut
Bull Flat	14%	14%	28%	32%	24%	8%	12%	21%	18%	23%
Bear Flat	8%	6%	14%	18%	11%	11%	7%	18%	24%	14%
Bull Steep	4%	10%	15%	10%	19%	7%	10%	18%	17%	19%
Bear Steep	9%	14%	22%	20%	24%	7%	11%	18%	16%	21%
Steep Twist	4%	7%	10%	8%	12%	7%	7%	14%	15%	13%
Flat Twist	5%	5%	11%	12%	10%	5%	6%	11%	10%	12%
<b>Total</b>	<b>44%</b>	<b>56%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>45%</b>	<b>55%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>
3 <sup>rd</sup> Order Changes	Hike	Cut	Total	Rescale Hike	Rescale Cut	Hike	Cut	Total	Rescale Hike	Rescale Cut
Negative Twist	21%	29%	50%	48%	52%	20%	28%	48%	45%	50%
Positive Twist	23%	27%	50%	52%	48%	25%	27%	52%	55%	50%
<b>Total</b>	<b>44%</b>	<b>56%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>45%</b>	<b>55%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

**Table 30** – Frequency of 1st, 2nd and 3rd order swap and bond curve scenarios under interest rate hikes/ cuts using monthly data from January 2001 until July 2024. 1st order parallel down scenarios occurred more frequently given declining inflation. 3rd order positive twist scenarios were more prevalent during hiking cycles with negative twists being more common during cutting cycles. Bull flattening is most common during both hiking and cutting cycles, with bear steepening also occurring frequently during hiking cycles. Source Data: IRESS and Bloomberg.

This is intuitive as interest rate cuts lead to steeper curves as short- and medium-dated rates move lower relative to longer-dated rates, especially when it is early into the cutting cycle and several interest rate cuts are anticipated. During a recession, there is the possibility that longer-dated rates rise due to increased fiscal risk as growth will turn negative and government/corporates will have to increase their borrowing requirements to make up for the revenue shortfall, resulting in the curve bear steepening. Next, we assess the performance of the swap and bond factors under these curve scenarios.

## 9.2 Butterfly Factor Returns during Curve Scenarios and Rate Cycles

Table 31 and Table 32 illustrate the top and bottom swap and bond average gross monthly returns during 1st order scenarios (parallel up and down) respectively. The top S-DOM and S-AFR factors have positive returns under both parallel up and down scenarios whilst the bottom S-DOM and S-AFR factors deliver negative returns during both parallel up and down scenarios. The bottom S-DEF factors have positive returns during parallel down scenarios and slight negative returns during parallel up scenarios with an average return of 4bps. For the individual swap factors the top SAS, SRP, SNSS, S/C+R, SA-US and SRev factors have the highest average returns between 11bps and 14bps. Similarly the bottom STS, SCVX and SSD factors outperformed the other bottom factors with average returns of 0bp to 6bps.

Comparing the bond butterfly factors in Table 32 during 1st order curve changes, we see the top B-DOM and B-AFR factors, and bottom B-DEF factors outperform during parallel down scenarios with 16bps, 15bps and 12bps respectively. The top BAS, BNSS, B/C+R, BRev and BEI factors have the highest average returns between 9bps and 11bps. The bottom B-DEF factors outperform during parallel down scenarios with the bottom BTS and BCVX factors delivering 15bps and 16bps respectively. On average the bottom B-DEF factors outperform the bottom B-DOM and B-AFR factors (3bps versus -4bps and -5bps respectively).

We see that both the swap and bond butterfly factors perform relatively better during bullish rate environments that offer parallel down scenarios. In theory, butterfly returns should be zero during parallel curve shifts as they are designed to be immunised against parallel shifts, however, these parallel up and down scenarios denote the average change in interest rates across the curve. Thus, interest rates at different maturities can change by differing amounts, resulting in non-zero butterfly returns.

Average Gross Monthly Returns of Top Swap Butterfly Factors under 1st order curve changes														
Frequency	Curve Scenarios	SAS	STS	SCVX	SSD	SRP	SNSS	S/C+R	SA-US	RSR	SRev	S-DOM	S-DEF	S-AFR
47%	Parallel Up	0.06%	0.04%	0.03%	0.00%	0.07%	0.09%	0.06%	0.08%	0.06%	0.08%	0.07%	0.02%	0.12%
53%	Parallel Down	0.17%	0.02%	0.01%	0.00%	0.15%	0.13%	0.18%	0.19%	0.11%	0.19%	0.16%	0.01%	0.17%
100%	Weighted Avg	0.12%	0.03%	0.02%	0.00%	0.11%	0.11%	0.12%	0.13%	0.08%	0.14%	0.12%	0.01%	0.14%
Average Gross Monthly Returns of Bottom Swap Butterfly Factors under 1st order curve changes														
Frequency	Curve Scenarios	SAS	STS	SCVX	SSD	SRP	SNSS	S/C+R	SA-US	RSR	SRev	S-DOM	S-DEF	S-AFR
47%	Parallel Up	-0.15%	-0.04%	-0.03%	-0.03%	-0.07%	-0.14%	-0.15%	-0.20%	-0.09%	-0.11%	-0.13%	-0.03%	-0.20%
53%	Parallel Down	-0.06%	0.11%	0.13%	0.04%	0.00%	0.00%	-0.06%	-0.02%	0.07%	-0.05%	-0.02%	0.09%	-0.05%
100%	Weighted Avg	-0.10%	0.04%	0.06%	0.00%	-0.04%	-0.06%	-0.10%	-0.11%	-0.01%	-0.07%	-0.07%	0.04%	-0.12%

**Table 31** – Average gross monthly returns of top swap butterfly factors from January 2001 until July 2024 under 1st order swap curve scenarios. The dominant factors consist of SAS, SRP, SNSS, S/C+R, SA-US, RSR AND SRev, whilst the defensive factors consist of the STS, SCVX and SSD. The top S-DOM and S-AFR, and bottom S-DEF factors have the highest gross monthly returns occurring during parallel down scenarios. The bottom S-DEF, S-DOM and S-AFR factors underperform during parallel up scenarios. Source Data: IRESS and Bloomberg.

Average Gross Monthly Returns of Top Bond Butterfly Factors under 1st order curve changes														
Frequency	Curve Scenarios	BAS	BTS	BCVX	BSD	BRP	BNSS	B/C+R	SBS	BEI	BRev	B-DOM	B-DEF	B-AFR
47%	Parallel Up	0.01%	0.06%	0.02%	-0.03%	-0.07%	-0.05%	-0.01%	0.04%	0.03%	0.03%	0.00%	0.02%	0.09%
53%	Parallel Down	0.21%	-0.03%	-0.02%	0.00%	0.13%	0.23%	0.18%	0.07%	0.18%	0.15%	0.16%	-0.02%	0.15%
100%	Weighted Avg	0.11%	0.01%	0.00%	-0.01%	0.04%	0.10%	0.09%	0.06%	0.11%	0.09%	0.08%	0.00%	0.12%
Average Gross Monthly Returns of Bottom Bond Butterfly Factors under 1st order curve changes														
Frequency	Curve Scenarios	BAS	BTS	BCVX	BSD	BRP	BNSS	B/C+R	SBS	BEI	BRev	B-DOM	B-DEF	B-AFR
47%	Parallel Up	-0.08%	-0.08%	-0.14%	0.02%	-0.07%	-0.04%	-0.08%	-0.12%	-0.10%	-0.05%	-0.09%	-0.07%	-0.13%
53%	Parallel Down	-0.06%	0.15%	0.16%	0.05%	0.08%	-0.06%	-0.05%	0.12%	0.08%	-0.01%	0.01%	0.12%	0.01%
100%	Weighted Avg	-0.07%	0.04%	0.02%	0.03%	0.01%	-0.05%	-0.06%	0.00%	-0.01%	-0.03%	-0.04%	0.03%	-0.05%

**Table 32** – Average gross monthly returns of top bond butterfly factors from January 2001 until July 2024 under 1st order bond curve scenarios. The dominant factors consist of BAS, BRP, BNSS, B/C+R, SBS, BEI AND BRev, whilst the defensive factors consist of the BTS, BCVX and BSD. The top B-DOM and B-AFR, and bottom B-DEF factors have the highest gross monthly returns occurring during parallel down scenarios. The bottom B-DEF, B-DOM and B-AFR factors underperform during parallel up scenarios. Source Data: IRESS and Bloomberg.

Table 33 and Table 34 display the average gross monthly returns of the top and bottom bond and swap butterfly factors under 2nd order curve scenarios (bull and bear flattening, bull and bear steepening, and steep and flat twists) with 3rd order scenarios discussed in Table 35 and Table 36 respectively. For the top S-DOM factors in Table 33 the highest gross monthly returns occur during bull flattening, flat and steep twists with average gross monthly returns of 15bps and 13bps respectively, with the other scenarios yielding between 7-11bps. For the top S-DEF factors, average gross monthly returns are flat except during bear flattening which yields an average of 5bps. The top S-AFR has consistent performance across most 2nd order scenarios with favourable returns during bull flattening and steepening, and steep and flat twists with average gross monthly returns of 15-22bps. The bottom S-DOM and S-AFR factors are mostly negative with small positive returns occurring during steep twists. Large underperformance

occurs during bear flattening and flat twists with returns between -31bps and -16bps. The bottom S-DEF factors produce modest positive returns except during bear flattening and flat twists (-11bps and -4bps respectively) which are still relative outperformers when compared to the bottom S-DOM and S-AFR factors.

Delving into the individual factors we see that the top SRev factor performs exceptionally well during steep twists and bull steepening (28bps and 24bps respectively), other standouts are the top SAS, S/C+R and SA-US factors that contribute 18 to 20bps during bull flattening and the top SNSS and SA-US factors that deliver 18bps and 17bps respectively during flat twists. The bottom SAS, SNSS, S/C+R, SA-US have large underperformance during bear flattening and flat twists with returns between -30bps and -17bps. The bottom SRev factors delivers negative returns for all scenarios with the bottom STS and SCVX factors producing mostly positive returns with the strongest performance during bull flattening with 12bps and 13bps respectively.

Average Gross Monthly Returns of Top Swap Butterfly Factors under 2nd order curve changes														
Frequency	Curve Scenarios	SAS	STS	SCVX	SSD	SRP	SNSS	S/C+R	SA-US	RSR	SRev	S-DOM	S-DEF	S-AFR
28%	<b>Bull Flat</b>	0.18%	0.02%	0.01%	-0.01%	0.17%	0.13%	0.18%	0.20%	0.09%	0.13%	0.15%	0.01%	0.15%
14%	<b>Bear Flat</b>	0.08%	0.09%	0.08%	-0.01%	0.01%	0.13%	0.07%	0.03%	0.08%	0.08%	0.07%	0.05%	0.11%
15%	<b>Bull Steep</b>	0.07%	0.02%	0.01%	0.01%	0.07%	0.07%	0.08%	0.12%	0.00%	0.24%	0.09%	0.01%	0.17%
22%	<b>Bear Steep</b>	0.13%	0.02%	0.01%	0.00%	0.13%	0.12%	0.13%	0.12%	0.07%	0.08%	0.11%	0.01%	0.10%
10%	<b>Steep Twist</b>	0.11%	0.00%	0.00%	0.00%	0.10%	0.02%	0.11%	0.15%	0.15%	0.28%	0.13%	0.00%	0.18%
11%	<b>Flat Twist</b>	0.12%	0.03%	0.01%	0.00%	0.13%	0.18%	0.12%	0.17%	0.14%	0.07%	0.13%	0.01%	0.22%
100%	<b>Weighted Avg</b>	0.12%	0.03%	0.02%	0.00%	0.11%	0.12%	0.12%	0.14%	0.08%	0.13%	0.12%	0.02%	0.15%
Average Gross Monthly Returns of Bottom Swap Butterfly Factors under 2nd order curve changes														
Frequency	Curve Scenarios	SAS	STS	SCVX	SSD	SRP	SNSS	S/C+R	SA-US	RSR	SRev	S-DOM	S-DEF	S-AFR
28%	<b>Bull Flat</b>	-0.09%	0.12%	0.13%	0.00%	-0.02%	-0.01%	-0.08%	-0.05%	0.07%	-0.03%	-0.03%	0.08%	-0.07%
14%	<b>Bear Flat</b>	-0.30%	-0.12%	-0.07%	-0.14%	-0.12%	-0.24%	-0.30%	-0.27%	-0.11%	-0.11%	-0.21%	-0.11%	-0.31%
15%	<b>Bull Steep</b>	-0.04%	0.04%	0.06%	0.08%	-0.04%	0.00%	-0.05%	-0.01%	0.09%	-0.12%	-0.02%	0.06%	-0.03%
22%	<b>Bear Steep</b>	-0.10%	0.08%	0.09%	-0.01%	-0.03%	-0.08%	-0.09%	-0.13%	-0.08%	-0.01%	-0.07%	0.05%	-0.13%
10%	<b>Steep Twist</b>	0.10%	0.03%	0.06%	0.19%	0.03%	0.06%	0.07%	0.03%	0.02%	-0.18%	0.02%	0.09%	0.02%
11%	<b>Flat Twist</b>	-0.19%	-0.02%	-0.01%	-0.08%	-0.08%	-0.17%	-0.18%	-0.26%	-0.12%	-0.10%	-0.16%	-0.04%	-0.26%
100%	<b>Weighted Avg</b>	-0.10%	0.04%	0.06%	0.00%	-0.04%	-0.07%	-0.11%	-0.11%	-0.01%	-0.07%	-0.07%	0.03%	-0.12%

**Table 33** – Average gross monthly returns of top and bottom swap butterfly factors from January 2001 until July 2024 under 2nd order swap curve scenarios. The dominant factors consist of SAS, SRP, SNSS, S/C+R, SA-US, RSR AND SRev, whilst the defensive factors consist of the STS, SCVX and SSD. The top dominant factors have the highest gross monthly returns occurring during bull flattening and flat twists with the bottom dominant factors experiencing large negative returns during bear flattening and flat twists. For the top defensive factors average gross monthly returns are close to zero with the bottom defensive factors contributing positive returns on average. The top S-AFR has consistent positive performance across all 2nd order scenarios with favourable returns during flat and steep twists, whilst the bottom S-AFR delivers mostly negative returns with the lowest returns experienced during bear flattening and flat twists. Source Data: IRESS and Bloomberg.

For the top B-DOM factors in Table 34 the highest gross monthly returns occur during bull flattening and steepening, and steep twists with average gross monthly returns between 17bps and 21bps, and the other scenarios yielding negative returns. For the top B-DEF factors, average gross monthly returns are negligible with the lowest performance occurring during bull steepening at -6bps. The top B-AFR has consistent performance across all 2nd order scenarios with favourable returns during bull flattening and steepening, and bear flattening with average gross monthly returns of 11-18bps.

Delving into the individual bond factors we see that the top BAS, BNSS, B/C+R, BEI and BRev factors perform exceptionally well during bull steepening with returns between 23-33bps. Bull flattening produces high returns for the top BAS, BRP and BNSS factors (20-26bps) with steep twists favouring the top BAS, BRP, BNSS, B/C+R, BEI and BRev factors with returns that between 15-23bps.

For the bottom bond factors in Table 34, the highest gross monthly returns occur for the bottom B-DEF factors during steep twists, bull flattening and steepening, with average gross monthly returns between 12bps and 24bps. Bear flattening and flat twists deliver the lowest returns for the bottom B-DEF, B-DOM and B-AFR factors with returns between -18bps and -41bps. The bottom BTS, BCVX, SBS and BEI factors have the lowest returns between -20bps and -37bps during bear flattening whilst the bottom BAS, BTS, BCVX, BNSS, SBS, BEI, BSD and BRP have the lowest returns between -20bps and -44bps during steep twists. On average, the bottom BAS, BNSS, B/C+R and BRev factors have the lowest returns whilst the bottom BTS, BCVX and BSD factors (defined as the bottom B-DEF factors) have the highest returns.

Looking at 3rd order changes (negative and positive twists) in Table 35 and Table 36, we see that positive twists for the top S-DOM and S-AFR factors lead to high returns of 24bps and 21bps respectively. This can also be seen by the outperformance of the individual swap factors: SAS, SRP, SNSS, S/C+R, RSR and SRev with average gross monthly returns between 21bps and 29bps. The bottom S-DOM and S-AFR factors deliver consistent negative returns during both negative and positive twists with the bottom S-DEF factor outperforming during positive twists with a return of 13bps. For the bond factors, the top B-DOM and B-AFR factors also outperform during positive twists (17bps and 14bps respectively) but the top B-AFR also delivers strong returns of 9bps during negative twists. The bottom B-DOM, B-DEF and B-AFR factors underperform during negative twists with returns between -13bps and -9bps, however during positive twists the bottom B-DEF factor outperforms with a return of 14bps.

Table 37 and Table 38 show the average gross monthly returns of the top and bottom swap and bond butterfly factors under hiking and cutting interest rate cycles respectively. The top S-DOM and S-AFR factors perform relatively better during interest rate cutting cycles with average gross monthly returns ranging between 12-18bps. The top SRev and S-AFR factors outperform during cutting cycles with average returns of 11bps and 12bps respectively. The bottom S-AFR and S-DOM factors underperform during both hiking and cutting cycles with average gross monthly returns between -7bps and -14bps. The bottom S-DEF factor performs relatively better than the bottom S-DOM and S-DEF factors with returns between -1bp and 7bps. The top B-DOM and B-AFR factors have relatively higher gross monthly returns occurring during cutting cycles (10bps and 16bps respectively). For the individual bond factors the top BAS and BEI factors outperform during cutting cycles with returns of 13bps and 15bps respectively. The bottom B-AFR and B-DOM factors underperform relatively more during cutting cycles than hiking cycles whilst the bottom B-DEF outperforms and has positive returns during both hiking and cutting cycles of 2bps and 4bps respectively. The bottom BAS and B/C+R factors underperform during cutting cycles with an average gross monthly return of -11bps whilst the bottom BTS, BCVX and BSD factors have positive returns between 2-5bps during both hiking and cutting cycles.

Average Gross Monthly Returns of Top Bond Butterfly Factors under 2nd order curve changes														
Frequency	Curve Scenarios	BAS	BTS	BCVX	BSD	BRP	BNSS	B/C+R	SBS	BEI	BRev	B-DOM	B-DEF	B-AFR
21%	<b>Bull Flat</b>	0.20%	-0.03%	-0.02%	0.12%	0.24%	0.26%	0.15%	0.14%	0.09%	0.14%	0.17%	0.02%	0.16%
18%	<b>Bear Flat</b>	-0.06%	0.11%	0.05%	-0.11%	-0.18%	-0.16%	0.00%	0.09%	-0.06%	-0.05%	-0.06%	0.02%	0.11%
19%	<b>Bull Steep</b>	0.29%	-0.08%	-0.02%	-0.09%	0.08%	0.23%	0.27%	0.03%	0.33%	0.23%	0.21%	-0.06%	0.18%
18%	<b>Bear Steep</b>	-0.02%	0.04%	-0.01%	0.01%	-0.02%	-0.04%	-0.07%	-0.03%	0.09%	0.07%	0.00%	0.01%	0.09%
13%	<b>Steep Twist</b>	0.16%	-0.01%	-0.02%	0.09%	0.15%	0.22%	0.23%	0.02%	0.20%	0.19%	0.17%	0.02%	0.05%
10%	<b>Flat Twist</b>	0.06%	0.10%	0.01%	-0.14%	-0.10%	0.05%	-0.07%	0.05%	-0.04%	-0.07%	-0.02%	-0.01%	0.09%
100%	<b>Weighted Avg</b>	0.11%	0.01%	0.00%	-0.01%	0.04%	0.10%	0.09%	0.06%	0.11%	0.09%	0.09%	0.00%	0.12%
Average Gross Monthly Returns of Bottom Bond Butterfly Factors under 2nd order curve changes														
Frequency	Curve Scenarios	BAS	BTS	BCVX	BSD	BRP	BNSS	B/C+R	SBS	BEI	BRev	B-DOM	B-DEF	B-AFR
21%	<b>Bull Flat</b>	-0.06%	0.16%	0.16%	0.02%	0.00%	-0.10%	-0.10%	0.03%	0.05%	-0.05%	-0.03%	0.12%	-0.03%
18%	<b>Bear Flat</b>	-0.09%	-0.28%	-0.37%	-0.05%	-0.19%	-0.08%	-0.15%	-0.30%	-0.20%	-0.15%	-0.18%	-0.23%	-0.26%
19%	<b>Bull Steep</b>	-0.02%	0.25%	0.26%	0.18%	0.21%	0.03%	-0.01%	0.33%	0.17%	0.09%	0.09%	0.23%	0.11%
18%	<b>Bear Steep</b>	-0.07%	-0.02%	-0.05%	0.06%	-0.02%	0.00%	0.00%	0.02%	-0.05%	-0.07%	-0.03%	0.00%	-0.03%
13%	<b>Steep Twist</b>	0.03%	0.29%	0.32%	0.11%	0.21%	0.11%	0.02%	0.25%	0.17%	0.19%	0.13%	0.24%	0.19%
10%	<b>Flat Twist</b>	-0.29%	-0.28%	-0.27%	-0.20%	-0.22%	-0.32%	-0.18%	-0.44%	-0.23%	-0.20%	-0.26%	-0.25%	-0.41%
100%	<b>Weighted Avg</b>	-0.07%	0.04%	0.02%	0.03%	0.01%	-0.05%	-0.07%	0.01%	0.00%	-0.03%	-0.04%	0.03%	-0.05%

**Table 34** – Average gross monthly returns of top and bottom bond butterfly factors from January 2001 until July 2024 under 2nd order bond curve scenarios. The dominant factors consist of BAS, BRP, BNSS, B/C+R, SBS, BEI AND BRev, whilst the defensive factors consist of the BTS, BCVX and BSD. The top dominant factors have the highest gross monthly returns occurring during bull flattening and steepening, and steep twists. For the top defensive factors average gross monthly returns are close to zero. The B-AFR has consistent performance across most 2nd order scenarios with favourable returns during bull steepening and flattening. Source Data: IRESS and Bloomberg.

Average Gross Monthly Returns of Top Swap Butterfly Factors under 3rd order curve changes														
Frequency	Curve Scenarios	SAS	STS	SCVX	SSD	SRP	SNSS	S/C+R	SA-US	RSR	SRev	S-DOM	S-DEF	S-AFR
50%	<b>Negative Twist</b>	-0.04%	0.01%	0.01%	0.00%	0.00%	0.02%	-0.04%	0.00%	-0.03%	0.07%	0.00%	0.01%	0.08%
50%	<b>Positive Twist</b>	0.29%	0.04%	0.03%	0.00%	0.23%	0.21%	0.29%	0.27%	0.20%	0.21%	0.24%	0.02%	0.21%
100%	<b>Weighted Avg</b>	0.12%	0.03%	0.02%	0.00%	0.11%	0.11%	0.12%	0.14%	0.09%	0.14%	0.12%	0.02%	0.15%
Average Gross Monthly Returns of Bottom Swap Butterfly Factors under 3rd order curve changes														
Frequency	Curve Scenarios	SAS	STS	SCVX	SSD	SRP	SNSS	S/C+R	SA-US	RSR	SRev	S-DOM	S-DEF	S-AFR
50%	<b>Negative Twist</b>	-0.07%	-0.10%	-0.10%	0.02%	-0.07%	-0.11%	-0.08%	-0.11%	-0.04%	-0.14%	-0.09%	-0.06%	-0.13%
50%	<b>Positive Twist</b>	-0.13%	0.18%	0.22%	-0.01%	-0.01%	-0.02%	-0.13%	-0.11%	0.03%	-0.01%	-0.06%	0.13%	-0.12%
100%	<b>Weighted Avg</b>	-0.10%	0.04%	0.06%	0.00%	-0.04%	-0.06%	-0.11%	-0.11%	-0.01%	-0.08%	-0.07%	0.03%	-0.12%

**Table 35** – Average gross monthly returns of top swap butterfly factors from January 2001 until July 2024 under 3rd order swap curve scenarios. The dominant factors consist of SAS, SRP, SNSS, S/C+R, SA-US, RSR AND SRev, whilst the defensive factors consist of the STS, SCVX and SSD. The top S-DOM and S-AFR, and bottom S-DEF factors have the highest gross monthly returns occurring during positive twists. The bottom S-DEF and S-DOM factors underperform during negative twists whilst the bottom S-AFR underperform during both positive and negative twists. Source Data: IRESS and Bloomberg.

Average Gross Monthly Returns of Top Bond Butterfly Factors under 3rd order curve changes														
Frequency	Curve Scenarios	BAS	BTS	BCVX	BSD	BRP	BNSS	B/C+R	SBS	BEI	BRev	B-DOM	B-DEF	B-AFR
48%	Negative Twist	0.00%	0.04%	0.02%	-0.12%	-0.05%	-0.01%	-0.01%	-0.04%	0.05%	0.01%	0.00%	-0.02%	0.09%
52%	Positive Twist	0.22%	-0.01%	-0.02%	0.08%	0.12%	0.19%	0.19%	0.14%	0.16%	0.17%	0.17%	0.02%	0.14%
100%	Weighted Avg	0.11%	0.01%	0.00%	-0.01%	0.04%	0.10%	0.09%	0.05%	0.11%	0.09%	0.09%	0.00%	0.12%

Average Gross Monthly Returns of Bottom Bond Butterfly Factors under 3rd order curve changes														
Frequency	Curve Scenarios	BAS	BTS	BCVX	BSD	BRP	BNSS	B/C+R	SBS	BEI	BRev	B-DOM	B-DEF	B-AFR
48%	Negative Twist	-0.12%	-0.14%	-0.18%	0.05%	-0.05%	-0.08%	-0.07%	-0.11%	-0.10%	-0.07%	-0.09%	-0.09%	-0.13%
52%	Positive Twist	-0.03%	0.21%	0.21%	0.01%	0.06%	-0.02%	-0.05%	0.10%	0.07%	0.01%	0.01%	0.14%	0.02%
100%	Weighted Avg	-0.07%	0.04%	0.02%	0.03%	0.01%	-0.05%	-0.06%	0.00%	-0.01%	-0.03%	-0.04%	0.03%	-0.05%

**Table 36** – Average gross monthly returns of top bond butterfly factors from January 2001 until July 2024 under 3rd order bond curve scenarios. The dominant factors consist of BAS, BRP, BNSS, B/C+R, SBS, BEI AND BRev, whilst the defensive factors consist of the BTS, BCVX and BSD. The top B-DOM and B-AFR, and bottom B-DEF factors have the highest gross monthly returns occurring during positive twists. The bottom B-DEF, B-DOM and B-AFR factors underperform during negative twists. Source Data: IRESS and Bloomberg.

Average Gross Monthly Returns of Top Swap Butterfly Factors under Interest Rate Cycles														
Frequency	Rate Cycle	SAS	STS	SCVX	SSD	SRP	SNSS	S/C+R	SA-US	RSR	SRev	S-DOM	S-DEF	S-AFR
45%	Hiking	0.06%	0.02%	0.01%	0.00%	0.04%	0.11%	0.06%	0.07%	0.02%	0.11%	0.07%	0.01%	0.12%
55%	Cutting	0.17%	0.04%	0.03%	0.00%	0.17%	0.12%	0.18%	0.19%	0.14%	0.16%	0.16%	0.02%	0.17%
100%	Weighted Avg	0.12%	0.03%	0.02%	0.00%	0.11%	0.12%	0.13%	0.14%	0.09%	0.13%	0.12%	0.02%	0.15%

Average Gross Monthly Returns of Bottom Swap Butterfly Factors under Interest Rate Cycles														
Frequency	Rate Cycle	SAS	STS	SCVX	SSD	SRP	SNSS	S/C+R	SA-US	RSR	SRev	S-DOM	S-DEF	S-AFR
45%	Hiking	-0.08%	-0.01%	-0.01%	-0.01%	-0.05%	-0.07%	-0.08%	-0.08%	-0.02%	-0.10%	-0.07%	-0.01%	-0.10%
55%	Cutting	-0.12%	0.09%	0.12%	0.01%	-0.03%	-0.06%	-0.12%	-0.13%	0.00%	-0.06%	-0.07%	0.07%	-0.14%
100%	Weighted Avg	-0.10%	0.04%	0.06%	0.00%	-0.04%	-0.06%	-0.11%	-0.11%	-0.01%	-0.08%	-0.07%	0.04%	-0.12%

**Table 37** – Average gross monthly returns of top and bottom swap butterfly factors from January 2001 until July 2024 under hiking and cutting interest rate cycles. The dominant factors consist of SAS, SRP, SNSS, S/C+R, SA-US, RSR AND SRev, whilst the defensive factors consist of the STS, SCVX and SSD. The top S-DOM and S-AFR have relatively higher gross monthly returns occurring during cutting cycles. The bottom S-AFR and S-DOM factors underperform relatively more during cutting cycles than hiking cycles whilst the bottom S-DEF outperforms and has positive returns during cutting cycles and relatively better returns during hiking cycles. Source Data: IRESS and Bloomberg.

Average Gross Monthly Returns of Top Bond Butterfly Factors under Interest Rate Cycles														
Frequency	Curve Scenarios	BAS	BTS	BCVX	BSD	BRP	BNSS	B/C+R	SBS	BEI	BRev	B-DOM	B-DEF	B-AFR
42%	Hiking	0.09%	-0.01%	0.02%	0.00%	0.02%	0.08%	0.09%	0.05%	0.05%	0.09%	0.07%	0.00%	0.07%
58%	Cutting	0.13%	0.03%	-0.02%	-0.02%	0.05%	0.11%	0.09%	0.06%	0.15%	0.10%	0.10%	0.00%	0.16%
100%	Weighted Avg	0.11%	0.01%	0.00%	-0.01%	0.04%	0.10%	0.09%	0.06%	0.11%	0.09%	0.09%	0.00%	0.12%

Average Gross Monthly Returns of Bottom Bond Butterfly Factors under Interest Rate Cycles														
Frequency	Curve Scenarios	BAS	BTS	BCVX	BSD	BRP	BNSS	B/C+R	SBS	BEI	BRev	B-DOM	B-DEF	B-AFR
42%	Hiking	-0.02%	0.02%	0.03%	0.02%	0.03%	-0.03%	0.00%	-0.01%	0.00%	-0.04%	-0.01%	0.02%	-0.03%
58%	Cutting	-0.11%	0.05%	0.02%	0.04%	-0.01%	-0.06%	-0.11%	0.01%	-0.02%	-0.02%	-0.06%	0.04%	-0.07%
100%	Weighted Avg	-0.07%	0.04%	0.02%	0.03%	0.01%	-0.05%	-0.06%	0.00%	-0.01%	-0.03%	-0.04%	0.03%	-0.05%

**Table 38** – Average gross monthly returns of top bond butterfly factors from January 2001 until July 2024 under interest rate cycles. The dominant factors consist of BAS, BRP, BNSS, B/C+R, SBS, BEI AND BRev, whilst the defensive factors consist of the BTS, BCVX and BSD. The top B-DOM and B-AFR factors have relatively higher gross monthly returns occurring during cutting cycles. The bottom B-AFR and B-DOM factors underperform relatively more during cutting cycles than hiking cycles whilst the bottom B-DEF outperforms and has positive returns during both hiking and cutting cycles. Source Data: IRESS and Bloomberg.

### 9.3 Butterfly Factor Returns during Global Risk-Off Events

Table 39 and Table 40 display the average gross monthly returns of the top and bottom swap and bond factors during global risk-off events respectively. The distinction between systemic and idiosyncratic risk-off events, as well as the varying impacts of such events in developed and emerging markets, is well-documented in financial literature. Systemic risk-off events are characterised by broad sell-offs across multiple asset classes and financial markets globally. These events often originate from significant shocks in developed economies, which, due to their large capital bases and interconnected financial systems, can lead to widespread market disruptions. For instance, the Bank for International Settlements (BIS 2021) notes that global risk-off shocks can be highly destabilising for financial markets and, absent an adequate policy response, may trigger severe recessions.

Conversely, idiosyncratic risk-off events are typically confined to specific domestic markets with limited spillovers. These events often originate from localised issues within emerging markets, such as political instability or economic downturns, and generally do not have immediate global repercussions. The European Central Bank (ECB 2014) discusses how sovereign contagion, often originating from domestic shocks like fiscal troubles, can lead to increased co-movement across bond markets, and quite specifically an issue for the euro area itself.

The IMF (2016) further elaborates on the growing importance of financial spillovers from emerging markets, noting that while these markets have become more integrated into the global financial system, their shocks are still often more localised compared to those originating from developed economies.

Thus, while both systemic and idiosyncratic risk-off events can lead to market sell-offs, the former typically involves widespread global impacts originating from developed economies, whereas the latter is more localised, often confined to specific domestic markets, particularly in emerging economies.

Average Gross Monthly Returns during Global Risk-Offs									
Global Risk-Off Events	Avg Yld Chg (%)	Start	End	Top Swap Factors			Bottom Swap Factors		
				S-DOM	S-DEF	S-AFR	S-DOM	S-DEF	S-AFR
9/11, Dotcom Bubble	1.8	30-Nov-01	30-Sep-02	0.19%	0.19%	0.11%	-0.41%	-0.30%	-0.68%
Global Financial Crisis	2.7	31-Oct-07	30-Jun-08	0.23%	0.00%	0.22%	-0.15%	0.02%	-0.18%
US Taper Tantrum	2.4	30-Apr-13	31-Jan-14	0.13%	0.02%	0.15%	-0.01%	0.14%	-0.05%
COVID	1.3	31-Dec-20	31-Oct-21	-0.01%	0.01%	0.04%	-0.16%	-0.10%	-0.19%
RUS-UKR war (inflation Spike)	2.0	28-Feb-22	30-Sep-22	-0.10%	0.00%	-0.01%	-0.06%	-0.11%	-0.08%
	1.5	Average		0.09%	0.05%	0.10%	-0.16%	-0.07%	-0.24%
	0.5	Minimum		-0.10%	0.00%	-0.01%	-0.41%	-0.30%	-0.68%
	2.7	Maximum		0.23%	0.19%	0.22%	-0.01%	0.14%	-0.05%

**Table 39** – Average gross monthly returns of top and bottom swap factors from January 2001 until July 2024 during global risk-off events. The top S-DOM and S-AFR factors have the highest average gross returns during these global risk-off events with a minimum of -10bps and -1bp respectively during the RUS-UKR war whilst the top S-DEF factor has positive returns throughout all the global risk-off events with an average of 5bps and 0bps during the RUS-UKR war. For the bottom swap factors the S-DEF factor outperforms with an average gross return during all the global risk-off events of -7bps, minimum of -30bps during the 9/11, dotcom bubble and maximum of 14bps during the US Taper Tantrum. Source: Bloomberg and IRESS data.

Average Bond Factor Gross Monthly Returns during Global Risk-Offs									
Global Risk-Off Events	Avg Yld Chg (%)	Start	End	Top Bond Factors			Bottom Bond Factors		
				B-DOM	B-DEF	B-AFR	B-DOM	B-DEF	B-AFR
9/11, Dotcom Bubble	1.3	30-Nov-01	30-Sep-02	-0.27%	-0.19%	-0.17%	-0.01%	-0.02%	-0.06%
Global Financial Crisis	2.7	31-Oct-07	30-Jun-08	0.01%	0.04%	0.13%	0.00%	0.03%	-0.06%
US Taper Tantrum	2.2	30-Apr-13	31-Jan-14	-0.05%	0.08%	0.23%	-0.09%	-0.23%	-0.22%
COVID	0.5	31-Dec-20	31-Oct-21	0.08%	0.11%	0.36%	-0.13%	-0.07%	-0.20%
RUS-UKR war (inflation Spike)	1.1	28-Feb-22	30-Sep-22	0.02%	0.00%	0.09%	-0.58%	-0.58%	-0.80%
	1.6	Average		-0.04%	0.01%	0.13%	-0.16%	-0.17%	-0.27%
	0.5	Minimum		-0.27%	-0.19%	-0.17%	-0.58%	-0.58%	-0.80%
	2.7	Maximum		0.08%	0.11%	0.36%	0.00%	0.03%	-0.06%

**Table 40** – Average gross monthly returns of top and bottom bond factors from January 2001 until July 2024 during global risk-off events. The top B-AFR factor has the highest average gross return of 13bps during these global risk-off events with a minimum of -17bps during the 9/11, dotcom bubble and maximum of 36bps during the COVID pandemic. For the bottom bond factors the B-DOM and B-DEF factors outperform with an average gross return during all the global risk-off events of -16bps and -17bps respectively, with minimums of -58bps during the RUS-UKR war, and maximums around 0bps during the global financial crisis. Source: Bloomberg and IRESS data.

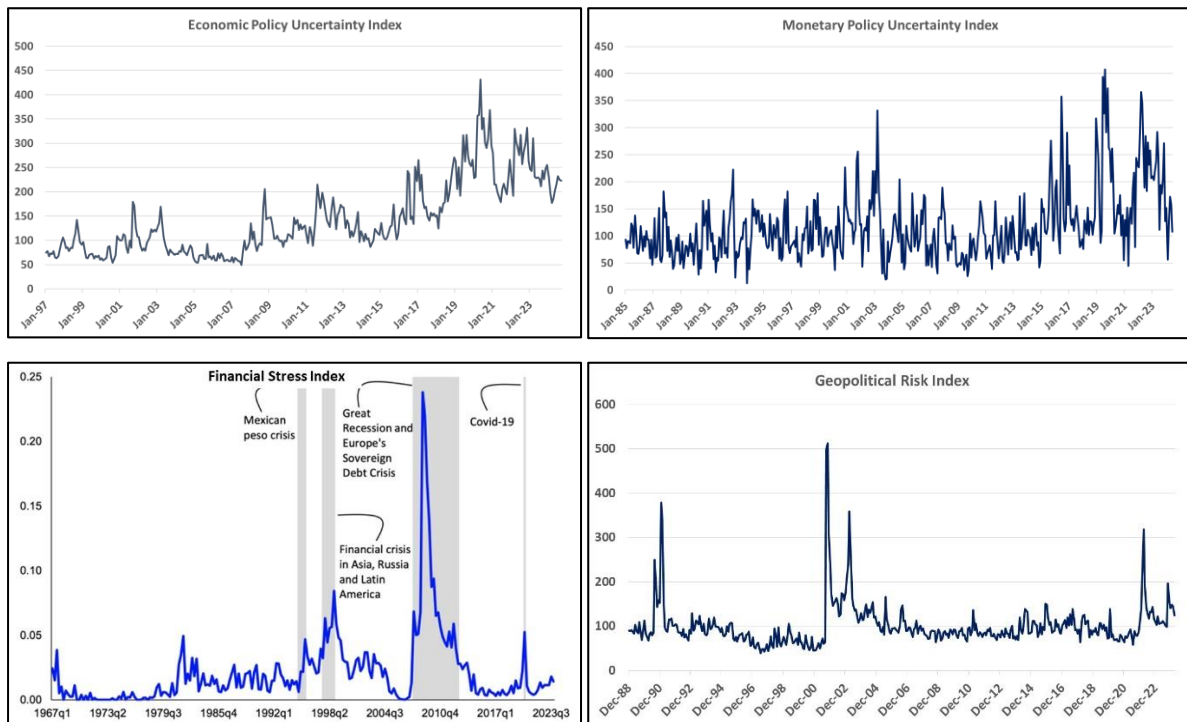
To classify global risk-off events, we utilised non-asset market indices introduced by Baker et al. (2016), including the Economic Policy Uncertainty (EPU) index, the Monetary Policy Uncertainty (MPU) index from Husted et al. (2017), developed using Baker et al.’s methodology, the Geopolitical Risk (GPR) index by Caldara and Iacoviello (2022), and the IMF’s Financial Stress Index (FSI), which captures financial stress across various economies.

The US EPU index, constructed by Baker et al. (2016), identifies relevant articles from ten major US newspapers based on specific terms. For other countries, this methodology is adapted with analogous criteria. Article counts are scaled by the total monthly publication volume for each newspaper, and each series is standardised to have a unit standard deviation over the sample period. These series are averaged and normalized to a mean of 100. The index shows significant spikes during major uncertainty-inducing events, such as the Gulf Wars, 9/11 attacks, the Lehman Brothers bankruptcy, and the 2011 US debt ceiling crisis, among others.

Similarly, the MPU index, developed by Husted et al. (2017), employs a narrower text-based approach, focusing on monetary policy-specific terms. This methodology isolates monetary policy events from broader economic uncertainties captured in the EPU index. The US MPU index reveals notable spikes during critical monetary policy events, such as the 2013 taper tantrum and the Federal Reserve's 2015 interest rate lift-off. The index also reflects its sensitivity to macroeconomic shocks, like the 2003 Iraq invasion.

The GPR index, developed by Caldara and Iacoviello (2022), measures geopolitical risks by analysing newspaper articles discussing adverse geopolitical events. Using automated searches across ten major newspapers, the index categorises articles into themes such as War Threats, Terror Acts, and Military Buildups. Monthly counts of relevant articles, expressed as a share of total articles, form the basis of this index, which traces geopolitical tensions and their economic impacts over time.

The IMF's FSI, introduced by Ahir et al. (2023), identifies risk sentiment by analysing Economist Intelligence Unit (EIU) reports rather than newspaper articles. These reports draw on expertise from field specialists, public data, and in-house models, undergoing rigorous peer review and quality control. While the FSI occasionally produces false positives or negatives, adjustments have enhanced its accuracy. This index captures financial stress across banking, equity, and exchange rate markets, often spiking during periods of market turmoil and risk aversion.



**Figure 16** – The above charts illustrate the EPU, MPU, GPR, and FSI indices over the various periods that were used to ascertain systemic risk-off events. The FSI chart was reproduced from Ahir et al. (2023). We notice increased financial stress during the global financial crisis during the 2007-2010 period, heightened economic, monetary policy and geopolitical risks during 9/11 and the dotcom bubble in the early 2000's and COVID pandemic in 2020.

By leveraging the EPU, MPU, GPR, and FSI indices which are illustrated in

Figure 16, we introduced objectivity into this classification. Systemic risk-off events were identified when global risk indices exhibited spikes above their long-term averages alongside parallel movements across multiple countries. Conversely, if risk indices remained stable while one country experienced localized disruptions, the event was categorized as idiosyncratic to that country.

Analysing the performance of the swap and bond factors under global risk-off events, we see that the top S-DOM and S-AFR factors have the highest average gross returns with a minimum of -10bps and -1bp respectively during the RUS-UKR war and a maximum of 23bps and 22bps respectively during the global financial crisis. The top S-DEF factor delivers consistent positive returns (between 0bps and 19bps) throughout all the global risk-off events with an average of 5bps. For the bottom swap factors the S-DEF factor outperforms with an average gross return during all the global risk-off events of -7bps, minimum of -30bps during the 9/11, dotcom bubble and maximum of 14bps during the US Taper Tantrum. The bottom S-AFR factor underperforms with an average of -24bps, minimum of -68bps during the 9/11, dotcom bubble and maximum of -5bps during the US Taper Tantrum.

For the bond factors we find that the top B-AFR factor has the highest average gross return of 13bps during these global risk-off events with a minimum of -17bps during the 9/11, dotcom bubble and maximum of 36bps during the COVID pandemic. The top B-DOM factor has relative underperformance with an average gross return of -4bps, minimum of -27bps during the 9/11, dotcom bubble and maximum of 8bps during the COVID pandemic. The top B-DEF factor displays steady performance during the global risk-off events with an average gross return of 1bp and minimum of -19bps during the 9/11, dotcom bubble. For the bottom bond factors the B-DOM and B-DEF factors outperform with average gross returns during all the global risk-off events of -16bps and -17bps respectively, minimums of -58bps each during the RUS-UKR war, and maximums around 0bps during the global financial crisis. The bottom B-AFR is the relative underperformer with an average gross return of -27bps, and minimum of -80bps during the RUS-UKR war.

What we notice from these global risk-off events is that the top factors outperform the bottom factors with respect to both swaps and bonds. The top S-AFR and B-AFR provide diversification and outperformance during these global risk-off events, with the corresponding bottom S-AFR and B-AFR factors underperforming. Thus, the top and bottom factors illustrate clear polarity and distinct properties. Taking a long position in the top factors and short position in the bottom factors (in both swaps and bonds) would be advantageous during global risk-off events.

Based on the average gross returns, the most beneficial trade during these global risk-off events would be a long position in the top S-AFR/B-AFR factor and short position in the bottom S-AFR/B-AFR factor given their wide return divergences. Long and short positions in the other top and bottom factors (namely S-DEF/B-DEF and S-DOM/B-DOM respectively) would also be effective, but to a lesser degree.

## 9.4 Dissecting Swap and Bond Butterfly Factor Returns

To determine the effectiveness of the defensive factors (S-DEF and B-DEF) we dissect the top and bottom, swap and bond factor returns into quartiles. Table 41 and Table 42 illustrate the average gross monthly returns of the top and bottom swap and bond factors respectively based on one-month average swap yield changes (aka parallel shifts). For large parallel up shifts as in Q4, we see that the top and bottom S-DEF factors showcase their defensive capabilities with greater average returns relative to the top and bottom S-DOM factors. The bottom S-DEF factor

outperforms the top S-DEF factor during Q1-Q3 but underperforms during the large parallel up curve shift. Overall the top S-DEF factor provide more stability over the bottom S-DEF factor. The top and bottom S-DEF factors do provide improved downside protection with minimum gross monthly returns of -0.09% and -1.1% respectively over the S-DOM factors but the bottom S-DEF has greater upside potential as illustrated in Q1-Q3. Analysing the bond factors in Table 42, we see that during large parallel up shifts as in Q4, the top B-DEF factor showcases its' defensive capabilities with greater average returns relative to the top B-DOM factor (0.06% vs. -0.07%) and a greater minimum return (-0.73% vs. -1.13%). The bottom B-DEF factor outperforms the top B-DEF factor during Q1-Q3, however the bottom B-DEF factor underperform the top B-DEF factor during Q4 including a lower minimum return for the bottom B-DEF factor (-1.67% vs. -0.73%). Overall the top B-DEF factor provides more stability over the bottom B-DEF factor.

Quartiles		Avg Yield Chg	Top Swap Factors			Bottom Swap Factors		
			S-DOM	S-DEF	S-AFR	S-DOM	S-DEF	S-AFR
0%-25%	Q1	-0.4	0.16%	0.01%	0.19%	-0.04%	0.08%	-0.05%
25%-50%	Q2	-0.1	0.16%	0.01%	0.14%	-0.01%	0.11%	-0.05%
50%-75%	Q3	0.1	0.16%	0.01%	0.18%	-0.08%	0.07%	-0.14%
75%-100%	Q4	0.4	0.01%	0.03%	0.08%	-0.18%	-0.13%	-0.25%
Average		-0.0	0.12%	0.02%	0.15%	-0.08%	0.04%	-0.12%
Min		-1.7	-1.27%	-0.09%	-1.79%	-4.12%	-1.10%	-4.66%
Max		1.0	2.04%	2.01%	3.07%	1.39%	1.26%	1.43%

**Table 41** – Average gross monthly returns of top and bottom swap factors from January 2001 until July 2024 arranged in quartiles according to the average one-month change in the level of swap yields (aka parallel shifts). For large parallel up shifts as in Q4, we see that the top and bottom S-DEF factors showcase their defensive capabilities with greater average returns relative to the top and bottom S-DOM factors. The bottom S-DEF factor outperforms the top S-DEF factor during Q1-Q3 but underperforms during the large parallel up shift. Overall the top S-DEF factor provides more stability over the bottom S-DEF factor. Source Data: IRESS and Bloomberg.

Quartiles		Avg Yield Chg	Top Bond Factors			Bottom Bond Factors		
			B-DOM	B-DEF	B-AFR	B-DOM	B-DEF	B-AFR
0%-25%	Q1	-0.4	0.23%	-0.01%	0.22%	0.01%	0.20%	0.04%
25%-50%	Q2	-0.1	0.11%	-0.02%	0.06%	0.03%	0.10%	0.01%
50%-75%	Q3	0.1	0.06%	-0.02%	0.02%	0.02%	0.07%	0.04%
75%-100%	Q4	0.4	-0.07%	0.06%	0.11%	-0.15%	-0.20%	-0.24%
Average		-0.0	0.08%	0.00%	0.10%	-0.02%	0.04%	-0.04%
Min		-1.6	-1.13%	-0.73%	-1.59%	-1.46%	-1.67%	-2.49%
Max		1.2	2.67%	0.79%	1.50%	0.87%	3.93%	1.79%

**Table 42** – Average gross monthly returns of top and bottom bond factors from January 2001 until July 2024 arranged in quartiles according to the average one-month change in the level of bond yields (aka parallel shifts). For large parallel up shifts as in Q4, we see that the top B-DEF factor showcases its' defensive capabilities with greater average returns relative to the top B-DOM factor and a greater minimum return (-0.73% vs. -1.13%). The bottom B-DEF factor outperforms the top B-DEF factor during Q1-Q3, however the bottom B-DEF factor underperforms the top B-DEF factor during Q4 including a lower minimum return (-1.67% vs. -0.73%). Overall the top B-DEF factor provides more stability over the bottom B-DEF factor. Source Data: IRESS and Bloomberg.

To get more insight into the defensive nature of the S-DEF and B-DEF factors, we arranged the S-DOM factors into quartiles and compared the average returns of the S-DEF and S-AFR factors in Table 43. The same approach was done for the bond factors in Table 44, namely arranging the B-DOM factor returns into quartiles and comparing the B-DEF and B-AFR factor returns. Analysing the swap factor returns, we find that the top S-DEF factor provides relatively greater returns when the top S-DOM returns are very low as in Q1 with returns of 0% versus -0.23% respectively. When returns increase as in Q3 and Q4 we see that the top S-DOM and S-AFR factors outperform the top S-DEF factor. This illustrates that the top S-DEF factor provides downside protection at the expense of upside participation.

For the bottom S-DEF factor, we find that it provides both upside potential and downside protection relative to the bottom S-DOM and S-AFR factors. When the bottom S-DOM returns are low as in Q1, the bottom S-DEF factor delivers returns of -0.21% versus the bottom S-DOM and S-AFR factors that have returns of -0.39% and -0.48% respectively. When the bottom S-DOM factor returns are higher as in Q3 and Q4 we observe that the bottom S-DEF factor outperforms (0.09% versus 0% for Q3, and 0.26% versus 0.18% respectively).

		Top Swap Factors					Bottom Swap Factors		
Quartiles		S-DOM	S-DEF	S-AFR	Percentiles		S-DOM	S-DEF	S-AFR
0%-25%	Q1	-0.23%	0.00%	-0.17%	0%-25%	Q1	-0.39%	-0.21%	-0.48%
25%-50%	Q2	0.02%	0.01%	0.06%	25%-50%	Q2	-0.10%	0.01%	-0.15%
50%-75%	Q3	0.16%	0.01%	0.17%	50%-75%	Q3	0.00%	0.09%	-0.03%
75%-100%	Q4	0.55%	0.05%	0.42%	75%-100%	Q4	0.18%	0.26%	0.17%
Average		0.12%	0.02%	0.15%	Average		-0.08%	0.04%	-0.12%
Min		-1.27%	-0.09%	-1.79%	Min		-4.12%	-1.10%	-4.66%
Max		2.04%	2.01%	3.07%	Max		1.39%	1.26%	1.43%

**Table 43** – Average gross monthly returns of top and bottom S-DEF and S-AFR factors from January 2001 until July 2024 arranged in quartiles according to the top and bottom S-DOM factors. When the top and bottom S-DOM factors produce their lowest returns in Q1, we see that the top and bottom S-DEF factors showcase their defensive capabilities with greater returns relative to the S-DOM and S-AFR factors. During the high returning periods (as in Q3 and Q4) we see that the top S-DOM and S-AFR factors outperform the top S-DEF factor. However, the bottom S-DEF factor outperforms the bottom S-DOM and S-AFR factors during Q3 and Q4 indicating both upside potential and downside risk management. Source Data: IRESS and Bloomberg.

We notice a similar pattern for the bond factors in that the top B-DEF factor has downside protection and limited upside potential relative to the top B-DOM and B-AFR factors, whilst the bottom B-DEF factor has downside protection and upside potential relative to the bottom B-DOM and B-AFR factors. Looking at the returns in Table 44, we see that for low Q1 returns, the top B-DOM factor underperforms the top B-DEF factor (-0.07% versus -0.29% respectively). When the top B-DOM factor has higher returns as in Q3 and Q4, we see that the top B-DEF factor underperforms (0% and 0.06% versus 0.15% and 0.48% respectively). For the bottom B-DEF factor, we see that it outperforms the bottom B-DOM and B-AFR factors

during low returns in Q1 (-0.35% versus -0.41% and -0.56% respectively) and during high returns in Q4 (0.48% versus 0.33% and 0.45% respectively).

Quartiles		Top Bond Factors			Percentiles		Bottom Bond Factors		
		B-DOM	B-DEF	B-AFR			B-DOM	B-DEF	B-AFR
0%-25%	Q1	-0.29%	-0.07%	-0.14%	0%-25%	Q1	-0.41%	-0.35%	-0.56%
25%-50%	Q2	0.00%	0.02%	0.08%	25%-50%	Q2	-0.08%	-0.12%	-0.08%
50%-75%	Q3	0.15%	0.00%	0.14%	50%-75%	Q3	0.06%	0.16%	0.05%
75%-100%	Q4	0.48%	0.06%	0.35%	75%-100%	Q4	0.33%	0.48%	0.45%
<b>Average</b>		0.08%	0.00%	0.10%	<b>Average</b>		-0.02%	0.04%	-0.04%
<b>Min</b>		-1.13%	-0.73%	-1.59%	<b>Min</b>		-1.46%	-1.67%	-2.49%
<b>Max</b>		2.67%	0.79%	1.50%	<b>Max</b>		0.87%	3.93%	1.79%

**Table 44** – Average gross monthly returns of top and bottom B-DEF and B-AFR factors from January 2001 until July 2024 arranged in quartiles according to the top and bottom B-DOM factors. When the top and bottom B-DOM factors produce their lowest returns in Q1, we see that the top and bottom B-DEF factors showcase their defensive capabilities with greater returns relative to the B-DOM and B-AFR factors. During the high returning periods (as in Q3 and Q4) we see that the top B-DOM and B-AFR factors outperform the top B-DEF factor. However, the bottom B-DEF factor outperforms the bottom B-DOM and B-AFR factors during Q3 and Q4 indicating both upside potential and downside risk management. Source Data: IRESS and Bloomberg.

### Conclusion:

1. Cutting cycles have occurred more frequently than hiking cycles in South Africa due to declining and stable inflation, a hawkish central bank, and below-trend growth post the 2008 global financial crisis.
2. Interest rate cuts result in bull and bear steepening, and bull flattening. Interest rate hikes, where short-dated rates rise more than long-dated rates, lead to curve flattening scenarios such as bull and bear flattening, and flat twists.
3. While both systemic and idiosyncratic risk-off events can lead to market sell-offs, the former typically involves widespread global impacts originating from developed economies, whereas the latter is more localised.
4. During global risk-off events the top factors outperform the bottom factors with respect to both swaps and bonds. The top S-DEF and B-DEF factors provide downside protection at the expense of upside participation relative to the top S-DOM/S-AFR and top B-DOM/B-AFR factors respectively.
5. The dominant and all-factors outperform defensive factors during interest rate cutting cycles and bullish curve scenarios in both swap and bond spaces.

## Chapter 10 - Correlations to Financial and Economic Indicators

*"Economic policy must be data-driven, not ideology-driven, because the numbers tell the real story." – Christine Lagarde (ECB President)*

### Objectives:

- Explore the correlations between swap and bond butterfly factors and various financial/economic indicators.
- Use bar charts and tables to illustrate the relationships between butterfly factors and indicators such as bond indices, currencies, commodities, equities, economic indicators, volatility measures, and credit spreads.

The work in this chapter is based on the below publications:

- Investments Analysts Journal - Hariparsad, S. and Maré, E (2023.1),
- The South African Journal of Economic and Management Sciences - Hariparsad, S. & Maré, E. (2024.1).

Understanding the relationship between butterfly factors and financial and economic indicators is crucial for optimising a successful strategy. This chapter examines the correlations between the swap and bond factors and various economic and financial indicators, providing insights into the optimal timing for implementing long and short butterfly strategies.

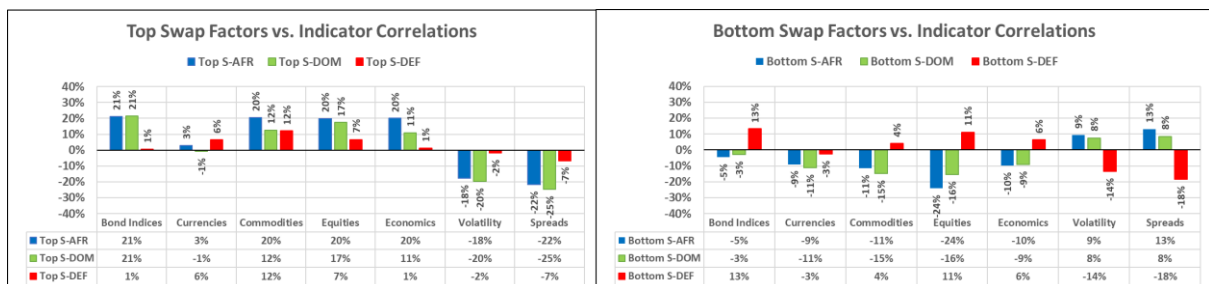
### 10.1 Swap Butterfly Factors versus Indicators

Figure 17 and Figure 18 illustrate bar charts of correlations across the top and bottom swap (S-AFR, S-DOM, S-DEF) and bond (B-AFR, B-DOM, B-DEF) factors respectively, using lagged quarterly financial and economic data due to reporting delays. Table 45 defines the indicators and details their lag lengths and quarterly changes used in the correlation analysis. The economic data incorporate a one-quarter lag, reflecting the timing of their release, with absolute and percentage changes provided for each indicator.

Classification	Indicator Code	Description	Change	Quarterly Lag
Bond Indices	ALBI	SA All-Bond Index Total Return (in ZAR)	Quarterly Percentage Change	0
	CILI	SA Inflation Linked Composite Index Total Return (in ZAR)	Quarterly Percentage Change	0
	US10YTR	US 10-year Treasury Total Return Index (in USD)	Quarterly Percentage Change	0
Currencies	USDZAR	1 USD in South African Rands	Quarterly Percentage Change	0
	DXY	US Dollar Index Total Return ((in USD)	Quarterly Percentage Change	0
Commodities	BRENT	Generic Brent Crude Spot Price (in USD)	Quarterly Percentage Change	0
	GOLD	Gold Spot Price (in USD)	Quarterly Percentage Change	0
Equities	ALSI	JSE All Share Index Total Return (in ZAR)	Quarterly Percentage Change	0
	SABANKS	JSE Banks Index Total Return (in ZAR)	Quarterly Percentage Change	0
	SARESI	JSE Resources Index Total Return (in ZAR)	Quarterly Percentage Change	0
	SAREITS	JSE Real Estate Investment Trust Index Total Return (in ZAR)	Quarterly Percentage Change	0
	SAGENR	JSE General Retailers Index Total Return (in ZAR)	Quarterly Percentage Change	0
Volatility	VIX	S&P500 1-Month Implied Volatility Index	Absolute Quarterly Change	0
	SAVI	JSE All Share Index Implied Volatility Index	Absolute Quarterly Change	0
	MOVE	Implied volatility of U.S. Treasury Options (across various maturities)	Absolute Quarterly Change	0
Credit Spreads	SASYCDS	SA Sovereign 5-Year Credit Default Swap Spread	Absolute Quarterly Change	0
	USHYSPRD	US High Yield Bond Spread	Absolute Quarterly Change	0
	EMBISPRD	Emerging Market Bond Index Spread	Absolute Quarterly Change	0
Economics	SABAL	SA Budget Balance (as % GDP)	Absolute Quarterly Change	1
	SACURRACC	SA Current Account Deficit (as % GDP)	Absolute Quarterly Change	1
	SACORECPI	SA Core Inflation	Quarterly Percentage Change	1
	SAGDP	SA Real GDP	Quarterly Percentage Change	1
	USGDP	US Real GDP	Quarterly Percentage Change	1

**Table 45** – Definitions of bond, currency, commodity, equity, volatility, credit spread, and economic indicators used to find correlations of top and bottom S-AFR, S-DOM, S-DEF, B-AFR, B-DOM and B-DEF factors using quarterly data. Source: Bloomberg and IRESS data.

In Figure 17, we see the top S-AFR and S-DOM factors are positively correlated to equity, bond, commodity and economic indicators, negative correlations to spread and volatility indicators and are both uncorrelated to currencies. The bottom S-AFR and S-DOM factors are negatively correlated to bond, equity, commodity, currency and economic indicators, with positive correlations to volatility and spread indicators. The top and bottom S-DEF factors also exhibit positive correlations to bond, commodity, equity and economic indicators, and negative correlations to volatility and spread indicators with the top S-DEF factor having relatively weaker negative correlation to volatility and spread indicators.



**Figure 17** – Bar charts depicting the correlation between the top (left chart) and bottom (right chart) S-AFR, S-DOM and S-DEF factors relative to several economic, credit spread, volatility, equity, commodity, currency, and bond indicators using quarterly data from January 2001 until July 2024. Source Data: IRESS and Bloomberg.

Figure 17 and Figure 18 classify the relative correlation strength of the bond, currency, commodity, equity, volatility, credit spread, and economic indicators to the top and bottom S-AFR, S-DOM and S-DEF, B-AFR, B-DOM and B-DEF factors respectively. We classify correlations greater than +20% or less than -20% as strongly positive or strongly negative respectively. Correlations between +10 and +20% are classified as weakly positive, and correlations between -10 and -20% as weakly negative, whilst correlations between -10% and +10% are classified as none, due to their relatively weak relationships.

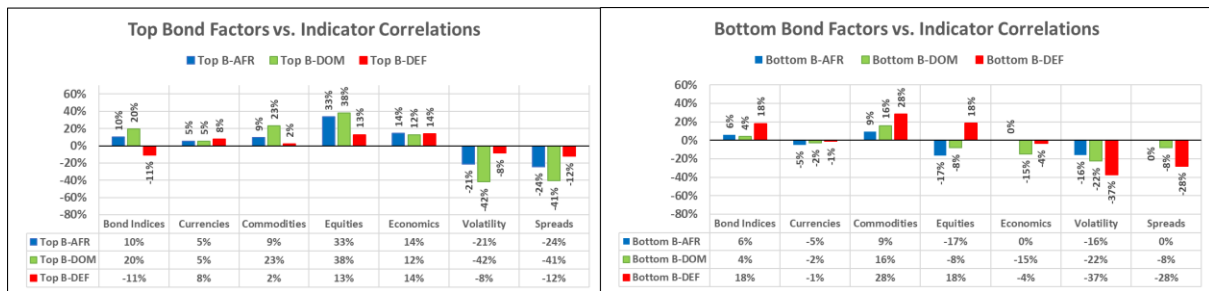
	Top Swap Factors			Bottom Swap Factors		
	S-AFR	S-DOM	S-DEF	S-AFR	S-DOM	S-DEF
<b>Bond Indices</b>	Strong +ve	Strong +ve	None	None	None	Weak +ve
<b>Currencies</b>	None	None	None	None	Weak -ve	None
<b>Commodities</b>	Strong +ve	Weak +ve	Weak +ve	Weak -ve	Weak -ve	None
<b>Equities</b>	Weak +ve	Weak +ve	None	Strong -ve	Weak -ve	Weak +ve
<b>Economics</b>	Strong +ve	Weak +ve	None	None	None	None
<b>Volatility</b>	Weak -ve	Weak -ve	None	None	None	Weak -ve
<b>Spreads</b>	Strong -ve	Strong -ve	None	Weak +ve	None	Weak -ve

**Table 46** – Classifies the relative correlation strength of the bond, currency, commodity, equity, volatility, credit spread, and economic indicators to the top and bottom S-AFR, S-DOM and S-DEF factors using quarterly data from January 2001 until July 2024. Source: Bloomberg and IRESS data.

For the swap factors in Table 46, the strongest positive correlations relative to the indicators (defined as greater than +20%) are found between the top S-AFR and S-DOM factors relative to the bond indicators, and the top S-AFR factor relative to the commodity and economic indicators. The strongest negative correlations relative to the indicators (defined as less than -20%) are found between the top S-AFR and S-DOM factors relative to the spread indicators, and the bottom S-AFR factor relative to the equity indicator.

## 10.2 Bond Butterfly Factors versus Indicators

In Figure 18, the top B-AFR, B-DOM and B-DEF factors demonstrate positive correlations to equity, commodity, currency and economic indicators, and negative correlations to volatility and spread indicators. The bottom B-AFR and B-DOM factors show negative correlations to equity, volatility, spreads and economic indicators, with positive correlations to bond and commodity indices. The bottom B-DEF factor displays positive correlations to bond, commodity and equity indicators and negative correlations to currency, volatility, spread and economic indicators.



**Figure 18** – Bar charts depicting the correlation between the top (left chart) and bottom (right chart) B-AFR, B-DOM and B-DEF factors relative to several economic, credit spread, volatility, equity, commodity, currency, and bond indicators using quarterly data from January 2001 until July 2024. Source Data: IRESS and Bloomberg.

For the bond factors in Table 47, the strongest positive correlations (defined as greater than +20%) relative to the indicators are found between the top B-AFR and B-DOM factors relative to the equity indicators, and the top B-DOM and bottom B-DEF factors relative to the commodity indicators. The strongest negative correlations (defined as less than -20%) relative to the indicators are found between the top B-AFR, top B-DOM and bottom B-DEF factors relative to the volatility and spread indicators, and the bottom B-DOM relative to the volatility indicators.

	Top Bond Factors			Bottom Bond Factors		
	B-AFR	B-DOM	B-DEF	B-AFR	B-DOM	B-DEF
<b>Bond Indices</b>	None	Weak +ve	Weak -ve	None	None	Weak +ve
<b>Currencies</b>	None	None	None	None	None	None
<b>Commodities</b>	None	Strong +ve	None	None	Weak +ve	Strong +ve
<b>Equities</b>	Strong +ve	Strong +ve	Weak +ve	Weak -ve	None	Weak +ve
<b>Economics</b>	Weak +ve	Weak +ve	Weak +ve	None	Weak -ve	None
<b>Volatility</b>	Strong -ve	Strong -ve	None	Weak -ve	Strong -ve	Strong -ve
<b>Spreads</b>	Strong -ve	Strong -ve	Weak -ve	None	None	Strong -ve

**Table 47** – Classifies the relative correlation strength of the bond, currency, commodity, equity, volatility, credit spread, and economic indicators to the top and bottom B-AFR, B-DOM and B-DEF factors using quarterly data from January 2001 until July 2024. Source: Bloomberg and IRESS data.

### 10.3 Significant Findings of Butterfly Factors versus Indicators

Displaying positive correlations to bond, currency, equity, commodity and economic indicators and negative correlations to volatility and spreads suggests that investors have increased risk tolerance. These conditions are characterised by a strong ZAR exchange rate, declining South African sovereign bond yields, low global volatility and credit spreads, and positive local and global growth, which supports rising commodity prices and South Africa’s fiscal stability. Contrary to this, investors risk tolerance reduces during increased volatility and/or widening

credit spreads, declining bond, equity, commodity and currency returns and weakening economic indicators. Comparing the factor correlations to all the indicators we see that the top S-AFR, S-DOM, B-AFR and B-DOM factors suggest outperformance during increased investor risk tolerances which generally occur under bull steepening, bull flattening, and steep twists, typical of risk-seeking behaviour. The top S-DEF and B-DEF, and bottom S-DEF and B-DEF factors also display outperformance during increased investor risk tolerances but with relatively lower sensitivity given the factors weakly positive correlations which suggests a conservative element. The bottom S-AFR and S-DOM factors illustrate a defensive nature and are likely to outperform during decreased investor risk tolerance such as bear steepening, bear flattening and flat twists. The bottom B-AFR and B-DOM factors maintain relatively greater sensitivity to decreased investor risk tolerances given the factors stronger negative correlations to volatility and spread indicators.

The defensive nature of the bottom S-AFR and S-DOM factors offer relatively better capital protection during decreasing investor risk tolerances compared to the other factors, albeit with lower long-term returns. Conversely, investors with higher risk appetite may prefer the top S-AFR, S-DOM, B-AFR and B-DOM factors, which offer greater upside potential at the expense of reduced capital protection during decreased investor risk tolerances.

Additionally, all the swap and bond factors, except the top S-DEF and B-DEF factors exhibit negative correlations with the South African budget. This may be attributed to the relationship between the budget deficit and the yield curve, as the budget deficit improves (becoming less negative), reduced government borrowing requirements lead to a flattening of the curve, with long-dated bonds outperforming medium-dated bonds. The top S-DEF and B-DEF factors display positive correlation to the South African budget implying that a wider budget deficit would increase the government's borrowing requirement leading to a steepening of the yield curve and outperformance of the top S-DEF and B-DEF factors.

As can be seen, understanding the financial and economic relation of each swap and bond factor and by identifying changing investor risk tolerances based on an active investment process will assist in successful tactical swap and bond factor selection and improved returns. The Chartered Financial Institute (CFA 2022) discusses how tactical asset allocation involves adjusting portfolio weights based on expected performance, thereby establishing active risk and potential return. According to the MSCI (2020) factor-based strategies can be used to guide tactical asset allocation decisions between bonds and cash and help manage interest rate risk.

## Conclusion:

1. Positive correlations with assets like bonds, equities, and commodities indicate higher risk tolerance, while negative correlations with volatility and spreads signal risk aversion.
2. The top S-AFR, S-DOM, B-AFR, B-DOM factors outperform in bull steepening/flattening. The bottom S-AFR, S-DOM perform better in risk-off scenarios (bear steepening/flattening).
3. Negative correlations are observed between most factors and the SA budget deficit, implying that an improving deficit flattens the curve.
4. The top S-DEF and B-DEF factors favour steepening yield curves with wider deficits.
5. Tactical allocation based on risk tolerance and factor performance improves returns, whilst factor strategies guide bond/cash allocations and interest rate risk management.



# Chapter 11



## Chapter 11 – Summarised Chapter Conclusions

*"You can't predict. You can prepare." - Howard Marks (Investor and Author)*

### Objectives:

- Summarises the key findings, emphasising the superior performance of top-ranked swap and bond factors, particularly the all-factor rank (AFR) approach.
- Reiterates the importance of incorporating trade costs in the evaluation of butterfly strategies.
- Proposes future research such as rebalancing frequencies, exploration of optimisation techniques and incorporation of macroeconomic variables into factor models.
- Highlights insights into the drivers of factor performance and potential signals for tactical allocation decisions.
- Stresses the importance of integrating factor analysis with macroeconomic and financial market insights for effective portfolio management.

This thesis investigates the dynamics of sovereign yield curves in emerging and developed markets, analysing the frequency of parallel and non-parallel shifts and their underlying causes. Non-parallel shifts were shown to be more prevalent in EM countries due to higher political and economic risks, greater volatility, and increased risk-off betas. Parallel shifts do coincide between emerging and developed markets, but their correlation is low (18%), influenced by proximity to economic hubs (e.g., MEX to the US, POL to Europe). Since 2009, both EM and DM have experienced frequent rate-cutting cycles, with bull flattening and bear steepening as common 2nd order scenarios, and positive convexity dominating 3rd order scenarios for DM countries.

We back-tested a long butterfly strategy (2v5v10) from June 2007 to July 2024 on several EM and DM countries which revealed that steeper slopes and increased curvature correlated to higher returns. EM countries like SA demonstrated strong returns due to steep slopes and positive curvature, whilst ITL outperformed among DM countries with similar characteristics.

Conversely, TRL and JPN underperformed due to inverted and flat curves caused by inconsistent or loose monetary policies respectively. Volatility in slope and curvature changes amplified opportunities for capturing non-parallel risk premia, benefiting countries like ITL, the US, GER, SA, POL, and BRA, while TRL suffered due to extreme policies and political risks. Inflation volatility was also seen to positively impact returns, as it necessitates aggressive monetary and fiscal adjustments. However, the effects differ by country: SA benefits from a credible central bank, while TRL suffers from inverted curves and unconventional policies.

To quantify monetary and fiscal policy impact, policy scores were created (excluding TRL due to extreme policies). Using these policy scores we observed that EM countries generally exhibited tighter monetary and fiscal policies compared to DM countries, reflecting higher real rates to control inflation and lower debt levels. DM countries, benefitted from their reserve currencies status by increasing debt levels resulting in relatively looser fiscal policies. Post-COVID-19, global inflation surged necessitating tighter policies across both EM and DM countries.

Our findings indicated that countries with divergent monetary and fiscal policies offered higher return potential, while those with complementary policies required tactical butterfly strategies. For EM countries, SA and BRA provided optimal policy alignments for long butterfly strategies, whereas TRL's loose monetary and tight fiscal policies favour short butterfly strategies. Among DM countries, ITL favoured long butterfly strategies, but most DM countries benefitted from tactical allocations between long and short butterfly strategies.

Having identified SA as an opportune market to extract non-parallel risk premia, we went on to define ten swap and bond butterfly factors using monthly SA swap rates and bond yields from January 2001 to July 2024 and back-tested a long butterfly investment strategy. According to the results, the top S-AFR and B- AFR factors had the best performance over the period with gross annualised returns of 1.8% and 1.5% respectively whilst the bottom S- AFR and B- AFR factors had the lowest annualised gross returns of -1.5% and -0.7%. Thus, the top AFR's outperform the bottom AFR's in both the SA swap and bond markets with the following attractive butterfly characteristics: high absolute spreads and risk premiums, large positive NSS differences, high carry and roll, wide spreads over US swaps, recent underperformance over the past month offering upside potential, and very low net term spreads and convexities. These are also the characteristics of the top S-DOM and B-DOM factors with the only difference being that the top S-DOM and B-DOM have butterfly strategies with much wider wingspans. Wider wingspans mean that the right wing of the butterfly strategy is positioned in a much

longer-dated bond relative to the AFR's, resulting in greater upside but also greater downside potential. The absolute returns and risk statistics (maximum drawdown, CVaR, omega, skew and kurtosis) of the top S- AFR, B- AFR, S-DOM and B-DOM factors are also relatively better than the corresponding bottom S- AFR, B- AFR, S-DOM and B-DOM factors. Taking a long butterfly position in the top AFR's and DOM's and a short butterfly position in the bottom AFR's and DOM's has resulted in impressive returns with the top less bottom AFR's being the outperformer due to improved diversification that balance upside and downside risks. Thus, we showed that non-parallel risk premia does exist in the South African interest rate market suggesting a weak or semi-strong EMH backdrop.

The top S-DEF and B-DEF factors have net term spreads and convexities close to zero with low carry and roll, absolute spreads and risk premiums which indicates that their butterfly points are relatively close together. This reduces their expected return and risk profile, thus they produce low absolute returns but attractive risk-adjusted returns due to their low volatility. The bottom S-DEF and B-DEF factors have very low net term spreads and convexities but relatively higher carry and roll, absolute spreads and risk premiums which increases their risk profile relative to the top S-DEF and B-DEF factors and allows for higher absolute but lower risk-adjusted returns. In contrast, the top S-DOM and B-DOM factors have high carry and roll, absolute spreads, risk premiums, net terms spreads and convexity resulting in high absolute returns but also the possibility of relatively larger drawdowns.

We then analysed the gross monthly returns for the all the swap and bond butterfly factors during interest rate cycles and 1st, 2nd and 3rd order curve scenarios. We showed that both swap and bond factors outperformed during bullish rate environments (more so for the AFR and DOM factors relative to the DEF factors) such as parallel down, bull flattening, steep and flat twists, and positive convexity. This was further confirmed when we compared the correlations of several financial and economic indicators to the swap and bond factor performances. Comparing the swap and bond factor correlations to the indicators we see that the top S-AFR, S-DOM, B-AFR and B-DOM factors outperform during increased investor risk tolerances. The top S-DEF and B-DEF, and bottom S-DEF and B-DEF factors also display outperformance during increased investor risk tolerances but with relatively lower sensitivity given the factors weakly positive correlations to the indicators. The bottom S-AFR, B-AFR, S-DOM and B-DOM factors illustrated a defensive nature and were likely to outperform during decreased investor risk tolerance. This suggests that risk-on environments would result in the top swap and bond factors outperforming whilst the bottom factors would outperform during

risk-off environments. In fact, when we assessed the gross monthly returns of the swap and bond factors during major global risk-off events, we found that the opposite occurred in that the top swap and bond factors outperformed the bottom swap and bond factors. This is contradictory but a plausible explanation could be that the bottom swap and bond factors outperform the top swap and bond factors during the initial risk-off environment, but if the risk-off environment persists for several months/years the attractive characteristics of the top factors emerges (i.e. high carry and roll, compression in risk premiums and a reversion in cheap valuations). Thus, despite the short-term underperformance, the top swap and bond factors will still outperform the bottom swap and bond factors as time passes.

In future it is difficult to assume that bull flattening, bull and bear steepening will continue to be the most common curve scenarios as level, slope and curvature changes are a function of the macroeconomic, business and consumer cycles. Having a robust investment process will help identify which curve scenarios are more likely and assist in the correct factor selection. However, we do know that over the long-term and under various curve scenarios the performance of the top S-DOM and B-DOM factors is persistently positive with attractive risk-adjusted returns. Thus, utilising the top S-DOM and B-DOM factors as a core strategy and fine-tuning factor allocations in a tactical manner based on an investment view and manager skill would be a practical investment strategy.

A critical aspect of butterfly strategies are trade costs. As described in chapters 5.8 Incorporating Trade Costs into the Butterfly Weight Scheme Strategies, 6.3 Describing Butterfly Trade Costs and Chapter 8 - Rebalancing Frequencies, trade costs can be significant and if we take the average spread duration of the top S-DOM and B-DOM factors over the period to be 7 and each roundtrip trade cost to be 1bp in spread, total annualised trade costs with monthly rebalancing can be 0.84% which is sizeable. From a practical standpoint it makes sense to review the frequency of rebalancing, maintaining healthy relationships with service providers for efficient trading and ensuring sufficient market liquidity before executing trades. This is easier said than done but practical risks that need to be managed to ensure meaningful returns.

To extend this research and possibly improve results further, predicting curve scenarios based on VAR (vector auto regressive) processes and lagged economic variables as in Audrino and Serwart (2022), Fabozzi et al (2005), Pal (2007), Morita and Bueno (2008) and Patel et al (2018) would be a valuable next step. Fabozzi et al (2005) do mention that US slope and curvature factors are mean reverting so utilising butterfly strategies and exploiting these risks

has potential value. Audrino and Serwart (2022) use VAR models with macro sentiment data to predict changes in the yield curve and find that inflation sentiment data to be useful in predicting curvature changes. The swap butterfly risk premia could also be applied to other interest rate markets (both bond and interest rate swaps) to test if it is a universal process.

In conclusion, effective extraction of non-parallel risk premia required understanding monetary and fiscal regimes. While passive long or short butterfly strategies can be profitable under certain conditions, tactical strategies are crucial in others. Careful and pragmatic management of trading costs and rebalancing frequencies is also essential to ensure meaningful net returns.

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## Appendix A

Table A1 and Table A2 provide a summary of key years when the proportion of non-parallel shifts increased in frequency relative to their historic norms in EM and DM countries respectively with idiosyncratic and systemic explanations of what occurred during the period.

### Major Idiosyncratic and Systemic Events of Emerging Markets

**Table A1** - Summary of the calendar years of major idiosyncratic and systemic events of emerging markets where non-parallel shifts increased in frequency relative to their historic norms.

Emerging Markets	Year	Idiosyncratic Risks	Systemic Risks
Indonesia	2006	Political uncertainty and corruption issues, such as scandals involving government officials.	Rising global commodity prices, particularly oil, creating inflationary pressures and tightening monetary policies globally.
	2007	Political instability due to regional conflicts and changes in regulatory frameworks affecting investment sentiment.	Early signs of global financial turmoil, increased volatility in capital flows.
	2011	Localised natural disasters impacting agriculture and infrastructure, such as earthquakes and volcanic eruptions.	Eurozone crisis impacting global markets.
	2018/19	Trade tensions with major partners, currency depreciation, and domestic political uncertainties ahead of elections.	Global trade wars, particularly between the US and China, and a slowing Chinese economy impacting global trade flows and market sentiment.
	2020	COVID-19 Response: Lockdowns, reduced consumer spending, and tourism decline.	Pandemic: Global economic shutdown, capital outflows, and recession.
	2021	Vaccination Rollout: Slow pace impacting recovery. Domestic Policies: Ongoing fiscal and monetary measures.	Pandemic: Continued impact and global supply chain issues.
	2022	Economic Recovery: Inflation pressures, balancing growth and stability. Pre-election uncertainties.	Global Inflation: Rising prices globally. Geopolitical: Ukraine–Russia conflict.
	2023	Political Dynamics: Approaching elections, structural reform challenges.	Global Economic Uncertainty: Slowdown risks, tightening financial conditions.
South Africa	1992	End of apartheid leading to significant political and economic restructuring and uncertainty.	Global recession and high global interest rates affecting emerging markets.
	1994	First South African democratic elections creating uncertainty and market volatility.	Emerging market crises affecting investor sentiment globally.
	2000	Political uncertainties, economic policy changes.	Dot-com bubble burst, global economic impact.
	2004	Political stability, economic reform measures.	Global economic recovery post-2001 recession but rising oil prices affecting emerging markets.
	2009	Domestic economic recovery efforts, Jacob Zuma elected president after Arms deal and financial corruption charges withdrawn.	Global financial crisis aftermath, global recession.
	2010	Labour strikes, particularly in the mining sector, and ongoing political instability.	Global economic recovery, European debt crisis.
	2017	Cyril Ramaphosa elected ANC leader and incoming South African president.	UK snap election and initiation of Brexit. Donald Trump elected US president.
	2021	COVID-19 vaccination efforts, civil unrest and riots, particularly in July, along with ongoing energy supply issues and political uncertainties.	Ongoing pandemic impact, global supply chain issues causing inflationary pressures.
	2022	High inflation, economic policy uncertainty, and concerns about government fiscal stability.	Global inflation, geopolitical tensions (Ukraine–Russia conflict), tightening global financial conditions.
Mexico	2010	Escalating drug-related violence, political uncertainty, and economic reforms.	Uneven global economic recovery, the European debt crisis, and volatility in commodity prices.
	2014	Reforms in energy and telecommunications sectors causing short-term uncertainties and adjustments.	Global oil price decline affecting revenues and economic stability, emerging market volatility.

	2016	Corruption scandals involving high-level government officials and political instability.	US election impact, heightened trade tensions, global economic uncertainty.
	2017	Impact of a significant earthquake, NAFTA renegotiation concerns affecting trade relations with the US and Canada.	Continued global trade tensions and vulnerabilities in emerging markets affecting investor sentiment.
	2020–22	The COVID-19 pandemic causing economic recession, health crises, and policy changes impacting business environments.	The global pandemic leading to economic shutdowns, supply chain disruptions, and geopolitical tensions affecting global markets.
India	2000/01	Slow economic reforms, political instability, and the Kargil conflict with Pakistan creating uncertainty.	The dot-com bubble burst leading to a global economic slowdown and market volatility.
	2003	Banking sector weaknesses and slow industrial growth impacting investor confidence.	Global economic recovery concerns and the impact of the SARS outbreak on markets.
	2006	High inflation, political corruption, and controversies such as the telecom scandal affecting market stability.	Rising global commodity prices and monetary tightening policies globally impacting markets.
	2010	High inflation, numerous corruption scandals (e.g., Commonwealth Games scam), and policy paralysis affecting economic growth.	The Eurozone crisis causing global market volatility and economic uncertainty.
	2018	Non-performing assets in the banking sector, political instability, and policy changes such as the implementation of GST.	Trade wars and global economic slowdown affecting markets and investment flows.
	2020–23	COVID-19 pandemic impact causing economic disruptions, health crises, and policy uncertainties.	The global pandemic leading to economic shutdowns, supply chain disruptions, rising inflation, and geopolitical tensions affecting global markets.
China	2007	Stock market bubble and subsequent crash, concerns about the overheating of the economy.	Global financial instability and the beginning of the global financial crisis impacting markets worldwide.
	2010	Housing market concerns, tightening of monetary policy to curb inflation, and regulatory crackdowns.	Global economic recovery uncertainty and the Eurozone crisis impacting global trade and investment flows.
	2016–18	Economic slowdown, trade war with the US leading to tariffs and trade barriers, and regulatory crackdowns on industries.	Global trade tensions (US and China), economic slowdown, and uncertainties affecting global markets.
	2020	COVID-19 impact, domestic lockdown measures.	Global COVID-19 pandemic, global recession.
	2023	Regulatory changes affecting technology and education sectors, geopolitical tensions with the US and other countries.	Global inflation, economic slowdown, and geopolitical tensions like the Ukraine-Russia conflict impacting markets.
Turkey	2008	Political instability, economic imbalances, and concerns about government policies.	The global financial crisis leading to economic downturns and market volatility worldwide.
	2010–12	High inflation, political instability, and concerns about government intervention in the economy.	The Eurozone crisis and global economic uncertainty impacting investor sentiment and capital flows.
	2015–19	Political instability, a failed coup attempt in 2016, economic mismanagement, and high inflation.	Global economic slowdown, regional geopolitical tensions, and emerging market vulnerabilities.
	2020–23	COVID-19 pandemic causing economic disruptions, high inflation, currency depreciation, and political instability.	The global pandemic causing economic shutdowns, supply chain disruptions, rising inflation, and geopolitical tensions affecting global markets.
Brazil	2012–14	Corruption scandals, economic slowdown, high inflation, and political instability affecting investor confidence.	Decline in global commodity prices impacting export revenues and economic stability.
	2018	Political uncertainty due to elections and corruption investigations, economic mismanagement.	Global trade tensions and vulnerabilities in emerging markets impacting investment flows.
	2020	COVID-19 pandemic causing severe economic recession, health crisis, and policy uncertainty.	The global pandemic leading to economic shutdowns and a severe global recession.
Poland	2001	Shifts in political leadership and new economic policies created uncertainty among investors.	The global economy slowed down following the dot-com bubble burst, impacting Poland's economic growth.
	2002	Continued economic reforms and political instability led to market concerns.	The global economic environment remained unstable after the 9/11 attacks, affecting investor confidence.
	2004	Poland's accession to the EU brought significant economic adjustments and policy changes, causing initial uncertainty.	Rising oil prices and geopolitical tensions affected global inflation and economic stability.
	2005	Ongoing political instability and uncertain economic policies created a volatile market environment.	Continued global economic concerns, including rising oil prices, influenced market sentiment.
	2006	Economic reforms and political instability continued to affect investor confidence.	A period of global economic growth driven by increased trade and investment influenced Poland's economy positively.
	2009	The global financial crisis led to economic slowdown and necessary policy adjustments in Poland.	The aftermath of the global financial crisis and the European debt crisis created widespread economic instability.

	2010	Poland focused on policy adjustments to sustain economic growth amid a challenging environment.	The European debt crisis raised concerns about financial stability in the region.
	2011	Policy changes and political uncertainties influenced market dynamics.	The global economic environment slowed, with the Eurozone crisis impacting markets.
	2012	Poland faced economic slowdown and implemented policy responses to maintain growth.	Ongoing global economic uncertainty, particularly due to the Eurozone crisis, affected market sentiment.
	2014	Political changes and new economic policies created a challenging market environment.	The recovery from the European debt crisis and geopolitical tensions, notably in Ukraine, influenced market stability.
	2016–17	Political instability, judicial reforms causing concerns about the rule of law, and economic policy shifts.	Global economic slowdown, trade tensions, and uncertainties affecting emerging markets.
	2020	COVID-19 Pandemic Impact: The pandemic led to domestic lockdowns and significant economic disruptions.	The COVID-19 pandemic caused widespread economic disruptions and supply chain issues globally.
	2022	Poland faced challenges in economic recovery and inflation pressures.	Rising global inflation and geopolitical tensions, particularly the Ukraine–Russia conflict, caused market volatility.
	2024	Ongoing economic policy changes and political uncertainties affected market conditions.	A global economic slowdown and tightening financial conditions due to rising interest rates influenced markets.

## Major Idiosyncratic and Systemic Events of Developed Markets

**Table A2** - Summary of the calendar years of major idiosyncratic and systemic events of developed markets where non-parallel shifts increased in frequency relative to their historic norms.

Developed Market	Year	Idiosyncratic Risks	Systemic Risks
France	1998	Domestic political instability, strikes, and labour protests over pension reforms.	Asian financial crisis leading to global market volatility, Russian debt default impacting emerging markets.
	2000–01	Economic policy adjustments, domestic reforms creating uncertainty and an economic slowdown.	Dot-com bubble burst, causing significant declines in technology stocks and broader market turbulence. 9/11 attacks causing global shock, subsequent global economic slowdown.
	2009–10	Economic recession due to global financial crisis, domestic policy measures to combat downturn, pension reform protests leading to public unrest.	Global financial crisis aftermath, European debt crisis causing widespread economic instability.
	2014	Economic stagnation, high unemployment affecting consumer spending and business investments.	European recovery from debt crisis, geopolitical tensions influencing market sentiment.
	2018–19	Yellow vest protests, economic reforms creating domestic instability and market volatility.	Global economic slowdown, trade tensions between US and China impacting global trade.
	2021	COVID-19 recovery efforts, vaccination rollout challenges, policy adjustments.	Ongoing pandemic impact, global supply chain disruptions causing economic uncertainty.
Germany	1997–98	Domestic political and economic challenges, reunification impact on fiscal policies.	Asian financial crisis causing global economic instability, Russian debt default, LTCM crisis causing global market turbulence.
	2000–01	Economic slowdown, policy reforms impacting business confidence.	Dot-com bubble burst leading to significant declines in technology stocks. 9/11 attacks causing global economic shock and market volatility.
	2005	Political instability, economic reforms causing uncertainty in business environment.	Global economic uncertainty, rising oil prices impacting global inflation.
	2008–09	German banks faced significant challenges during the global financial crisis, leading to a domestic recession.	Global financial crisis causing severe economic downturn, European debt crisis causing widespread economic instability.
	2015	Volkswagen emissions scandal affecting corporate confidence, economic policy adjustments.	Global economic slowdown, Greek debt crisis impacting European financial stability.
	2019	Economic slowdown, manufacturing sector downturn impacting overall economic growth.	Global economic slowdown, trade tensions between US and China.
Japan	1993	Economic stagnation, banking sector issues leading to financial instability.	Global economic slowdown following Gulf War and oil price spike, affecting export-driven economies.
	1996–97	Banking crisis, domestic economic policies aimed at recovery.	Asian financial crisis causing regional economic instability.
	2000	Economic policy adjustments, banking sector restructuring affecting financial stability.	Dot-com bubble burst causing global market turbulence.

	2002–03	Deflation, continued banking sector problems leading to financial instability.	Global economic uncertainty, recovery from dot-com bubble burst. SARS outbreak impacting global economic activity.
	2006–07	Economic recovery, structural reforms improving domestic economic conditions. Political instability, economic policy concerns leading to market uncertainty.	Global economic boom driving increased trade and investment. Early signs of global financial turmoil, US subprime mortgage crisis beginning to unfold.
	2010–12	Economic stagnation, policy adjustments aimed at stimulating growth and combating deflation.	Global economic recovery, European debt crisis causing concerns about financial stability.
	2014–16	Abenomics, economic policy adjustments aimed at stimulating growth.	Global economic uncertainty, oil price volatility impacting global markets.
	2018–20	Trade tensions, economic slowdown due to global trade conflicts.	US-China trade war, global economic slowdown, COVID-19 pandemic causing significant market disruptions.
	2022–23	COVID-19 impact, supply chain issues leading to economic challenges, political stability concerns.	Global inflation, geopolitical tensions (Ukraine–Russia conflict) causing market volatility, tightening global financial conditions due to rising interest rates.
UK	1993	Maastricht Treaty aimed at European integration and a unified currency, welfare reforms, labour disputes in transport and public services sectors.	Global economic slowdown affecting domestic economy.
	1998–2001	Strong pound depressed UK exports specially manufacturing, BOE granted operational independence in 1997 impacting monetary policies and business confidence. Pension fund deficits, foot and mouth disease impacting agriculture and election uncertainty.	Asian financial crisis, Russian debt default, Dot-com bubble burst, 9/11 attacks causing global instability.
	2007	The onset of the global financial crisis hit UK banks hard, leading to economic policy challenges.	The global financial crisis began to spread globally, affecting the UK.
	2010–12	Economic recovery, austerity measures affecting public spending, economic stagnation and double-dip recession fears.	Global economic recovery, European debt crisis impacting financial stability and creating volatility.
	2014–15	Scottish independence referendum creating political uncertainty, economic policy concerns, Brexit uncertainties causing market instability.	European recovery, geopolitical tensions (Ukraine crisis) influencing market sentiment. Global economic slowdown, Greek debt crisis impacting European financial stability.
	2018–23	Brexit transitions, leadership concerns with Conservative Party, 2019 elections, cost of living crisis, economic policy adjustments creating uncertainty in business environment.	US-China trade war, global economic slowdown, COVID-19 pandemic, global inflation, geopolitical tensions.
Canada	1999–2001	Economic policy adjustments, volatile currency and managing public debt.	9/11 attacks, dot-com bubble burst, global economic slowdown causing market instability.
	2004–05	High dependence on the energy sector whilst manufacturing exports struggled from a strong currency.	Global economic uncertainty, rising oil prices impacting global inflation.
	2008	Economic recession due to global financial crisis, policy responses to combat downturn.	Global financial crisis causing widespread economic instability.
	2011	The European debt crisis affected global demand, impacting Canada’s export-driven economy. Housing market bubble, fiscal austerity, fluctuating commodity prices.	Global economic uncertainty, Eurozone crisis impacting global markets.
	2015	Commodity price decline affecting resource-dependent economy, diversifying into technology and manufacturing, new government under Justin Trudeau.	Global economic slowdown, oil price volatility impacting global markets.
	2021–22	COVID-19 recovery efforts, vaccination rollout challenges impacting economic recovery, inflation pressures due to supply chain disruptions, extreme weather and green energy transition.	Ongoing pandemic impact, global supply chain disruptions causing economic uncertainty, geopolitical tensions (Ukraine–Russia conflict) causing market volatility.
US	1991–93	Economic recession, President Bush ousted by President Clinton, President Clinton’s administration pushing for healthcare reforms, high fiscal deficits.	Gulf War causing global economic uncertainty and slowdown.
	1997–98	LTCM crisis required federal intervention, policy adjustments aimed at controlling inflation. Corporate scandals affecting market confidence.	Asian financial crisis causing global market volatility. Russian debt default, LTCM crisis causing global market turbulence.
	2000–02	9/11 attacks, dot-com bubble burst causing recession and loose monetary and fiscal policies.	9/11 attacks, dot-com bubble burst causing significant declines in technology stocks.
	2008–10	The housing market collapse and banking sector failures led to a severe economic downturn.	Global financial crisis, European debt crisis impacting financial stability.
	2012	Political changes, concerns over budgetary and fiscal issues created significant market uncertainty.	Global economic uncertainty, Eurozone crisis causing market volatility.
	2014	Obamacare, Affordable Care Act, widening income inequality.	Global economic recovery, geopolitical tensions (Ukraine crisis) influencing market sentiment.
	2019–23	Trade policy uncertainties between the US and China affecting business confidence, supply disruptions elevating	COVID-19, global economic slowdown, trade tensions between major economies, supply chain disruptions, geopolitical tensions

		inflation, political instability during 2020 elections following President Trump's victory.	(Ukraine–Russia conflict), tightening global financial conditions due to rising interest rates.
<b>Australia</b>	<b>2000</b>	GST introduction caused confusion, high spending for Sydney 2000 Olympics and long-term financial impact.	Dot-com bubble burst causing global market turbulence, Asian financial crisis effects.
	<b>2003–05</b>	Severe drought impacting agriculture and water supply, housing affordability issues given rising prices.	Global economic recovery driving increased trade and investment.
	<b>2008</b>	The global financial crisis led to significant challenges for Australian banks and a recession.	Global financial crisis causing widespread economic instability.
	<b>2011</b>	The European debt crisis affected global demand, impacting Australia's export-driven economy. Severe natural disasters required significant government expenditure, introduction of carbon tax.	Global economic uncertainty, Eurozone crisis impacting global markets.
	<b>2013–14</b>	Frequent political changes, economic reforms to diversify economy away from resources, housing affordability challenges.	Global economic uncertainty and trade tensions impacting business confidence.
	<b>2016–17</b>	Housing affordability concerns and speculation, immigration growth increasing infrastructure and social costs, energy grid reliability.	Global economic uncertainty, oil price volatility impacting market stability, trade tensions between major economies.
	<b>2019–21</b>	Economic slowdown/recession due to global trade conflicts and COVID-19 pandemic, renewable energy debates.	Global economic slowdown, trade tensions, COVID-19 pandemic causing significant market disruptions.
<b>Italy</b>	<b>2000–02</b>	Several corporate scandals that undermined investor confidence. Banking sector vulnerabilities due to slow economic growth and weak regulatory oversight. Transition to Euro with new monetary and fiscal policy adjustments.	The aftermath of the dot-com bubble burst and the economic shock from the 9/11 attacks led to a global economic slowdown, affecting Italy's export-driven economy.
	<b>2004–05</b>	Frequent changes in government and contentious labour and pension reforms, political instability, and high debt levels.	Rising oil prices and geopolitical tensions contributed to global inflationary pressures and economic uncertainty.
	<b>2008–10</b>	Italy faced a severe recession, significant stress in the banking sector from non-performing loans and declining asset values. High sovereign debt levels, austerity measures and political instability.	The global financial crisis led to widespread economic downturns, significantly impacting European economies, including Italy.
	<b>2014</b>	Prolonged economic stagnation and high unemployment rates eroded consumer confidence and domestic demand.	The slow recovery from the European debt crisis and geopolitical tensions, particularly the Ukraine crisis, influenced market sentiment.
	<b>2016</b>	Italy's banking sector faced significant challenges, and political instability, highlighted by the constitutional referendum, created uncertainty.	The Brexit vote led to market volatility, and a global economic slowdown exacerbated uncertainties.
	<b>2018</b>	Sergio Mattarella taking presidency from Giorgio Napolitano, ongoing banking sector problems, budget disputes with EU as Italy wanted to increase spending and reduce taxes.	Trade conflicts (US and China), and a slowing European economy affected global and local markets.
	<b>2022–23</b>	Cost of living crisis, EU recovery fund assistance, fragmented government and unclear economic policies created an uncertain investment climate.	Rising global inflation and geopolitical conflicts, notably the Ukraine–Russia conflict, contributed to market volatility.

## Appendix B

### Principal Component Analysis (PCA):

Is a statistical technique used to reduce the dimensionality of a dataset while retaining as much variance as possible. PCA transforms correlated variables into a smaller number of uncorrelated variables called principal components (PCs). The first few PCs capture most of the variability in the dataset, making PCA a powerful tool for feature extraction, dimensionality reduction, identifying patterns in large datasets, and noise reduction.

#### Key Steps in PCA

- Standardise the Data:
- Centre the data by subtracting the mean.
- Scale to have unit variance if required.

Equation 17 : Standardised Data Point

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma_j},$$

where  $x_{ij}$  is the  $i$ -th observation of variable  $j$ ,  $\bar{x}_j$  is the mean and  $\sigma_j$  is the standard deviation.

#### Compute the Covariance Matrix:

The covariance matrix  $\Sigma$  shows the relationships between variables.

Equation 18 : Covariance Matrix

$$\Sigma = \frac{1}{n-1} X^T X,$$

or when expanded is show as:

Equation 19 : Expanded Covariance Formula

$$\frac{1}{n} \sum_{i=1}^n (X_i - \mu) (X_i - \mu)^T ,$$

where  $n$  is the number of data points, and  $X$  is the vector of observations.

### Perform an Eigenvalue Decomposition:

- Solve for eigenvalues ( $\lambda$ ) and eigenvectors ( $v$ ) of the covariance matrix.

Equation 20 : Solve Eigenvectors and Eigenvalues

$$\Sigma v = \lambda v .$$

- The eigenvalues represent the variance explained by each principal component.

### Selecting Principal Components:

- Rank eigenvalues in descending order.
- The eigenvalues represent the variance explained by each principal component, so the proportion explained by the  $i$ -th principal component is:

Equation 21 : Variance Explained by Principal Components

$$\text{Variance Explained} = \frac{\lambda_i}{\sum_j \lambda_j} .$$

### Project the Data:

Transform the original data to the new basis formed by the selected principal components.

Equation 22 : Transformed Data

$$Y = XW ,$$

where  $W$  is the matrix of eigenvectors.

## Pros and Cons

### Pros:

1. *Dimensionality Reduction:* PCA reduces the number of variables in a dataset while preserving as much variance as possible which simplifies and speeds up computations.
2. *Removes Multicollinearity:* PCA transforms correlated variables into orthogonal (uncorrelated) components, improving model performance and interpretation.
3. *Data Visualisation:* PCA helps visualise high-dimensional data in lower-dimensional spaces, making it easier to identify patterns and clusters.
4. *Noise Reduction:* PCA captures the most significant variations in data, often filtering out noise and irrelevant details.
5. *Feature Extraction:* PCA creates new features (principal components) that might capture underlying structures in the data better than the original variables.

### Cons:

1. *Loss of Interpretability:* Principal components are linear combinations of the original variables and lack direct interpretability to the original features.
2. *Assumption of Linearity:* PCA assumes that the data's variance is best captured by linear relationships, which may not always.
3. *Sensitive to Scaling:* Variables with larger magnitudes can dominate the principal components, requiring careful standardisation or normalisation.
4. *Variance Bias:* PCA focuses on maximising variance, which may not always align with the most relevant features for a specific task (e.g. classification accuracy).
5. *Data Dependency:* PCA is data-dependent, meaning the principal components derived from one dataset may not generalise well to other datasets.

## Application

1. *Finance*: identify major factors driving asset returns, aiding risk analysis and diversification, detect underlying market risks or hidden correlations between assets.
2. *Image Processing*: Compression to reduce the number of features (pixels) in image datasets, and to enhance patterns in facial recognition, and object detection.
3. *Genomics*: to identify key genetic markers or clusters.
4. *Marketing*: Reduce customer data to discover distinct customer groups and their preferences.
5. *Anomaly Detection*: Detect unusual patterns or outliers
6. *Machine Learning*: Reduce data dimensions for supervised and unsupervised learning, create meaningful features for clustering or classification.
7. *Natural Language Processing (NLP)*: Reduce the dimensionality of high-dimensional word embeddings for visualisation or further processing.

## Appendix C

### Nelson-Siegel-Svensson (NSS) Yield Curve Model:

The Nelson-Siegel-Svensson (NSS) yield curve model is an extension of the Nelson-Siegel model. Both models are widely used in finance to estimate the term structure of interest rates (yield curves) because of their flexibility and parsimonious representation. The NSS model adds two additional parameters to the Nelson Siegel (NS) model to capture a more diverse range of yield curve shapes, including multiple humps and changes in curvature. This makes it particularly useful for describing complex term structures in bond markets.

#### Model and Equation

The NSS model expresses the instantaneous forward rate  $f(t)$  or the zero-coupon yield  $y(t)$  as a function of time to maturity  $t$  using a combination of exponential decay terms and linear terms. For the zero-coupon yield curve, the NSS formula is:

Equation 23 : NSS Formula

$$y(t) = \beta_0 + \beta_1 \frac{1 - e^{-\frac{t}{\tau_1}}}{\frac{t}{\tau_1}} + \beta_2 \left( \frac{1 - e^{-\frac{t}{\tau_1}}}{\frac{t}{\tau_1}} - e^{-\frac{t}{\tau_1}} \right) + \beta_3 \left( \frac{1 - e^{-\frac{t}{\tau_2}}}{\frac{t}{\tau_2}} - e^{-\frac{t}{\tau_2}} \right),$$

where:

- $\beta_0$ : Long-term level of the yield curve, represents the asymptotic long-term interest rate as maturity approaches infinity.
- $\beta_1$ : Short-term component of the curve, captures the steepness of the yield curve, particularly the difference between short-term and long-term rates.
- $\beta_2$ : Medium-term curvature component, capturing humps in the medium-term.
- $\beta_3$ : Additional curvature component (specific to the Svensson extension), accounts for an additional degree of curvature, allowing the model to represent more complex shapes.
- $\tau_1, \tau_2$ : Decay factors that control the location and extent of the humps or twists in the curve.

## Calibration

The NSS model is calibrated to market data by estimating the parameters ( $\beta_0, \beta_1, \beta_2, \beta_3, \tau_1, \tau_2$ ) using optimisation techniques. The most common approach is to minimise the sum of squared errors (SSE) between the observed market yields and the model's predicted yields. This requires:

1. *Input data:* Market yields from zero-coupon bonds or stripped yield curves.
2. *Optimisation:* Numerical methods like non-linear least squares are used to find the best-fit parameters.
3. *Constraints:* Parameter bounds may be applied to ensure realistic and stable estimates.

## Application

The NSS model is widely used for:

1. *Yield Curve Construction:* Creating smooth yield curves from bond market data.
2. *Pricing:* Pricing fixed-income securities and derivatives.
3. *Risk Management:* Assessing interest rate risk through scenario analysis.
4. *Monetary Policy:* Evaluating term premiums and market expectations of future rates.
5. *Benchmarking:* Serving as a standard for central banks and financial institutions.

## Pros and Cons

*Pros:*

1. *Flexibility:* Can capture a variety of yield curve shapes, including monotonic, humped, and S-shaped curves.
2. *Parsimonious:* Uses a small number of parameters to represent the entire yield curve.
3. *Economic Interpretability:* Parameters have clear economic meanings related to level, slope, and curvature.
4. *Widespread Use:* Standardised and familiar to practitioners and academics.

*Cons:*

1. *Overfitting Risk:* Adding additional parameters ( $\beta_3, \tau_2$ ) increases complexity and may lead to overfitting.

2. *Numerical Challenges*: Calibration can be sensitive to initial values and may converge to local minima. () increases complexity and may lead to overfitting.
3. *Lack of No-Arbitrage Guarantee*: Does not explicitly enforce arbitrage-free conditions, which can be problematic in derivative pricing.
4. *Limited Dynamic Capability*: Not ideal for modelling the evolution of the yield curve over time without further extensions.