Master's Degree in Economics and Finance
Major in Finance

Chair of Fixed Income Credit and Derivatives

Multi-signal Based Model to Trade Duration

A Macro Hedge Fund Strategy

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Introduction

This paper is divided into three sections. In the first part we describe a set of rules for trading duration, through 10-year government bond of different countries as the point of view of a European investor. In the second part of the paper we deal the FX risk management and analyze its implications. In the last chapter we perform an analysis that tries to capture the influence of the carry trade between the Japanese yen and the Australian dollar on the main currencies movements, with the aim of producing a forecast model that performs better than the "classic" random walk.

The first part of this work aims to expand and, where possible, enhance the methodology developed by Seamus Mac Gorain in his paper *Investment Strategies No. 74: Simple Rules to Trade Duration*. In that study, the author outlines a set of straightforward systematic rules for trading duration in the 10Y government bonds of the US, Germany, Japan, and the UK.

The main lack we identify in Mac Gorain's work, which we aim to address in this paper, is the absence of geographic diversification. In an increasingly globalized context, we seek to achieve decorrelation of strategies across different geographical areas. Indeed we can easily observe in Figure 1 the similar movement that characterized the fixed income assets since the 1990s.

Additionally, we introduce new economic indicators. Specifically, we will incorporate inflation dynamics and the Leading Indicator Index, which we will discuss in more detail later. We also extend the analysis period by examining the behavior of the signals in the years following Mac Gorain's study, up to the present day. This is particularly relevant, as recent years have been marked by a bull fixed income market of Westernized economies that hasn't been seen since the early 2000s (Figure 1). The key question we aim to address is whether the macro economical curve forecast signals can predict a drastic reversal of the macro trend.

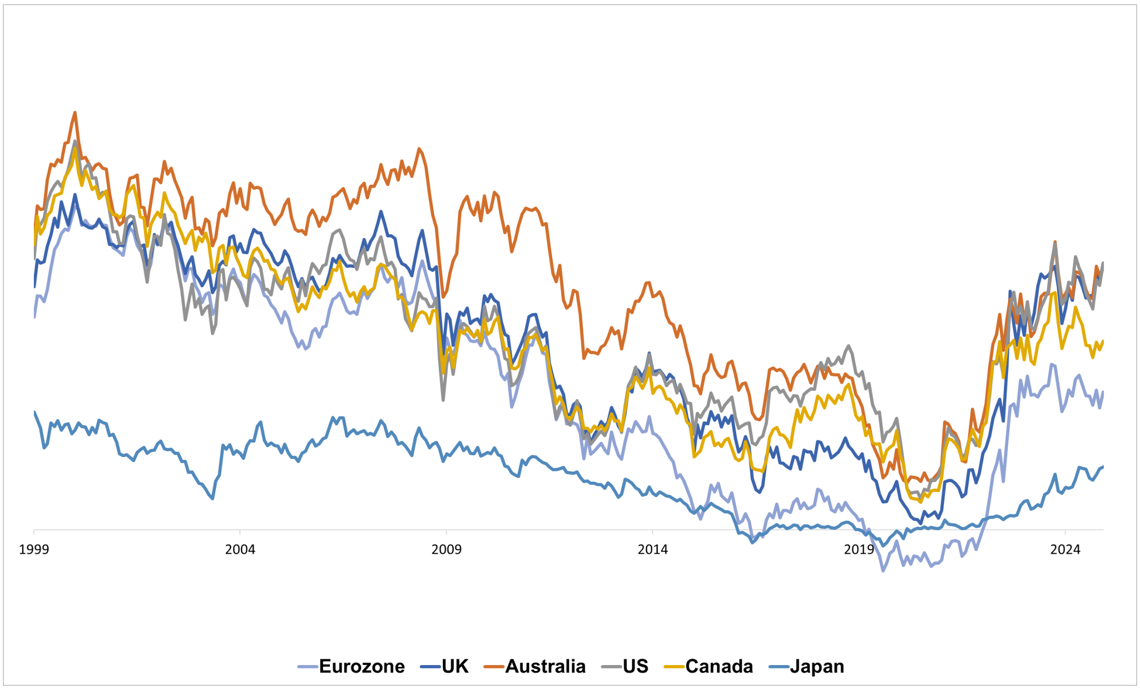


Figure 1: 10 Years Government Yield 1999 - 2025 (Developed Economies)

In our attempt to achieve this objective, we have sought to replicate as faithfully as possible the dynamics that would unfold in the real world. For this reason, in addition to considering the costs associated with individual trades, we have extended the analysis to account for the implications of investing in foreign currencies. The issue we aim to address seeks to answer a common question in the practitioner community: is it really worth investing in international curves compared to local ones? From the perspective of a European investor, this translates into investigating whether an investment in foreign curves, taking into account the volatility of spot exchange rates or the costs of hedging, is more advantageous than trading the Euro curves.

Many investors see currency risk as an unrewarded risk and therefore often choose to fully hedge their foreign currency exposure. However, currency hedging requires the purchase of foreign exchange derivatives and an operational and governance structure to manage these. All these things costs and reduce the returns of the investments. For this reason, in addition to the speculative aspect, a huge literature have been produced seeking to develop a forecasting model for currencies. At the foundation of this studies lies the renowned paper by Richard Meese and Kenneth Rogoff *"Empirical Exchange Rate Models of the seventies. Do they fit out of sample?"* The study critically assessed the predictive performance of various structural exchange rate models developed during the 1970s, comparing them against a simple random walk model. They found that no structural model consistently outperformed a naive random walk model in out-of-sample forecasting. As we said a huge literature has been produced on this line of research. To make our contribution on the matter, in the third chapter we adopt a structural approach to investigate the existence of a link between currency movements and the jPY-AUD carry trade variations . If such a link is found, it could provide valuable support for currency forecasting. Our thesis is based on the belief that the significant monetary flows generated whenever the aforementioned carry trade becomes more or less attractive can influence Forex movements.

The importance of geographical diversification and bets de-correlation

It is well known that diversification can be highly beneficial for portfolios. However, an important aspect of diversification is often overlooked: the benefits of geographic diversification. Doing so can be difficult because many economies are closely linked, especially to US conditions, making their markets highly correlated. Geographic diversification is one of the cheapest ways for investors to make their portfolios more robust. Today, most investors are overly concentrated in US assets, particularly after a decade of US equity outperformance. But even when accounting for this outperformance, a simple geographically diverse portfolio (weighting economies equally) has performed in line with US-dominated portfolios and has been less volatile. While the US could continue to have the best-performing assets in the world for the next decade, past outperformance has now been discounted, raising the hurdle going forward. But while geographic diversification is desirable in theory, maximizing its benefits can be difficult in practice. The most diversifying markets are those where the key drivers of asset prices—growth, inflation, and monetary policy—are lowly correlated to other economies. But because the US is the largest economy in the world, by far the largest importer of goods, and a large capital provider, it tends to influence those drivers in other markets, limiting their diversification potential.

Japan stands out as a premier destination for global diversification, hosting the world's third-largest bond and fourth-largest equity markets. Its economy bridges East and West, with balanced trade exposure to the U.S. and China, resulting in one of the lowest economic correlations to the U.S. among developed nations. Decades of disinflation led to prolonged accommodative policies, decoupling its monetary cycle from global trends. Post-COVID inflationary pressures have prompted cautious policy normalization (e.g., ending yield curve control), yet Japan's monetary stance remains distinct, sustaining low asset correlation with global markets. Despite this shift, investors remain underweight Japanese assets, offering room for strategic positioning.

Korea's equity market, led by the tech giant Samsung (31% of KOSPI 200), is heavily tied to the cyclical semiconductor sector—critical for AI, automotive, and consumer tech. Semiconductor cycles, driven by multi-year supply-demand imbalances, are less influenced by U.S. demand than traditional goods, enhancing diversification. Korea's trade links with Asia (particularly China) further insulate it from Western market volatility, providing investors indirect exposure to regional growth and commodity-like cyclicality in tech.

India mirrors China's early growth trajectory, combining rapid expansion with a relatively closed economy. Its exports are dominated by services (40%, mostly IT), which are less prone to sharp downturns, buffering the economy during global crises. A large domestic consumer base (supported by strong demographics) and minimal foreign asset ownership reduce vulnerability to capital flight. India's growth and inflation exhibit low correlation with U.S. cycles, allowing autonomous monetary policy. Regulatory hurdles persist, but its equity market offers pure-play

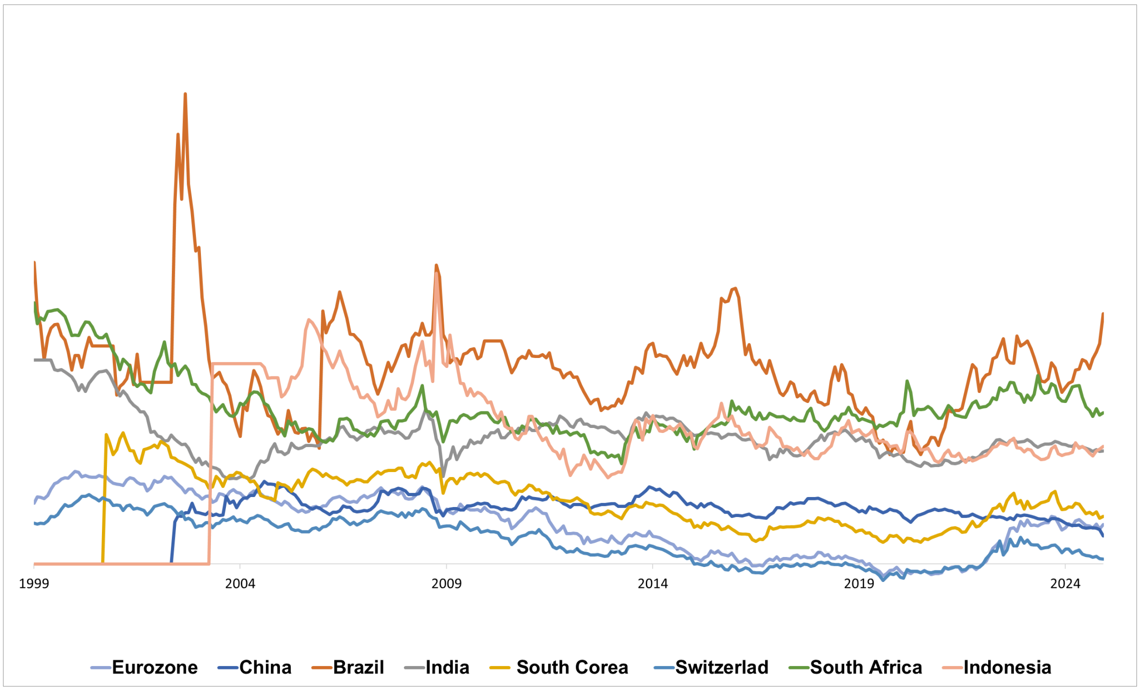


Figure 2: 10 Years Government Yield 1999 - 2025 (Emerging Economies)

exposure to a burgeoning domestic economy.

As the largest EM after China, Brazil leverages commodity exports (soybeans, iron ore, oil) tied to global cycles and Chinese demand. A robust domestic economy (70% of corporate sales) and sticky long-term investments lessen reliance on volatile portfolio flows. Proactive monetary policy—tightening early and easing ahead of developed markets—has bolstered resilience. Historically, Brazilian assets have outperformed during U.S. downturns, underscoring their diversification appeal. .[5]

1 The trading model

We now turn to the analysis of the model we have developed. First, we will present the methodology and the fundamental formulas used to evaluate the strategies. Next, we will outline the composition of the dataset employed. Finally, we will review each strategy and examine the corresponding results.

1.1 Methodology

As previously mentioned, the model we have developed is based on a set of systematic rules for trading duration using 10-year government bonds of various countries. For our model we decided for an empirical approach instead of a pure econometrical one. Indeeed, an empirical approach offers significant advantages when forecasting bond yields using macroeconomic variables. Econometrical and structural models rely on theoretical assumptions about economic relationships, such as rational expectations and equilibrium conditions. While these models provide valuable insights into economic mechanisms, they often struggle with predictive accuracy and adaptability to changing market conditions. Empirical models, by contrast, rely on historical data and economical relationships rather than rigid theoretical constraints. This flexibility allows them to capture non-linear interactions, regime shifts, and dynamic market behavior that structural models may overlook. Financial markets are influenced by a broad range of factors, including investor sentiment, policy changes, and unexpected economic shocks, making it difficult for purely structural models to consistently generate accurate forecasts. Moreover, structural models assume stable economic relationships, but macroeconomic dynamics often change due to several correlated or non-correlated reasons like monetary policy shifts, financial crises, or technological innovations. Empirical approaches, can adjust over time, improving their forecasting performance in real-world applications.

A huge theme is the so called "misspecification risks" inherent in structural approaches. A structural model may impose relationships that do not hold in reality, leading to biased or misleading forecasts. Empirical models, by contrast, prioritize predictive accuracy, allowing them to incorporate a wider range of variables, even those without a strong theoretical foundation but with proven forecasting power. These is the reason behind our choice to extend the number of economic factors taken as signals. Diversification benefit is a fact in finance and this paper will try to confirm it.

We can also say that empirical approaches align better with trading and investment objectives. Since one of the pillar we impose ourself was to reproduce reality as faithfully as possible, we thought that profitability and risk-adjusted returns were more important than theoretical purity. Empirical models can be optimized for key performance metrics such as Sharpe ratio, Max Drawdowns, or volatility, making them more practical for decision-making in a trading strategy.

From a practical point of view the model combine six signals for duration timing:

- Local Equity Index price Momentum;
- Local Bond Return Index Momentum;
- The slope of the yield curve, as a measure of carry;
- Equity analysts' earnings forecast revisions Momentum;
- Real Yield Relative Value;
- Composite Leading Indicator Index momentum.

Together, these signals seek to capture a range of influences on bond yields, in a simple and transparent fashion. Those influences include economic news (via the earnings revisions), investor perceptions of risk (via past equity returns) , value/carry (via the curve slope and the real yield) and the economic cycle (via the Leading Indicator Index). For each strategy, different signal combinations will be tested. To choose the best one, that will be used to implement a combined strategy, we will follow this systematic approach:

- first, we will choose the two signal combinations with the highest return to risk ratio;
- among these, we will select the combination with the lowest correlation between countries.

The analysis is based on trading 10-year government bond of two set of countries:

- *Country set n1:* Eurozone, UK, Australia, US, Canada, and Japan.
- *Country set n2:* China, Brazil, India, South Korea, Switzerland, South Africa.

When Eurozone data are not directly available we used Germany as a proxy. In the second group, Switzerland stands out as somewhat out of context. We decided to include it among emerging markets, not because it is a developing or moderately growing economy, but rather because its financial market is often under-looked. However, we still expect that Swiss bond market dynamics will largely follow those of the Eurozone and other Western economies, giving us a good proxy to analyze the correlations of emerging economies. For example, a fair correlation between the Western economies and South Korea will be revealed several times thanks to the Swiss bod analysis. Moreover, it would have certainly been more consistent to swap Switzerland and Japan. However, we decided to include Japan in the first set of countries to better compare our results with those obtained by Mac Gorain.

All the signals are rebalanced monthly, at the end of the month. We adjust the returns with transaction costs. We assumed different levels of transaction costs for each set of countries:

- For the 1$^{\text{st}}$ set of countries we assumed, per trade, a transaction cost of 0.01% for the 10Y Government Bonds. We also assumed 0.005% for the cash (1 Months yield);
- For 2$^{\text{nd}}$ set of countries we assumed, per trade, a transaction cost of 0.04% for the 10Y Government Bonds. We also assumed 0.01% for the cash (1 Months yield).

1.1.1 Practical Considerations on the Calculations

Each strategy is driven by signals generated on a period-by-period basis. By observing the data at time t, the strategy will decide the position to take at time t, which will be closed at time t+1. IN the next three paragraphs we exposed how the six signals have been exploited.

Momentum A momentum strategy is an investment approach that capitalizes on the tendency of assets that have performed well in the past (i.e., have positive returns) to continue performing well in the future, and similarly, assets that have performed poorly (i.e., have negative returns) to continue under performing. Momentum signals have been implemented in two different ways depending on the nature of the variable under analysis:

- For equity indices and their influence on bond returns, acknowledging that these are assets whose values are directly observable in the market and assuming a continuous price distribution, we opted for a method using moving averages with rolling time windows. The trading signal is therefore the difference between the observed value at time t and the n-period moving average from time t-1-n to t-1. In these cases, the signal was compared to threshold levels to determine the direction of the position. If the threshold has not been hit in any directions there would be no positioning.

$$\text{Momentum} = \text{data}_t - \frac{1}{n}\sum_{i=t-1-n}^{t-1}\text{data}_i$$

- In the case of economic data (LII, IBES ERR, FCI), considering that these are released discretely at regular intervals and the reported value represents the composite situation for the month in question, we decided to calculate the momentum signal as the change relative to previous periods. The signal at time t is therefore given by the difference between the observed data at time t and the observed data at time t-n, where n is the chosen look-back period. In these cases we do not apply a threshold, i.e. any increase or fall of the variables is sufficient to generate a trading signal.

$$\text{Momentum} = \text{data}_t - \text{data}_{t-n}$$

In both cases, it was decided not to account for the possibility that a strategy could generate the same signal in two consecutive periods. Therefore, in each period, there will be one sell operation and one buy operation (except in the cases the positioning in t-1 is 0). We chose this approach instead of operating only when the signal changes, based on the assumption that the signals are short-term in nature. While this approach leads to higher transaction costs (with cumulative returns remaining unchanged), it offers greater consistency when combined with other strategies.

The direction of the trade, in both cases, will be represented by a dummy variable that takes the values of -1, 0, or 1, depending on whether the position is short, neutral, or long.

Relative Value The Real Yield has been exploited using a relative value strategy. A relative value strategy is an investment approach that seeks to exploit price inefficiencies between similar or correlated financial instruments. This strategy involves taking a long position in an asset that is believed to be undervalued and a short position in an asset that is believed to be overvalued, based on a comparative valuation. The strategy aims to profit from this convergence process by capitalizing on the relative mispricing.

From a practical standpoint, we assign a value between -1 and 1 to each country in each period based on the real interest rate of the individual country relative to the others. A value of 1 corresponds to a long position and is assigned to the country with the highest real rate, while -1 corresponds to a short position and is assigned to the country with the lowest real yield. An economic interpretation of this decision will be provided in the section dedicated to this strategy. Other countries will be assigned a scaled value between -1 and 1 in a linear manner. Below is the formula used in mathematical form:

$$\text{Rel. Value}(t,n) = \begin{cases} 1 & \text{if } data_{t,n} = \max(data_n) \\ -1 & \text{if } data_{t,n} = \min(data_n) \\ 2 \cdot \frac{(data_{t,n} - \min(data_n))}{\max(data_n) - \min(data_n)} - 1 & \text{otherwise} \end{cases}$$

Where:

- $data_{t,n}$ is the n-th country in period t,
- $\max(data_t)$ and $\min(data_t)$ are the maximum and minimum values of the vector $data_n$ in period t.

Value The Slope of the curve has been exploited with a value strategy, A value strategy is an investment approach that focuses on identifying and purchasing assets (such as stocks, bonds, or other securities) that are undervalued relative to their intrinsic value. The idea behind this strategy is that the market often misprices securities, and that over time, the price will correct itself to reflect the true underlying value.

From a practical standpoint, we implemented the Slope strategy by establishing a linear relationship between the value at time t and the values taken in the previous periods, within a time window of n periods, ranging from the data at time t-n-1 to t-n. The function that links the value of the slope to the position we take in the market assumes the following form:

$$Position = 2(Rank.Perc_{t-n-1,t-n}(data_t) - 0.5)$$

Where:

- $data_t$ is the t-th observation of the carry
- $Rank.Perc_{t-n-1,t-n}(data_t)$ is a function that calculates the percentile of $data_t$ with respect to the look-back window of n periods.

This formulation allows the position on the duration to oscillate between -1 and 1, depending on the value of the most recent observation.

1.1.2 Returns Estimation

Since it is not possible to have the bid and ask prices for the bonds we are assuming to trade, we need to find a way to estimate the returns from buy and sell operations month by month. To do this, we must make a rather strong assumption: when buying and selling month by month, we do not take into account the passage of time and assume that we hold a bond with a constant maturity.

In reality, this does not occur. When you buy a bond on the market, you lock in a yield to maturity, and the maturity decreases over time. After a month, the zero-coupon bond (ZCB) you bought will no longer have a 10-year maturity but 9 years and 11 months. This bond will be priced on the market at a different yield compared to a bond with a 10-year maturity.

Our assumption leads us into the realm of derivatives: by assuming a constant maturity, we are effectively calculating the return on hypothetical futures contracts on bonds with a constant maturity, rather than on the bonds themselves. Therefore, we can use the classic approximation formula derived from the Taylor expansion to calculate the yield:

$$\frac{\Delta P}{P} \approx Mod.Duration \cdot \Delta y + \frac{1}{2} \cdot Convexity \cdot (\Delta y)^2$$

Where:

- $\frac{\Delta P}{P}$ is the return over the period.
- Δy is the yield variation.
- Mod. Duration: measures the linear change in the price of a bond relative to changes in interest rates. It provides an approximation of how much the price of a bond will change for a small change in interest rates. We use Modified Duration instead of Macaulay Duration since our yield are expressed with annual compounding and not in continuous compounding.

  $$Mod.Duration = \frac{Duration}{1+y}$$

  For the sake of completeness, we should note that the duration of a Zero-Coupon Bond (ZCB) is equal to its remaining maturity. This is because a ZCB has no intermediate coupon payments, and its price sensitivity to interest rate changes is directly tied to its time to maturity. Therefore, the duration of a ZCB is simply the time left until its maturity date.
- Convexity: adds a quadratic term to improve the accuracy of the prediction, as the relationship between bond prices and interest rates is not linear. Convexity captures the curvature of the price-yield curve, accounting for the fact that the price change becomes more pronounced as interest rates change, especially for larger shifts in rates. The formula for the convexity of a ZCB is:

  $$Convexity = \frac{T \cdot (T+1)}{(1+y)^2}$$

The returns of the combined portfolios are calculated as weighted averages of returns of the single countries. For the singles strategies we adopted equal weights for the calculations, while for the combined strategy we will also optimize the weight to enhance the outperforming countries, always keeping a diversified environment.

1.1.3 Performance Indicators

To evaluate the strategies the following performance indicators have been used:

- ***Annualized return:*** calculated as:

  $$R_{\text{Annual}} = (1 + R_{\text{monthly}})^{\frac{1}{T}} - 1$$

  where T is the number of years of analysis and R is the compounded monthly return over the period:

  $$\text{R} = \prod_{i=1}^{t}(1 + r_i)$$

- ***Annualized Volatility*** calculated as:

$$\sigma_{\text{annual}} = \sigma_{\text{monthly}} \times \sqrt{12}$$

  where:

  - σ_{annual} is the annualized volatility,
  - σ_{monthly} is the monthly standard deviation of returns (monthly volatility),

- ***Alpha Generated***: is the excess return gained by the strategy vs the benchmark;

$$Alpha = R_{\text{Portfolio}} - R_{\text{risk free}}$$

- ***Sharpe Ratio:*** measure of the risk-adjusted return of an investment, calculated by dividing the annual excess return by its annual volatility;

$$SR = \frac{Alpha}{\sigma_{\text{annual}}}$$

  where:

  - R_p is the portfolio return,
  - R_f is the risk-free rate,
  - σ_p is the standard deviation of the portfolio returns (volatility).

- ***Expectancy:*** average amount of profit or loss you can expect per trade, factoring in both the win rate and the average profit/loss per trade;

$$E = (P_w \times A_w) - (P_l \times A_l)$$

  where:

  - E is the expectancy per trade,
  - P_w is the probability of a winning trade,
  - A_w is the average win per trade,
  - P_l is the probability of a losing trade,
  - A_l is the average loss per trade.

- ***Max Drawdown*:** is the largest peak-to-trough decline in the value of an investment or portfolio over a specific period of time. It measures the maximum loss an investor would have experienced if they had invested at the highest point and sold at the lowest point during that period;

$$MDD = -\max\left(\frac{P_{\text{peak}} - P_{\text{trough}}}{P_{\text{peak}}}\right)$$

  where:

  - P_{peak} is the highest portfolio value before a decline,
  - P_{trough} is the lowest portfolio value before a new peak.

- ***Tracking Error Volatility:*** The standard deviation of the difference between the return of an investment and the return of a benchmark index. It indicates how closely an investment tracks its benchmark;

$$\sigma_{\text{TEV}} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(R_{portfolio,i} - R_{benchmark,i})^2} \times \sqrt{12}$$

– σ_{TEV} is the annual tracking error volatility,
– $R_{p,i}$ is the return of the portfolio at time i,
– $R_{b,i}$ is the return of the benchmark at time i.
– N is the number of periods.

- ***Information Ratio:*** risk-adjusted performance measure that compares the excess return of the investment relative to the benchmark with the volatility of that excess return. A higher information ratio indicates better risk-adjusted returns;

$$IR = \frac{\prod_{i=1}^{t}[1 + (r_{port,i} - r_{bench,i})]}{\sigma_{\text{TEV}}}$$

where:

– R_p is the return of the portfolio,
– R_b is the return of the benchmark,
– σ_{TE} is the annual tracking error volatility.

- ***Hit Ratio:*** percentage of profitable trades out of the total number of trades. We calculated the hit ratio accounting for funding and transaction costs.

$$HR = \frac{N_w}{N}$$

where:

– N_w is the number of winning trades (periods with positive returns),
– N is the total number of trades (or periods of trading).

1.1.4 Return to Risk Indicator: Which One to Choose?

There are two main Return to Risk indicator to measure the performance of a trading strategy: the Sharpe Ratio and the Information Ratio. Both the indicators are widely used in finance and originate from the mean-variance framework. However, their applications differ significantly.

The Sharpe Ratio, introduced by William Sharpe in 1966, measures excess return per unit of total risk (standard deviation). It is useful for evaluating the absolute performance of an investment, making it ideal for comparing strategies or asset classes without a benchmark. A higher Sharpe Ratio indicates better risk-adjusted returns, but it does not differentiate between upside and downside risk and assumes a normal distribution of returns.

In contrast, the Information Ratio extends the Sharpe framework by substituting the benchmark return for the risk-free rate. It evaluates how consistently an active manager outperforms a benchmark, adjusting for tracking error. A higher Information Ratio suggests superior manager skill, but its usefulness depends on the chosen benchmark and time horizon.

Both ratios have limitations. The Sharpe Ratio penalizes both positive and negative volatility, making it less suitable for asymmetric return distributions. The Information Ratio can be manipulated by selecting favorable benchmarks or time periods. Despite these shortcomings, both remain essential tools for evaluating risk-adjusted returns.

For the evaluation of the strategies examined in this paper, we have chosen the Information Ratio as the primary performance measure. Given that we are assessing an active trading strategy, we opted for a more dynamic metric.

However, as will become evident in the following sections, the Information Ratio and the Sharpe Ratio, rounded to the second decimal digit, are nearly identical in most cases. This is primarily due to the choice of benchmark. In our research, we use a long-only strategy on the 1-month rate as the benchmark, which naturally also serves as the risk-free rate. For the sake of completeness, we report both ratios.

There is an important factor to consider when interpreting this analysis. Mac Gorain, in assessing the actual performance of his strategies, uses an absolute measure. As shown on page

11, Figure 22 of his paper "Investment Strategies No.74. Simple Rules to Trade Duration", he calculates the return-to-risk ratio simply as $\frac{return}{volatility}$, without apparently subtracting a benchmark or risk-free rate from the actual returns of the strategies. In contrast, we will evaluate strategies using the information ratio, which means we will subtract a benchmark return,in this case, the local risk-free rate, from strategy returns. This explains why, as we will see, some strategies may show negative ratios despite positive annual returns and expectancy, often due to very high short-term regional rates.

1.1.5 Data

The data used in this paper is sourced from the Bloomberg library, LSEG Datastream (formerly Refinitiv) and FRED. The dataset consists of the following:

- 2Y, 5Y, 7Y, 10Y, 20Y, 30Y Government Bond yield (monthly);
- 10Y Government Bond yield (daily);
- 1 month money market rate (deposit rate in local currency);
- 3 months Government Bond yield (for Australia we used 3 months AUD deposit);
- CPI YoY Core;
- Inflation Rate (if the CPI is not available);
- Equity index (log transformed);
- FX spot exchange rates;
- Composite Leading Indicator Index (Normalized);
- IBES Earnings Revision Ratio (ERR) which is composed of the following estimations:
  - Number Of Companies With 12-Month-Forward EPS Estimates Up Since Last Month;
  - Number Of Companies With 12 Month Forward EPS Estimates Down Since Last Month;
  - Number Of Companies In Aggregates With A 12-Month-Forward EPS Mean.

The economic relevance of the variables will be examined in the following sections.

The dataset has a monthly frequency and covers the following periods:

- *Country set n1: f*rom January 1999 to December 2024
- *Country set n2:* from January 2007 to December 2024

The following tables display, for each country, the corresponding stock index and the local currency expressed as the exchange rate against the Euro.

	Eurozone	**UK**	**Australia**	**US**	**Canada**	**Japan**
Stock Index	EURO Stoxx 50	FTSE 100 Index	S&P/ASX 200	S&P 500 Index	S&P/TSX Composite Index	Nikkei 225 Index
FX Rate		EUR/GBP	EUR/AUD	EUR/USD	EUR/CAD	EUR/YEN

	China	**Brazil**	**India**	**South Korea**	**Switzerland**	**South Africa**	**Indonesia**
Stock Index	Shanghai Composite Index	IBrX Index	BSE Sensex	KOSPI 200 Index	SMI Index	FTSE/JSE All Share	
FX Rate	EUR/CNY	EUR/BRL	EUR/INR	EUR/KRW	EUR/CHF	EUR/ZAR	

In the rare cases of missing values within a time series (for example, a 6-month gap in South Korea's 2-year yield), I used spline interpolation to fill the gaps.

We now proceed to analyze the Benchmark strategy returns and then the different strategies adopted.

1.2 The Benchmark

As we already anticipated we chose to adopt as a benchmark a long only strategy on the 1 month Rate in the local currency. When calculating returns, there are two possible approaches:

- *Mark-to-Market Approach*: Based on the monthly fluctuations in asset prices derived from monthly yields.
- *Buy-and-Hold Approach:* Assumes that securities are purchased and held until maturity, with the investment being rolled over.

For our analysis, we opted for the Buy-and-Hold approach using 1-month yields. In the Figure below are plotted the trajectories of the short term rate for the developed countries since 1999. As shown in the graph, there has been a decline in the correlation of short-term interest rates among Western countries, whose central banks have been increasingly acting in unison for some time. Japan, on the other hand, stands out with minimal variation and rates near zero for the past 20 years.

1.2.1 Benchmark of the 1st Set of Countries

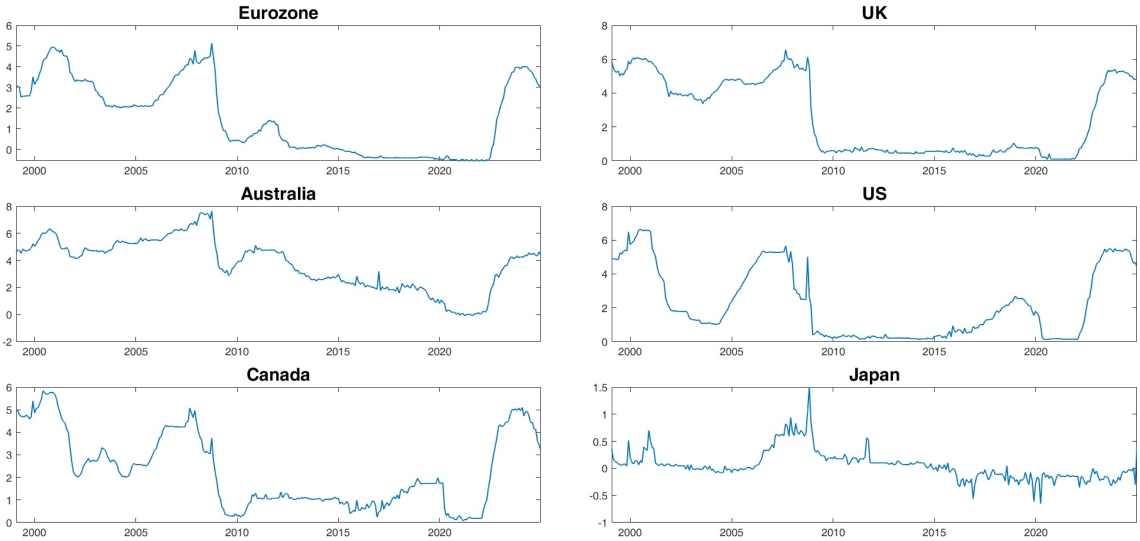


Figure 3: 1 Month Local Currency Deposit Rate

The analysis period for the 1st set of countries and for all the strategies will range from **May 2009 to December 2024**. This 10-year time lag relative to the available dataset (which begins in January 1999), was chosen to ensure the highest consistency of the strategies. Due to the nature of the signals, each strategy's return starts at different points in time. As we will see in the following paragraphs, the Slope strategy uses a 10-year look back window to determine positions, so all the strategies will be evaluated on the same time frame.

In the table below (Table 1 and Figure 4) are reported the main features of the benchmark for the developed countries.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Annualised Return %	0.46	1.14	2.62	1.34	1.45	-0.05	1.16
Annualised Volatility %	0.37	0.43	0.41	0.48	0.38	0.05	0.30
Expectancy %	0.05	0.12	0.12	0.12	0.12	0.04	0.11
Max Drawdown %	-7.19	-16.30	-33.12	-18.79	-20.21	-1.59	-16.43
Sharpe Ratio	1.23	2.64	6.36	2.80	3.81	-0.97	3.80

Table 1: Benchmark Features in the period May 2009 - December 2024

	2009 - 2016	2016 - 2020	2020 - 2022	2022 - 2024
Eurozone	0.37	-0.40	-0.50	2.43
UK	0.56	0.57	0.20	3.90
Australia	3.48	1.86	0.19	3.31
US	0.28	1.55	0.30	4.18
Canada	0.89	1.24	0.34	3.76
Japan	0.12	-0.19	-0.17	-0.15
Combined	0.94	0.77	0.06	2.90

Figure 4: Benchmark Annual Returns Variation over the Period

From the figures, it is evident that there is an upward trend in short-term interest rates, with the only exception being Japan, which displays a negative compounded annualized rate with very low volatility. In the following sections, we will see how the spike in interest rates over recent years has significantly influenced the results obtained.

1.2.2 Benchmark of the 2nd Set of Countries

The analysis period for the 2nd set of countries and for all the strategies will range from **January 2015 to December 2024**.

In Figure 5 are plotted the trajectories of the 2nd set of countries.

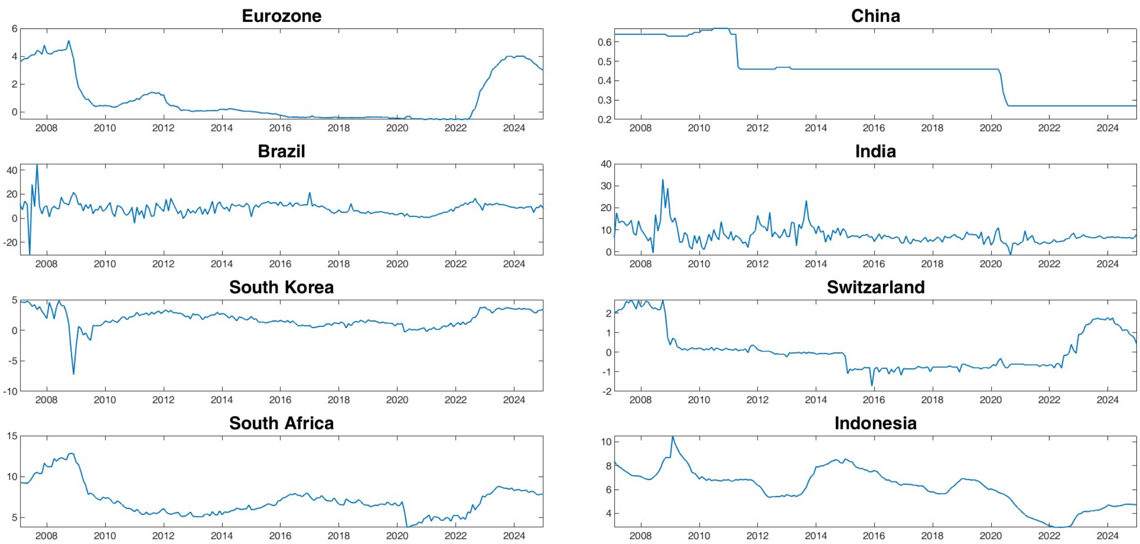


Figure 5: 1 Month Local Currency Deposit Rate

In the graph we observe that, apart from Switzerland, which, as previously mentioned, is a unique case within this group, short-term interest rates in emerging markets tend to follow independent trajectories. For example, it is evident that the rate spike that began in Western economies around 2022 did not materialize in countries like South Africa, India, or Indonesia.

In the tabes of Table 2 and Figure 6 are reported the main features of the benchmark for the emerging economies.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Annualised Return %	0.37	7.89	6.00	1.54	-0.30	6.68	5.42	3.46
Annualised Volatility %	0.03	1.08	0.46	0.32	0.25	0.34	0.41	0.27
Expectancy %	0.35	0.35	0.35	0.34	0.04	0.35	0.35	0.35
Max Drawdown %	-3.61	-52.87	-43.85	-14.02	-5.52	-47.38	-40.60	-28.64
Sharpe Ratio	13.76	7.32	13.06	4.81	-1.18	19.43	13.10	12.77

Table 2: Benchmark performances for the period January 2015 - December 2024

Notably, Brazil exhibits the highest annualized return at 7.89%, followed by India (6.00%) and South Africa (6.68%). Annualized volatility highlights substantial differences in risk levels. Brazil's volatility (1.08%) is the highest, reflecting its market fluctuations, whereas China nd Switzerland exhibit significantly lower volatility. Expectancy remains constant at 0.35% across most countries, with the exception of Switzerland (0.04%), indicating weaker returns for the Swiss market. Maximum Drawdowns emphasize the vulnerability of emerging markets. Brazil (-52.87%) and South Africa (-47.38%) suffered the most significant declines, while Switzerland experienced relatively minor losses (-5.52%). Overall, the data supports the notion that emerging markets offer high returns at the cost of greater volatility and Drawdowns. The combined portfolio appears to balance return and risk.

	2015 - 2020	2020 - 2022	2022 - 2024
Eurozone	-0.35	-0.50	2.43
China	0.46	0.30	0.27
Brazil	8.28	3.33	10.39
India	6.25	4.75	6.37
South Korea	1.16	0.41	2.95
Switzerland	-0.83	-0.63	0.83
South Africa	6.93	4.88	7.49
Indonesia	6.69	4.31	4.01
Combined	3.52	2.08	4.30

Figure 6: Benchmark Annual Returns Variation over the Period

From 2015 to 2024, the evolution of 1-month interest rates showed significant interesting features. The Euro area and Switzerland show similar movement as expected, keeping negative rates until 2022, before rising sharply in 2022-2024, in response to inflation. South Korea also followed a similar dynamic, with a rise from 0.41% to 2.95%. In emerging markets, on the other hand, rates have remained higher but volatile: Brazil has risen from 8.28% in 2015-2020 to a low of 3.33% in 2020-2022, before rising sharply to 10.39%. A similar trend is observed in South Africa (from 6.93% to 4.88% and then 7.49%) and in India, with more moderate fluctuations. China, on the other hand, has maintained stable levels around 0.30%. The combined portfolio reflects these global trends, with a reduction in rates during the pandemic period (2.08%) and a subsequent rise to 4.30%. These dynamics highlight the strong impact of monetary policies and macroeconomic conditions on short-term rates at a global level.

1.3 Equity Momentum

This strategy seeks to capitalize on the so-called "inverse wealth effect," where rising stock markets prompt investors to shift capital from bonds to riskier assets, pushing bond prices down and yields up. Beyond this direct relationship, bond returns remain statistically linked to various indicators of past risky asset performance, even when controlling for previous bond returns. These indicators include not only equity returns but also changes in implied equity volatility and high-yield bond spreads. What explains this connection? Ilmanen (1995) suggests that the predictive power of equity returns for subsequent bond performance stems from fluctuations in investor risk aversion. During periods of lower wealth—where equities serve as a proxy—investors tend to seek safer assets, increasing demand for bonds and influencing their returns accordingly.

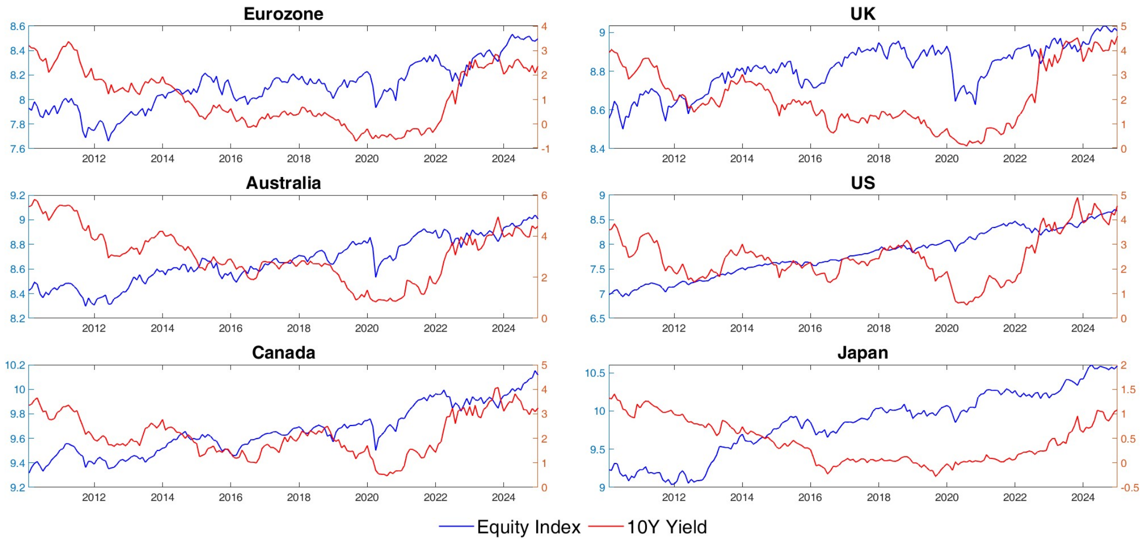


Figure 7: Equity Indexes Trajectories

The effectiveness of this signal largely depends on the persistence of the negative bond-equity correlation, which has been in place since the late 1990s. As shown in Figure 7, the positive correlation between equity returns and bond yields (or, equivalently, the negative correlation with bond prices) has decreased over the last period, contributing to significantly lower returns for this strategy compared to earlier decades.

At its core, the ability of equity momentum to predict bond returns stems from a common pattern of investor behavior—initial under reaction to news, followed by subsequent overreaction. However, whether strong equity returns should be expected to lead to weak bond returns depends on the underlying drivers of both markets, specifically the type of news investors are under reacting to.

For instance, in the case of a growth slowdown or financial turbulence, equities would likely decline while bonds rally, consistent with the wealth and risk aversion effects that traditionally link the two. Conversely, if the market is responding to further monetary policy easing—such as additional quantitative easing (QE)—both stocks and bonds could benefit simultaneously, all else being equal. This phenomenon can be easily d in Figure 2. Since 2013, it has been clear that countries most influenced by QE policies have experienced a period of positive correlation between bond prices and equity markets. [3]

1.3.1 The signal

The strategy goes long duration if the Local Equity Index for each country is behind its average for the past one, two, three, six or twelve months, and short otherwise. As mentioned previously, a threshold has been applied to avoid false trading signals. One advantage of comparing the current level to its past average rather than past single levels is that it avoids trading due to base effects instead of recent market movements. The signal rebalanced on the last day of each month, based on the previous day's closing prices.

1.3.2 Results 1st Set of Countries

	Eurozone	UK	Australia	US	Canada	Japan	Combined
1m	0.26	0.28	-0.13	0.17	0.38	0.09	0.22
2m	-0.04	0.63	-0.45	0.31	0.19	0.31	0.15
3m	0.03	0.52	-0.41	0.19	0.29	0.25	0.15
6m	0.05	0.66	-0.12	0.20	0.34	0.33	0.28
12m	0.00	0.74	-0.12	0.05	0.42	0.24	0.28

Table 3: Information Ratio for different signals

All of the momentum strategies have been profitable in each country, except of Australia. Over this period, the best return has come from 6-months and 12-months momentum, with a return to risk of 0.28 for all six countries combined. These two tenors are the ones which are short most of the times (around 70% of the times) being able to better capture the upward movement of interest rates in recent years.

The best signal To choose which of the two best signals (6 months or 12 months momentum) use in the computation of the final strategy we take a look to the correlation matrices of the returns of the two strategies.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Eurozone	1.00						
UK	0.52	1.00					
Australia	0.44	0.56	1.00				
US	0.46	0.50	0.62	1.00			
Canada	0.49	0.50	0.56	0.57	1.00		
Japan	0.37	0.28	0.23	0.26	0.19	1.00	
Combined	0.73	0.78	0.81	0.80	0.78	0.41	1.00

Figure 8: 6 months Moving Average

The correlation matrix shows a high correlation among all countries, with exception for Japan. The 6-months momentum displays the best results, with lower countries correlations (but still pretty high in absolute terms). We then choose the 12-months momentum as the best 10 years yield curve predictor. In the table are summered the main features of the strategy:

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Annualised Return %	0.43	6.57	1.65	1.68	4.27	0.56	2.26
Annualised Volatility %	6.82	7.44	8.22	7.60	6.79	2.54	4.04
Tracking Error Volatility %	6.81	7.38	8.21	7.58	6.75	2.54	4.01
Alpha Generated %	-0.03	5.43	-0.97	0.34	2.82	0.61	1.11
Expectancy %	0.12	0.40	0.11	0.28	0.28	0.13	0.23
Max Drawdown %	-24.60	-68.23	-32.57	-35.09	-55.49	-10.57	-35.39
Information Ratio	0.00	0.74	-0.12	0.05	0.42	0.24	0.28
Sharpe Ratio	0.00	0.73	-0.12	0.05	0.41	0.24	0.27
Hit Ratio %	52.66	63.30	52.13	58.51	58.51	53.19	56.91

We note the following aspects of the results:

- The strategy succeeds in the UK and Canada but struggles in low-yield environments (Eurozone/Japan) and Australia.
- The UK's high returns (6.57% annualized) and alpha (5.43%) likely reflect active exploitation of post-Brexit monetary policy shifts (e.g., BoE rate hikes and QE adjustments) and GBP fluctuations, amplifying opportunities in a volatile yield environment.
- Eurozone (0.43%) and Japan (0.56%) delivered low returns, but minimized Drawdowns (-24.60% and -10.57% respectively), likely due to prolonged low/negative rate environments. Japan's low volatility (2.54%) aligns with its stable, low-yield bond market.
- Expectancies are always positive, indicating our strategy succeeded in catching a signal for the 10y zcb trade.
- The positive alpha for the combined strategy (1.11%) indicates the strategy is able to outperform the risk free asset, so would have been convenient to implement.
- Probably the most important indicator is the hit ratio. In this case we have an hit ratio well above the 50% chance.
- Extreme Drawdowns (e.g., UK: -68.23%, Canada: -55.49%) suggest exposure to rate shocks or macroeconomic crises (e.g., inflation surprises, policy shifts), while the combined portfolio's -35.39% Drawdown highlights diversification benefits but still reflects significant risk.
- Higher returns (e.g., UK, Canada) correlate with higher volatility, but Australia's high volatility (8.22%) did not translate to adequate returns.

1.3.3 Results 2nd Set of Countries

Unlike what we observed for developed economies, in emerging markets, the strategy was not particularly effective during the period from January 2015 to December 2024.

	China	**Brazil**	**India**	**South Korea**	**Switzerland**	**South Africa**	**Indonesia**	**Combined**
1m	0.09	-1.08	-0.99	0.04	0.05	-0.72	-0.83	-1.19
2m	0.06	-0.82	-1.18	-0.11	-0.17	-0.75	-0.84	-1.26
3m	-0.13	-0.74	-1.12	-0.16	-0.25	-0.71	-0.52	-1.08
6m	-0.10	-0.27	-1.32	0.04	-0.09	-0.41	-0.47	-0.66
12m	-0.03	-0.25	-0.92	0.45	0.08	-0.42	-0.56	-0.49

Table 4: Information Ratio for different signals

In Figure 9 are displayed the local 10 years yield trajectories and the returns period by period.

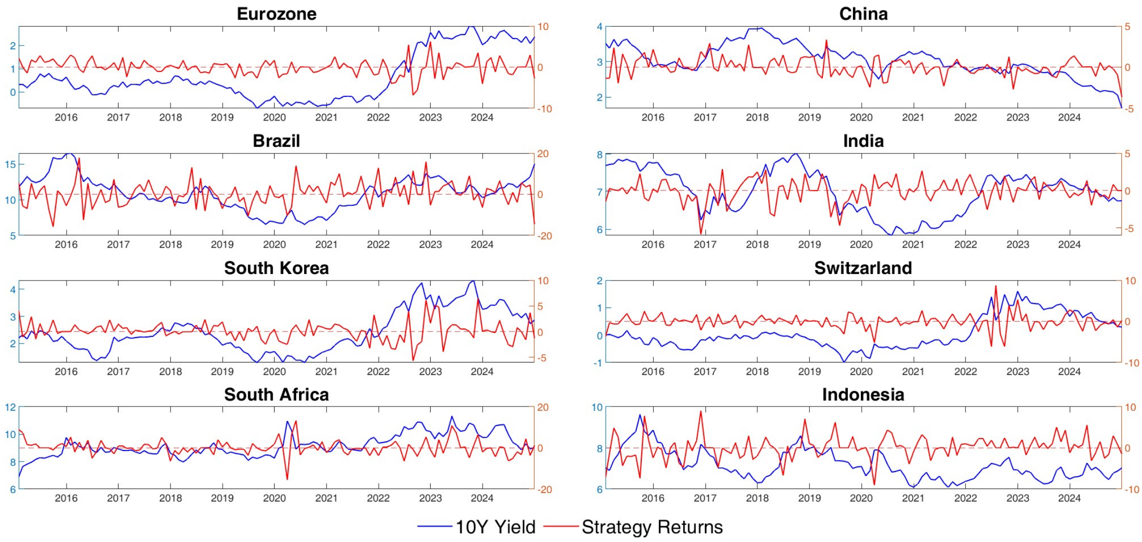


Figure 9: Performance of 6m momentum over the period January 2015 to December 2024

Form the graph is evident how the strategy struggles to exploit positive returns in higher volatility environments.

The best signal To choose which of the two best signals (1 month and 3 months momentum) use in the computation of the final strategy we take a look to the correlation matrices of the two strategies.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
China	1.00							
Brazil	-0.18	1.00						
India	0.05	0.03	1.00					
South Korea	-0.06	0.06	-0.14	1.00				
Switzerland	0.21	-0.03	0.15	0.11	1.00			
South Africa	-0.10	0.03	0.02	0.12	0.01	1.00		
Indonesia	0.09	0.11	0.00	0.10	0.00	0.31	1.00	
Combined	0.06	0.62	0.21	0.39	0.33	0.54	0.51	1.00

Figure 10: 12 Months Moving Average

For emerging markets the 12-months momentum shows the lowest correlations with an average correlation coefficient of 0.13. This is one of the rare cases where we selected the strategy which does not display the best performance in terms of information ratio. Once again, the correlation matrix shows lower absolute values, with exceptions in more Westernized countries (e.g., Switzerland or South Korea).

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Annualised Return %	0.25	2.69	0.95	4.61	0.23	1.45	-0.20	1.65
Annualised Volatility %	3.97	20.66	5.45	6.84	6.52	12.56	10.05	3.68
Tracking Error Volatility %	3.97	20.80	5.51	6.82	6.54	12.61	10.11	3.73
Alpha Generated %	-0.12	-5.20	-5.05	3.07	0.53	-5.23	-5.62	-1.81
Expectancy %	0.05	0.02	0.23	0.38	0.17	0.11	0.17	-0.01
Max Drawdown %	-20.99	-64.46	-22.60	-37.35	-18.62	-37.09	-31.59	-22.02
Information Ratio	-0.03	-0.25	-0.92	0.45	0.08	-0.42	-0.56	-0.49
Sharpe Ratio	-0.03	-0.25	-0.93	0.45	0.08	-0.42	-0.56	-0.49
Hit Ratio %	52.50	51.67	57.50	61.67	55.83	54.17	55.83	50.83

We note the following aspects of the results:

- Negative alpha dominates across most countries (e.g., India: -5.05%, Brazil: -5.20%, South
- Africa: -5.23%), indicating the strategy fails to outperform the benchmark, that in our case is the local risk free assets. The only exception is South Korea that generates a small positive alpha (3.07%), suggesting a strong outperformance of the risk free.
- Expectancies are always positive, but small. The hit ratios are positive (> 50%) in all countries. The combined portfolio also has a profitable hit ratio, albeit only to a small extent, indicating marginal reliability. South Korea achieves the highest success rates for trades, with the 61.67% ,
- The equal weight combined portfolio shows negative features: on one hand it managed to
- reduce the overall volatility producing a positive return, on the other it is not capable to
- outperform the benchmark, making the strategy unaffordable to implement.
- High volatility and Drawdowns dominate (e.g., Brazil's -64.46% Drawdown), likely due to
- macroeconomic instability or weaker equity index - 10 years yields linkages.

1.4 Bond Momentum

In addition to economic momentum, simple yield momentum has also been a consistently successful signal for trading duration. The underlying rationale here is the same: that investors initially under react to news, and perhaps later overreact. By definition, bond price momentum relies on changes in expectations about key market drivers being serially correlated. We have discussed above how this is likely the case for economic expectations, and the repeated disappointment in growth outcomes this year is in keeping with this pattern. Similarly, shifts in monetary policy have historically been very persistent, with central banks typically hiking by more than expected in tightening cycles, and especially easing by more than expected in loosening cycles. On the other hand, the increased importance of government interventions in driving market prices post crisis is perhaps a challenge for momentum. For example, Euro area leaders' approach of meeting severe market pressure with new policy proposals, but seeming to row back when market pressure abates, has contributed to the now-familiar up-and-down cycle for peripheral asset prices (albeit within the context of a longer-term downward trend).

In implementing the strategy, we did not limit ourselves to applying a momentum strategy solely on the historical data of the 1-year yield curve. Instead, following the approach of Mac Gorain, we utilized the momentum signal derived from a Bond Return Index. However, unlike what was done by the aforementioned economist, the value of the return index was not taken from historical values of a market index, but rather, it was constructed by us.

1.4.1 The Bond Return Index

We have constructed a composite index that tracks the yields of the most liquid tenors for each country. Therefore, the index includes the following maturities:

- 3 Months T-Bill;
- 2 years Government Bond;
- 5 years Government Bond;
- 7 years Government Bond;
- 10 years Government Bond;
- 20 years Government Bond;
- 30 years Government Bond;

Moreover, given the significant influence that stock markets have on the fixed income market, we also include the returns on the local equity indexes.. We also slightly adjust for the inflation rate. Therefore, our Local Bond Return Index takes the following form:

$$\begin{cases} Index_0 = 100 \\ R_t = 0.12 \cdot (r_{3M,t} + r_{2Y,t} + r_{5Y,t} + r_{7Y,t} + r_{10Y,t} + r_{20Y,t} + r_{30Y,t} + r_{Equity,t}) + 0.04 \cdot r_{infl}, \\ Index_t = Index_{t-1} + \prod_{i=1}^{t}(1 + R_i) \end{cases}$$

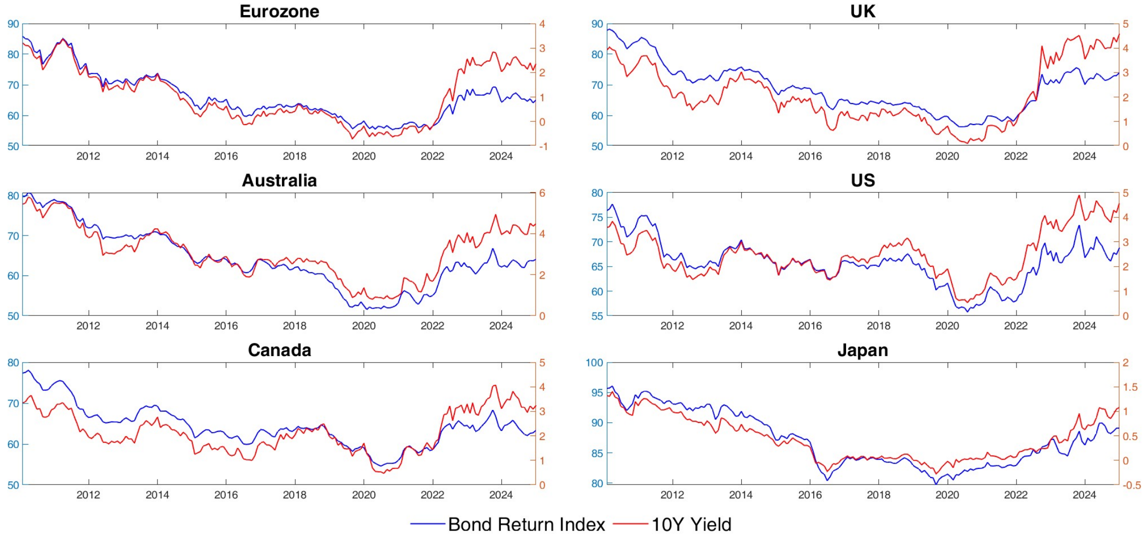


Figure 11: Bond Return Index Trajectory vs 10 Years Yield

In Figure 11 we observe that in the final part of the curve, during the interest rate spike period, the inflation component that was added to the index calculation tends to significantly lower its value, despite its relatively small weight within the formula.

1.4.2 The signal:

The strategy goes long duration if our Bond Return Index for each country is above its average for the past one, two, three, six or twelve months, and short otherwise. As mentioned previously, a threshold has been applied to avoid false trading signals. One advantage of comparing the current level to its past average rather than say, the one month-ago level, is that it avoids trading due to base effects instead of recent market movements. The signal rebalanced on the last day of each month, based on the previous day's closing prices, as do the two signals that follow.

1.4.3 Results 1st Set of Countries

	Eurozone	UK	Australia	US	Canada	Japan	Combined
1m	-0.27	0.56	1.71	-0.13	1.09	0.47	0.83
2m	-0.19	0.79	1.14	0.21	0.74	0.27	0.76
3m	-0.06	0.42	0.80	0.26	0.41	0.18	0.49
6m	0.10	0.17	0.49	-0.02	0.37	-0.02	0.26
12m	0.08	0.18	0.54	-0.17	0.52	-0.01	0.27

Table 5: Information Ratio for different signals

All of the momentum strategies have been solidly profitable in each country, except of US and Eurozone. Over this period, the best return has come from 1-month momentum, with a return to risk of 0.83 for all six countries combined. In interpreting this result, it is important to bear in mind that 1-month momentum has performed best because the signal was long less then the other momentum, as shown in Figure 12, being able to better capture the upward movement of interest rates in recent years.

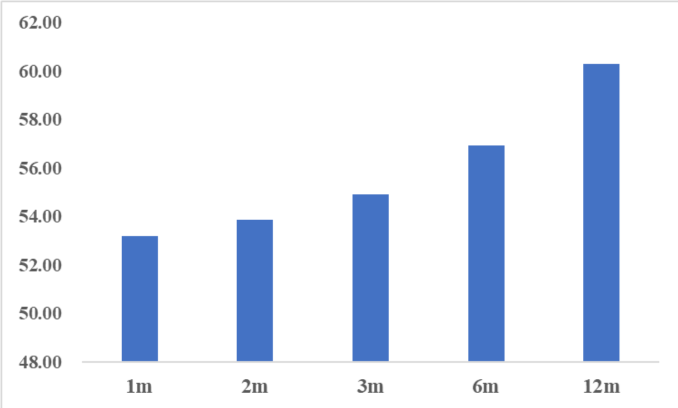


Figure 12: Proportion of months for which each signal is long

It is easy to see that a momentum strategy with such a short lookback window particularly struggles during periods of sideways movement. This is clearly evident, for instance, in the Eurozone graph, where the signals from 2016 to 2018 were discontinuous.

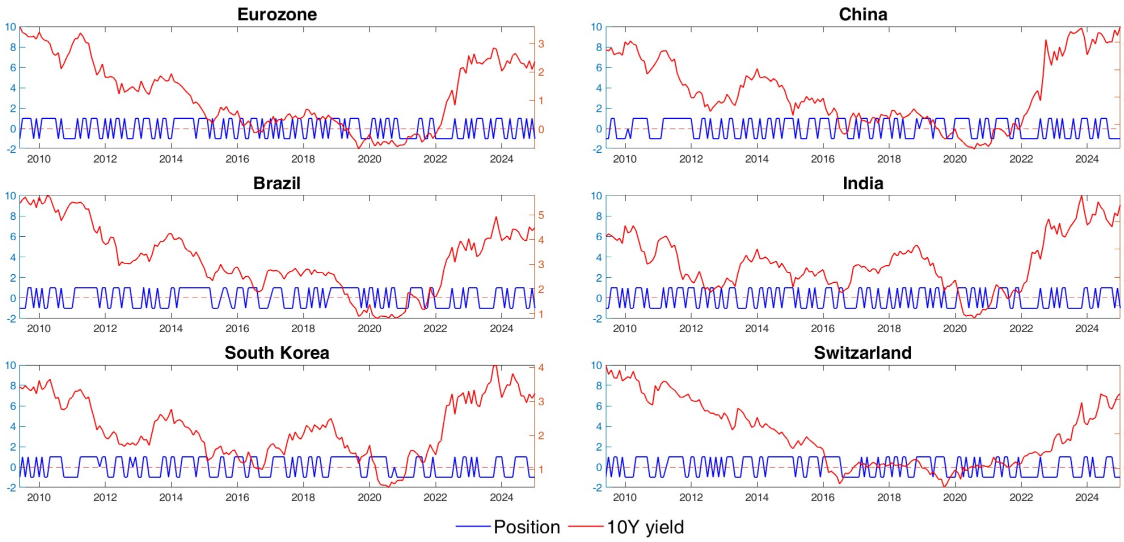


Figure 13: 1-month momentum positioning

The best signal: To choose which of the two best signals (1 month and 2 months momentum) use in the computation of the final strategy we take a look to the correlation matrices of the two strategies

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Eurozone	1.00						
UK	0.45	1.00					
Australia	0.21	0.21	1.00				
US	0.54	0.32	0.21	1.00			
Canada	0.38	0.45	0.28	0.41	1.00		
Japan	0.05	0.12	0.19	0.13	0.11	1.00	
Combined	0.73	0.72	0.56	0.72	0.71	0.27	1.00

Figure 14: 1 month Moving Average

The correlation matrix shows a significant correlation among all countries, except for Japan. The 1-month momentum still displays the best results, with lower countries correlations (average of 0.37 against 0.42 of the 2 month moving average). We then choose the 1-month omentum as the best 10 years yield curve predictor. In the table are summered the main features of the strategy:

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Annualised Return %	-1.49	5.87	15.55	0.28	8.99	1.17	4.34
Annualised Volatility %	7.10	8.46	7.49	8.08	6.87	2.59	3.83
Tracking Error Volatility %	7.15	8.49	7.56	8.13	6.89	2.60	3.86
Alpha Generated %	-1.95	4.73	12.93	-1.06	7.54	1.22	3.19
Expectancy %	0.14	0.39	0.86	0.15	0.70	0.24	0.41
Max Drawdown %	-27.35	-59.14	-90.27	-29.05	-76.18	-21.07	-50.43
Information Ratio	-0.27	0.56	1.71	-0.13	1.09	0.47	0.83
Sharpe Ratio	-0.27	0.56	1.73	-0.13	1.10	0.47	0.83
Hit Ratio %	48.94	57.98	74.47	49.47	68.62	52.66	58.51

We note the following aspects of the results:

- Australia and Canada shows Exceptional annualized return and risk-adjusted performance, driven by strong alpha and a high hit ratio. However, the extreme Max Drawdown signals significant downside risk during adverse periods.
- Combined Portfolio: Balances moderate returns with lower volatility and Drawdowns , achieving a respectable Sharpe Ratio.
- Eurozone & US: Negative alpha and Sharpe Ratios indicate poor risk-adjusted returns relative to benchmarks. Both regions also show weak hit ratios.
- Japan: Low returns and volatility reflect defensive positioning, but modest Sharpe and alpha suggest limited upside.
- Extreme Drawdowns in Australia (-90.27%), Canada (-76.18%), and the UK (-59.14%) highlight vulnerability to market shocks, likely due to concentrated exposures or leverage.
- The Combined Portfolio mitigates volatility (3.83% vs. regional averages of $\tilde{6}$-8%) and improves consistency (Hit Ratio: 58.51%), though returns remain subdued (4.34%). This suggests diversification reduces risk but dilutes upside.

1.4.4 Results 2nd Set of Countries

Unlike what we observed for developed economies, in emerging markets, the strategy was not particularly effective during the period from January 2015 to December 2024.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
1m	1.42	0.33	-0.88	-0.43	-0.26	-0.56	-0.59	-0.42
2m	1.37	-0.15	-0.95	-0.14	-0.65	-0.82	-0.19	-0.61
3m	1.12	0.09	-1.09	0.02	-0.47	-0.71	0.08	-0.33
6m	0.71	-0.16	-0.72	0.16	-0.11	-0.88	-0.43	-0.55
12m	0.81	-0.05	-0.41	0.16	0.36	-0.88	-0.80	-0.43

Table 6: Information Ratio for different signals

The best signal: To choose which of the two best signals (1 month and 3 months momentum) use in the computation of the final strategy we take a look to the correlation matrices of the two strategies.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
China	1.00							
Brazil	0.10	1.00						
India	0.03	-0.03	1.00					
South Korea	0.06	0.17	0.25	1.00				
Switzerland	-0.11	0.03	0.14	0.33	1.00			
South Africa	0.01	0.01	-0.01	-0.03	-0.04	1.00		
Indonesia	-0.19	0.26	0.13	0.26	0.10	0.04	1.00	
Combined	0.10	0.69	0.29	0.54	0.38	0.39	0.52	1.00

Figure 15: 1 month Moving Average

Also for emerging markets the 1-month momentum shows the lowest correlations, with an average coefficient of 0.16. It is notable how the geneal correlations are much lower then the developed markets.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Annualised Return %	5.55	14.62	1.07	-1.59	-2.04	-0.93	-0.71	1.78
Annualised Volatility %	3.66	20.70	5.61	7.22	6.66	13.57	10.40	4.01
Tracking Error Volatility %	3.65	20.70	5.59	7.24	6.68	13.58	10.43	4.01
Alpha Generated %	5.18	6.74	-4.93	-3.13	-1.74	-7.61	-6.12	-1.68
Expectancy %	0.74	0.48	0.26	-0.09	-0.06	0.00	0.16	0.20
Max Drawdown %	-42.50	-77.24	-15.76	-17.70	-23.34	-36.42	-28.24	-19.30
Information Ratio	1.42	0.33	-0.88	-0.43	-0.26	-0.56	-0.59	-0.42
Sharpe Ratio	1.42	0.33	-0.88	-0.43	-0.26	-0.56	-0.59	-0.42
Hit Ratio %	66.67	60.00	54.17	45.00	45.83	47.50	51.67	52.50

We note the following aspects of the results:

- Brazil had the highest return (14.62%), but it also had extremely high volatility (20.70%).
- China's strong return (5.55%) with low volatility (3.66%) made it the most efficient market for the momentum strategy.
- Annualized volatility in Brazil (20.70%) and South Africa (13.57%) highlights the instability of emerging market bonds.
- The combined portfolio volatility (4.01%) suggests that diversification helped smooth out some of the risk.
- The alpha was in Brazil (6.74%), despite high volatility, indicating that bond momentum worked well in this market. China had the highest Information Ratio (1.42) meaning it had the best risk-adjusted performance.

- The strategy suffered its largest Drawdown in Brazil (-77.24%), reflecting the extreme risk associated with Brazilian bonds.
- China (66.67%) and Brazil (60.00%) had the highest hit ratios, meaning the strategy was able to identify a factor that actually influences the market's movement.
- The strong performance in Brazil can be linked to high interest rates and significant monetary policy shifts, which create strong momentum opportunities. China's bond market benefited from capital inflows, policy-driven stability, and relatively lower volatility, making momentum trading effective.
- South Korea (-1.59%) and South Africa (-0.93%) struggled, likely due to inconsistent policy shifts or economic uncertainty reducing the effectiveness of momentum trades.
- The combined portfolio return (1.78%) with a volatility of 4.01% suggests that diversifying across multiple bond markets helped smooth returns. However,negative Information Ratios (-0.42) indicates that the overall momentum strategy underperformed on a risk-adjusted basis.

1.5 IBES Earnings Revision Ratio Momentum

Measures of economic momentum signal comes from equity analysts' earnings forecasts. In particular, we use the widely-followed earnings revision ratio, collated by the Institutional Brokers' Estimate System (IBES). This is calculated as:

$$ERR_t = \frac{ER_{up,t} - ER_{down,t}}{ER_{tot,t}}$$

Where:

- ERR_t is the Earnings Revision Ratio at time t.
- ER_{up} is the number of upward earnings revisions form t-1 to t.
- ER_{down} is the number of downward earnings revisions form t-1 to t.
- ER_{tot} is the total number of firms for which equity analysts provide 12-month-rolling earnings forecasts over the past month.

As such, it is a timely guide to whole-economy corporate earnings momentum. The monthly version is released on the Tuesday after the third Friday of each month, and is available for a wide range of equity indices, including global equities (e.g. MSCI World) and country/region indices. We interpret the revision ratio not as an equity market signal per se, but rather as a window from stock market earnings to overall economic prospects. In that respect it is similar to, and comoves closely with, the Global PMI.

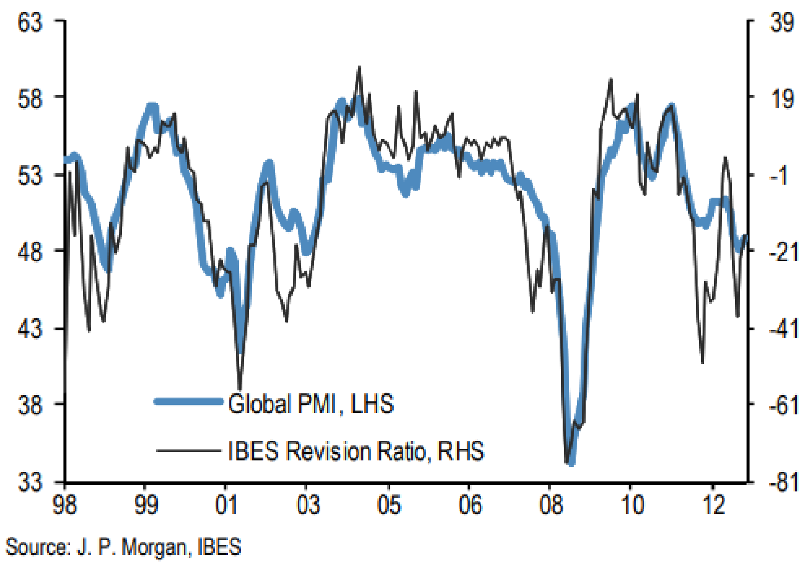


Figure 16: Global manufacturing PMI and MSCI World earnings revision ratio

Both indicators are closely related to global GDP growth. The Global Composite PMI can explain 66% of the variation in global GDP growth since 1998, while the revision ratio can explain 58%, though with the advantage of being released around a week and a half earlier. Because the revision ratio and the PMI have different coverage, and come at a slightly different point in the monthly data cycle, each measure contains information not captured by the other. [3]

1.5.1 The signal

This strategy is a pure period extension of the ones made by Mac Gorains in is paper. The aim is to check whether the strategy still brings good performance in the 10 years zcb yield movements prediction. For the sake of comparability we implement the same combinations. The Strategy relates bond returns to a monthly change in the Earing Revision ratios with the following relation:

$$Position_t = \begin{cases} -1 & \text{if } ERR_{t,n} > ERR_{t-p,n} \\ 1 & \text{if } ERR_{t,n} < ERR_{t-p,n} \\ 0 & \text{otherwise} \end{cases}$$

Where:

- p is the look-back number of periods.
- $ERR_{t,p}$ is the Earnings revision ratio signal observe for the n-th country in the t-th period.

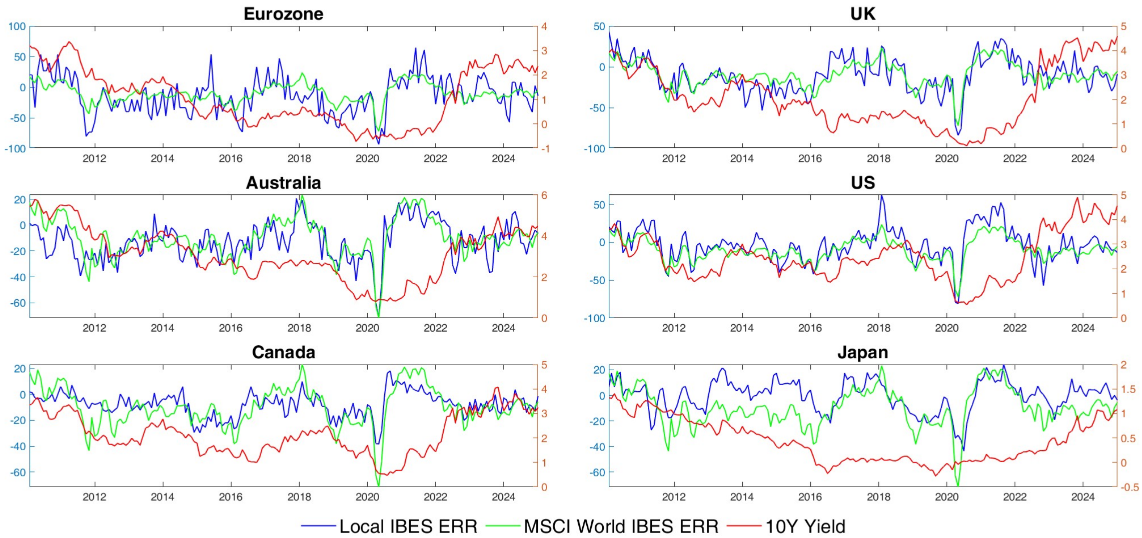


Figure 17: IBES Earing Revision ratios trajectories, from IBES

Basically the strategy goes long duration if the ERR fell over the previous observation, short if the ERR increases and take no position if it remains the same. We tested a look-back window of 1,2 or 3 periods. We also tested how the strategy performs taking as a signal:

- the local ERR, calculated on the base of the local equity index Index surveys;
- the global ERR, calculated on the base of the MSCI World Index surveys;
- a combination of the previous two signals, then going long if both the global and local ERR fell over the previous observations, short if both increase and take no position otherwise.

1.5.2 Results 1st Set of Countries

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Local							
1m	0.15	0.01	0.31	-0.20	-0.14	-0.04	0.04
2m	0.02	-0.44	-0.07	0.01	-0.25	-0.01	-0.27
3m	-0.27	-0.51	0.06	0.01	-0.21	0.24	-0.29
Global							
1m	0.22	0.10	-0.07	0.09	-0.02	0.24	0.07
2m	0.13	0.03	-0.26	0.03	-0.20	-0.07	-0.08
3m	0.01	0.03	-0.31	0.17	-0.13	0.21	-0.05
Combined							
1m	0.12	0.13	0.21	-0.05	-0.07	0.15	0.07
2m	0.09	-0.25	-0.19	0.04	-0.26	-0.02	-0.16
3m	-0.10	-0.30	-0.14	0.12	-0.19	0.32	-0.14

Table 7: Information Ratio for different signals

The table shows significantly less encouraging results compared to those found by Mac Gorain. Only the combinations with a 1-month momentum display positive performance, albeit to a small extent. Therefore, we would be inclined to select the Global and Combined signals with a 1-month look-back period as candidates. However, given the equal Information Ratio (both at 0.07), we choose the combined signal between the Local ERR and Global, leveraging the diversification of the ratios.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Eurozone	1.00						
UK	0.64	1.00					
Australia	0.41	0.54	1.00				
US	0.61	0.60	0.61	1.00			
Canada	0.54	0.50	0.59	0.63	1.00		
Japan	0.29	0.27	0.29	0.30	0.19	1.00	
Combined	0.78	0.81	0.78	0.86	0.79	0.40	1.00

Figure 18: 1 month change in ERR local and EER MSCI Global Index

Figure 18 reveals a strong correlation across the entire matrix, despite using a diversified signal, with an average correlation of 0.55. In the table below are reported the main results of this strategy.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Annualised Return %	1.14	2.05	3.96	0.99	1.02	0.27	1.42
Annualised Volatility %	5.61	7.00	6.59	7.38	5.89	2.10	3.87
Tracking Error Volatility %	5.60	7.00	6.56	7.39	5.86	2.10	3.86
Alpha Generated %	0.69	0.90	1.35	-0.35	-0.43	0.32	0.26
Expectancy %	0.14	0.20	0.38	0.04	0.21	0.14	-0.12
Max Drawdown %	-23.46	-32.29	-46.62	-25.24	-15.71	-7.71	-21.03
Information Ratio	0.12	0.13	0.21	-0.05	-0.07	0.15	0.07
Sharpe Ratio	0.12	0.13	0.20	-0.05	-0.07	0.15	0.07
Hit Ratio %	69.68	72.34	80.32	64.89	72.87	69.52	57.98

We note the following aspects of the results:

- Returns vary considerably by region, with Australia leading at 3.96% and Japan lagging at 0.27%; the overall combined return is 1.42%. These differences suggest that earnings revisions may have stronger predictive power in markets with more transparent or responsive earnings data (e.g., Australia and the UK), while in other regions, such as Japan, market dynamics may dampen the signal's effectiveness.

- Annualized volatility ranges from 2.10% in Japan to 7.38% in the US, with a combined volatility of 3.87%. Higher volatility in markets like the US and UK could reflect more rapid market reactions to earnings news and greater price sensitivity, whereas the lower volatility in Japan may indicate a more stable bond environment or a less pronounced response to earnings revisions.

- Positive expectancy in individual regions implies that on average, trades tended to be profitable. However, the slight negative combined expectancy suggests that gains in some regions are offset by weaker performance or more marginal opportunities in others, pointing to an uneven effectiveness of the signal across markets.

- The large Drawdowns, especially in Australia, highlight the potential risk exposure during adverse periods.

- Positive Information Ratios indicate that, on a risk-adjusted basis, the strategy has been successful in some regions by capturing value beyond the benchmark. Negative ratios in the US and Canada suggest that in these markets the additional risk did not translate into superior performance.

- A high hit ratio in many regions implies that a large proportion of trades were winners, particularly in Australia, which supports the effectiveness of the earnings revision signal there. The lower combined hit ratio, however, may indicate that when aggregating across diverse markets, the overall signal effectiveness is diluted.

1.5.3 Results 2nd Set of Countries

	China	**Brazil**	**India**	**South Korea**	**Switzerland**	**South Africa**	**Indonesia**	**Combined**
Local								
1m	-0.28	-0.11	-0.49	0.27	0.47	-1.02	-1.22	-0.79
2m	-0.25	-0.58	-1.28	-0.30	0.16	-0.53	-0.71	-0.93
3m	-0.04	-0.42	-0.90	-0.13	-0.17	-0.53	-0.84	-1.01
Global								
1m	0.47	-0.42	-0.60	-0.42	0.79	-0.81	-0.55	-0.49
2m	0.18	-0.46	-0.87	0.09	0.07	-0.74	-0.55	-0.58
3m	0.36	-0.30	-1.28	-0.01	-0.35	-0.48	-0.56	-0.62
Combined								
1m	0.18	-0.28	-0.66	-0.07	0.79	-1.21	-1.04	-0.73
2m	0.03	-0.61	-1.58	-0.09	0.19	-0.72	-0.74	-0.82
3m	0.27	-0.39	-1.46	-0.05	-0.30	-0.60	-0.94	-0.90

Table 8: Information Ratio for different signals

In the second set of countries, the combined portfolio's information ratio shows poor results. Except for Switzerland, 10-year yields in other countries seem unaffected by analysts' forecasts, with consistently negative return-to-risk ratios. China shows a slight connection to ERR, with an information ratio of 0.47 for the global signal. The best-performing combinations are the 1-month and 2-month changes in the MSCI Index ERR. Since the global signal is uniform across countries, we select the combination with the highest return-to-risk ratio. So the 1 month change in the global index is been chosen.

The best signal: Below are reported the results of the trade for the period January 2015 - December 2024

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Annualised Return %	2.24	-0.90	2.64	-1.51	4.95	-3.96	-0.33	1.01
Annualised Volatility %	3.94	20.84	5.57	7.25	6.63	13.15	10.50	5.04
Tracking Error Volatility %	3.94	20.93	5.59	7.25	6.65	13.20	10.48	5.04
Alpha Generated %	1.87	-8.79	-3.36	-3.05	5.25	-10.64	-5.75	-2.45
Expectancy %	0.38	-0.01	0.31	-0.14	0.44	-0.21	-0.18	0.12
Max Drawdown %	-22.94	-56.47	-27.80	-23.21	-40.14	-45.14	-41.59	-10.84
Information Ratio	0.47	-0.42	-0.60	-0.42	0.79	-0.81	-0.55	-0.49
Sharpe Ratio	0.47	-0.42	-0.60	-0.42	0.79	-0.81	-0.55	-0.49
Hit Ratio %	60.83	50.83	59.17	47.50	62.50	45.83	46.67	54.17

Some key insights:

- Brazil (20.84%) and South Africa (13.15%) exhibit extremely high volatility.
- Switzerland (0.44%) and China (0.38%) show very the strongest expectancy with a great hit ratio ($\approx$ 60%).
- In South Africa and Indonesia, the earnings signal may not be well-correlated with bond price movements.
- The strategy struggled in emerging markets (Brazil, South Africa, Indonesia) where macroeconomic instability and market inefficiencies may have overshadowed the signal.
- The strategy worked well in more developed markets like Switzerland and China, where earnings revisions appear to provide meaningful information about bond pricing.
- Overall the strategy was able to generate a positive return (1.01% of annual return), but it was not enough to beat a high 'average' risk free rate. However the strategy shows encouraging results for the 2nd set of countries compared to other strategies, with a positive expectancy of 0.12% monthly return.

1.6 OECD Composite Leading Indicator Index Momentum

We now introduce a strategy not featured in Mac Gorain's paper, but one that, due to its characteristics, is a strong candidate for delivering outstanding performance in our model. We developed this strategy in our search for a signal that provides insight into the state of the business cycle at both global and local levels. We required a signal with sufficient data to analyze all countries and one that is backed by a reputable institution known for its effectiveness in predicting business cycles. The Composite Leading Indicator has proven to be both effective and comprehensive in these respects, ensuring complete coverage across both time and geography. In the following paragraph we sum up what the index consist of and why, in our opinion, is a good predictor f the local long term zcb yield movements.

1.6.1 Overview of the index

The Composite Leading Indicator (CLI) is an index developed by the Organisation for Economic Co-operation and Development (OECD) to provide early signals of turning points in business cycles by capturing fluctuations in economic activity around its long-term potential. A country's CLI is constructed from a carefully selected set of key short-term economic indicators, chosen because they tend to change before the broader economy does. These indicators include:

- Stock market indices;
- Building permits;
- New orders for manufactured goods;
- Interest rate spreads;
- Consumer confidence indices.

CLIs convey short-term economic movements in qualitative rather than quantitative terms, making them an excellent candidate for our model. The CLI is presented as an index value, with deviations from 100 indicating the economy's performance relative to its long-term trend, as follows:

- Above 100: Suggests that the economy is growing above its long-term trend;
- Below 100: Indicates that the economy is growing below its long-term trend;
- Rising CLI: Signals an acceleration in economic activity;
- Falling CLI: Suggests a slowdown or potential contraction in economic activity.

The CLI is widely used in policy making—where governments and central banks use it to guide monetary and fiscal policies—as well as in business planning and investment decisions, helping companies anticipate demand changes and investors assess economic conditions for portfolio adjustments. It is important to note that CLIs are compiled only for G20 countries, plus Spain and five zone aggregates.[6]

1.6.2 Is the CLI a good predictor?

The index could serves as a valuable predictor of bond yield movements by offering early signals of shifts in economic activity, which in turn influence inflation expectations, central bank policies, and investor behavior.

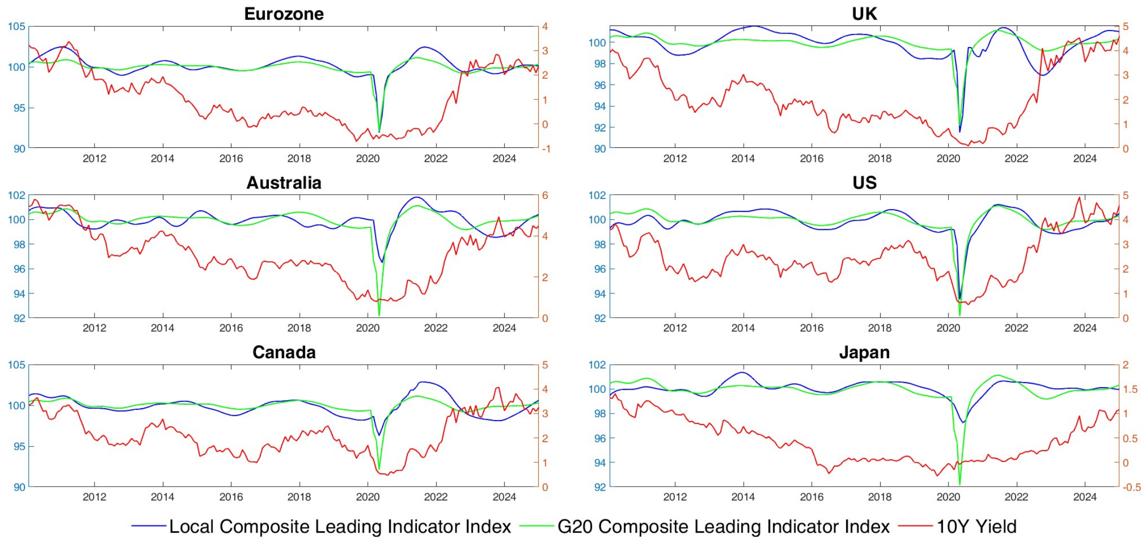


Figure 19: CLI Index trajectories for western economies

We can infer some useful information from the movements of the CLI:

- rising CLI can indicate an acceleration in economic growth. This could lead bond yields to climb as the markets anticipate higher inflation, tighter monetary policy (e.g., interest rate hikes), and a "risk-on" shift away from bonds toward equities.
- A falling CLI can be a signal of economic slowdown. This situation often precedes declining yields due to expectations of monetary easing (e.g. rate cuts), lower inflation, and a "flight to safety" into long term bonds.

This dynamic could suggest to use the momentum of the index to take a systematic position on duration: we can indeed short bond duration (to avoid losses from rising yields) with a rising CLI or adding long-duration bonds to portfolios as a recession hedge. Another good strategy could also be using the CLI as a cross - asset signal: pairing CLI trend with other indicators (e.g., inflation data) to get a stronger conviction. Indeed, since the CLI is a business cycle indicator, it surely works well when paired with with complementary indicators.

1.6.3 The signal

For our model we decided to exploit the Index using it as a momentum signal. The strategy relates bond yield returns to a monthly change in the Normalized Composite Leading Indicator with the following relation:

$$Position_t = \begin{cases} -1 & \text{if } LII_{t,n} > LII_{t-p,n} \\ 1 & \text{if } LII_{t,n} < LII_{t-p,n} \\ 0 & \text{otherwise} \end{cases}$$

Where:

- p is the look-back number of periods.
- $LII_{t,p}$ is the Normalized Composite Leading Indicator Index signal observe for the *n-th* country in the *t-th* period.

Basically the strategy goes long duration if the CLI fell over the previous observation, short if the CLI increases and take no position if it remains the same. We tested a look-back window of 1,2 or 3 periods. We also tested how the strategy performs taking as a signal:

- the local CLI;

- the global CLI, calculated by the OECD for the G20 countries ;
- a combination of the previous two signals, then going long if both the global and local CLI fell over the previous observations, short if both increase and taking no position otherwise.
-

1.6.4 Results 1st Set of Countries

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Local							
1m	0.14	0.02	-0.45	0.46	0.14	0.38	0.10
2m	0.06	0.19	-0.48	0.18	0.15	0.30	0.04
3m	0.25	0.22	-0.47	0.08	0.15	0.28	0.07
Global							
1m	0.46	0.56	0.46	0.67	0.58	0.72	0.61
2m	0.18	0.34	0.17	0.42	0.38	0.43	0.33
3m	0.03	0.13	0.01	0.19	0.13	0.28	0.11
Combined							
1m	0.34	0.35	0.01	0.64	0.42	0.64	0.44
2m	0.13	0.32	-0.17	0.34	0.33	0.45	0.23
3m	0.16	0.21	-0.26	0.16	0.18	0.33	0.11

Table 9: Information Ratio for different signals

All combinations show positive overall results. It is evident that there is a stronger relationship between yield movements and the G20 Global CLI Index. The poor performance of local signals negatively impacts the combined strategy, significantly weakening its effectiveness. A common pattern across all cases is the superior forecasting ability of the 1-month change compared to other tenors.

An interesting case is Australia, where the information ratio swings from -0.45 with the 1-month local index change to +0.46 with the 1-month global index change. This suggests that long-term Australian bonds are more closely tied to the global business cycle rather than domestic economic dynamics.

The best signal: Unlike previous cases, this time we will not favor the combined CLI to diversify the strategy's signal. In addition to exhibiting a worse risk-return profile, the heavy correlations between countries do not justify the resulting loss in profitability.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Eurozone	1.00						
UK	0.72	1.00					
Australia	0.49	0.52	1.00				
US	0.63	0.59	0.62	1.00			
Canada	0.65	0.57	0.67	0.76	1.00		
Japan	0.36	0.25	0.29	0.32	0.41	1.00	
Combined	0.83	0.81	0.79	0.86	0.87	0.46	1.00

Figure 20: Correlation Matrix with heat map

With an average correlation of 0.59, the correlation matrix for the 1 month combined signals strategy reveals an overwhelming parallelism in positioning. The highest value is observed between

Canada and the US (0.76), which is expected given their closely aligned business cycles. As previously mentioned, we therefore select the strategy that utilizes the Global signal with a 1-month look-back period as the signal for our model. Below is the table with the results.

	Eurozone	**UK**	**Australia**	**US**	**Canada**	**Japan**	**Combined**
Annualised Return %	3.72	5.82	6.40	6.61	5.57	1.80	4.34
Annualised Volatility %	7.09	8.34	8.37	7.88	7.14	2.57	5.23
Tracking Error Volatility %	7.04	8.30	8.28	7.88	7.12	2.57	5.19
Alpha Generated %	3.27	4.68	3.78	5.27	4.12	1.85	3.18
Expectancy %	0.36	0.38	0.49	0.41	0.46	0.39	0.44
Max Drawdown %	-51.01	-58.78	-60.89	-63.40	-59.10	-25.66	-48.46
Information Ratio	0.46	0.56	0.46	0.67	0.58	0.72	0.61
Sharpe Ratio	0.46	0.56	0.45	0.67	0.58	0.72	0.61
Hit Ratio %	53.72	54.26	57.98	55.32	56.91	54.79	56.38

Some interesting insight from the table above:

- Markets with more dynamic economic cycles, such as the US and Australia, seem to benefit more from early economic signals provided by theCLI, while Japan's lower return may reflect its prolonged low-growth environment.
- Stronger alpha in the US and UK implies these markets might be more sensitive to early economic trends, allowing the strategy to capitalize on deviations from risk free performance.
- All positive expectancies indicate that, on average, each countries is profitable. This consistency across markets supports the notion that the CLI provides a reliable edge in forecasting 10Y Yield movements.
- US and Australia experienced extreme level of max Drawdown (respectively –63.40% and -60.89%), while Japan had a less severe, but still significant, Drawdown (–25.66%). These values reflect periods of sharp reversals or stress when early signals might fail to anticipate rapid changes.
- The relatively high information ratios in Japan and the US suggest that, despite different return levels, the indicator is effective at generating value on a risk-adjusted basis in both stable and dynamic market conditions.
- The hit ratio results to be balanced across the markets ranging from about 53.72% (Eurozone) to 57.98% (Australia). Though the signal demonstrates similar effectiveness across all the countries under examination.
- Overall, this relative value strategy demonstrates attractive returns and effective risk-adjusted performance with a meaningful information ratio of 0.61. It is important to highlight that his profitness has been reached with a significantly high volatility (5.23%)

1.6.5 Results 2nd Set of Countries

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Local								
1m	0.48	-1.27	-0.59	-0.24	-0.12	-0.85	-1.27	-1.65
2m	0.50	-1.06	-0.50	-0.27	-0.29	-0.92	-1.10	-1.50
3m	0.28	-1.04	-0.40	-0.28	-0.10	-0.90	-0.92	-1.37
Global								
1m	-0.07	-0.28	-1.11	0.03	-0.21	-0.64	-0.91	-0.70
2m	-0.13	-0.36	-1.06	-0.17	-0.38	-0.83	-0.94	-0.89
3m	-0.23	-0.42	-1.00	-0.30	-0.45	-0.90	-0.91	-0.99
Combined								
1m	0.26	-0.91	-1.07	-0.10	-0.13	-0.87	-1.23	-1.24
2m	0.28	-0.80	-0.96	-0.23	-0.29	-1.05	-1.13	-1.27
3m	0.07	-0.83	-0.86	-0.30	-0.18	-1.08	-1.01	-1.28

Table 10: Information Ratio for different signals

The results are once again very negative. In non-westernized countries, the CLI does not demonstrate the ability to forecast long-term yield movements. As in the case of major economies, the global signal seems to have greater predictive power, with the exception of China that stands out as the only country with positive returns in the Local category across all time horizons. However the two best performing signals are the 1 month and 2 months change in the global CLI index.

The best signal: Since the two best performing signals are the 1 month and 2 months change in the global CLI index, we are going to choose the signal for the model just on the basis of the information ratio performance, since the global signal is equal across all the economies. Though we select the 1 month change as the best predictor. In the table below are reported the main features.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Annualised Return %	0.09	1.99	-0.24	1.73	-1.73	-1.79	-4.03	-0.07
Annualised Volatility %	4.01	20.96	5.61	7.25	6.71	13.14	10.41	5.05
Tracking Error Volatility %	4.00	21.13	5.61	7.22	6.71	13.14	10.42	5.05
Alpha Generated %	-0.28	-5.90	-6.24	0.20	-1.43	-8.47	-9.44	-3.53
Expectancy %	-0.05	0.09	0.02	0.28	-0.05	-0.11	-0.18	-0.01
Max Drawdown %	-20.46	-47.96	-17.98	-26.75	-25.87	-25.61	-45.42	-17.19
Information Ratio	-0.07	-0.28	-1.11	0.03	-0.21	-0.64	-0.91	-0.70
Sharpe Ratio	-0.07	-0.28	-1.11	0.03	-0.21	-0.64	-0.91	-0.70
Hit Ratio %	47.50	50.83	49.17	55.83	47.50	45.83	44.17	48.33

Some features about the strategy:

- The signal appears to work relatively better in some markets (e.g., Brazil and South Korea) but struggles in others. This may reflect how local bond markets in different countries react to the same global business cycle.
- Emerging Markets: Brazil (20.96%), South Africa (13.14%), and Indonesia (10.41%) show much higher annualized volatility compared to more stable markets like China (4.01%). At 5.05%, the overall risk profile is moderate, but this average masks significant regional disparities.
- Negative alpha suggests that the indicator fails as a drivers of bond price movements consistently.
- Values are close to zero overall (combined –0.01%), with only South Korea showing a more promising average trade return (0.28%). Hit Ratio ranges between about 44% and 56% (combined 48.33%), which is near random. Low expectancy and near even hit ratios imply that

the trading signal provides only a very narrow edge, if any, and that profitable opportunities are scarce or offset by losses. This could be due to noise in the economic data or a mismatch between the timing of the indicator's signals and actual bond market movements.

- Large Drawdowns, particularly in more volatile emerging markets, indicate that the strategy can suffer severe losses during adverse market conditions.
- Combined Returns are almost flat at –0.07%, indicating that on an aggregate basis the strategy barely produced any profit.
- The aggregated performance shows minimal returns and negative risk-adjusted metrics, suggesting that the Composite Leading Indicator, as applied in this countries, has not consistently generated value. While certain markets (like Brazil) show some promise, the overall strategy struggles to generate meaningful excess returns and poses significant risks.

1.7 Slope Value

The signals we have discussed so far are all momentum-based indicators. This means they tend to perform more effectively when combined with a measure of value, given the typically low or negative correlation between momentum signals—which follow market trends—and value signals—which often act contrarian to those trends. In bond markets, two clear measures of value stand out: real yields and the curve slope (i.e., carry. The curve slope, in particular, has proven to be a reliable predictor of both cross-market and outright bond returns.

A steep yield curve (a large positive difference between the long term and the short term yields) indicates high carry, which is often associated with a higher term premium (investors demand a more for locking in their money for a longer period). Additionally, a steep curve generally signals that loose monetary policy is supporting a weak economy, making it a slow-moving cyclical indicator that complements the more tactical economic signals discussed earlier. Moreover high carry typically indicates that investors expect stronger economic growth and/or higher inflation in the future.

When you buy a 10-year bond you potentially earn a capital gain (or loss) as the bond "rolls down" the yield curve. If the yield curve is steep and its shape remains relatively unchanged over time, as the 10-year bond ages it effectively becomes a 9-year bond, then an 8-year bond, and so on. If the yield curve's slope stays similar, the yield applicable to these shorter maturities will be lower than the original 10-year yield. This reduction in yield translates into a price increase (capital gain) for the bond, adding to the overall return.

Several studies support the notion that the yield curve slope holds predictive power for bond returns. For instance, Campbell and Shiller (1991) found that the yield spread can forecast excess returns on bonds over 1–5 year horizons, primarily because the spread encapsulates market expectations about future short-term rates and the associated term premium. Similarly, Cochrane (1999) provided an asset pricing perspective that links the yield curve slope with risk premia, reinforcing the idea that a steep curve—where long-term rates significantly exceed short-term rates—signals higher expected returns. This is because, under the roll-down effect, as a 10-year bond ages, it transitions to a part of the curve with a lower yield, thus realizing capital gains. Federal Reserve research further supports these findings, noting that a steep yield curve typically correlates with higher subsequent 10-year bond returns if term premiums dominate, while an inverted curve often indicates falling yields (and rising bond prices). [1][2]

A more nuanced approach to using the curve slope for predicting returns involves scaling it by the volatility of 10-year bond returns, resulting in a carry-to-risk measure. The rationale behind this is that investors are more willing to extend duration in pursuit of higher yields when volatility is low. A prime example of this dynamic is Japan, where the curve slope (carry) is unusually low, but carry-to-risk remains relatively high due to years of suppressed volatility caused by stagnant policy rates.

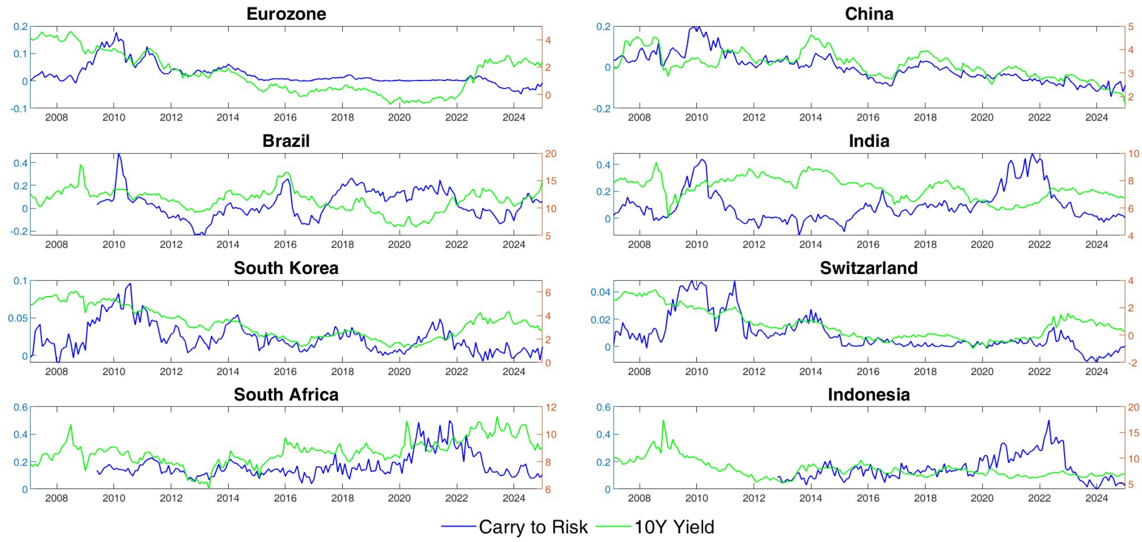


Figure 21: Carry to Risk of the Emerging Economies

We prefer using carry-to-risk over raw carry as a signal for two main reasons. First, there is the possibility of "Japanisation" in other major bond markets—characterized by flat yield curves and low volatility due to persistently low growth and unchanged policy rates. Second, historically, carry-to-risk has been a slightly more effective outright duration signal than carry alone. This makes it a more robust tool for navigating bond markets, especially in environments where traditional signals may lose their predictive power. however, we have tested both the measures and the results always displays the superiorness of the Carry to Risk as a bond returns predictor.

1.7.1 The signal

We decided to test both the value signals, either Carry and Carry to Risk:

$$\begin{cases} Carry_t = y_{10y,t} - y_{10y,t} \\ \\ Carry\ to\ Risk_t = \frac{Carry_t}{\sigma_t} \end{cases}$$

Even if the standard practice is to evaluate the carry between the 10 years and the 2 years yield, we decided to calculate the carry as the yield difference between the 10 years yield and the 3 months yield. We took this decision for consistency and comparability with the Mac Gorain's paper.

The Carry to Risk is defined as the slope scaled by the volatility (σ_T). Monthly volatility is obtained as the realized conditional daily volatility evaluated with a GARCH(1,1) model. We also tested the strategy using a EWMA daily volatility with decay factor of 0.97, but the GARCH(1,1) model displays better results.

The trading position is given by the linear function:

$$Position = 2(Rank.Perc_{t-n-1,t-n}(signal_t) - 0.5)$$

This relation permits to have a full long position on duration when the carry or the carry to risk is at its maximum over the selected time frame and a full short position when it is at its minimum. Moreover we are able to weigh the position depending on the intensity of the signal: stronger is the signal and stronger is the position, in both directions. This more nuanced approach gives us more flexibility in interpreting the signal.

We have also decided to test different time windows for calculating the signal percentile. Unlike Mac Gorain, who uses only a 10-year window, we will also test 5-year and 3-year windows.

1.7.2 Results 1st Set of Countries

Contrary to what Mac Gorain found for the period 1990–2012, the strategy has not been profitable in the subsequent period. Below, we report the results for both signals across different time windows.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Carry							
3y	-0.34	0.01	-0.77	-0.36	-0.45	-0.26	-0.53
5y	-0.18	0.15	-0.66	-0.19	-0.38	-0.35	-0.37
10y	0.06	0.26	-0.65	-0.03	-0.34	-0.39	-0.26
Carry to Risk							
3y	-0.15	0.08	-0.67	-0.16	-0.44	-0.20	-0.39
5y	0.05	0.25	-0.54	0.03	-0.29	-0.29	-0.19
10y	0.04	0.31	-0.55	0.13	-0.26	-0.31	-0.13

Table 11: Information Ratio for different signals

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Carry							
3y	-0.34	0.01	-0.77	-0.36	-0.45	-0.26	-0.53
5y	-0.18	0.15	-0.66	-0.19	-0.38	-0.35	-0.37
10y	0.06	0.26	-0.65	-0.03	-0.34	-0.39	-0.26
Carry to Risk							
3y	-0.15	0.08	-0.67	-0.16	-0.44	-0.20	-0.39
5y	0.05	0.25	-0.54	0.03	-0.29	-0.29	-0.19
10y	0.04	0.31	-0.55	0.13	-0.26	-0.31	-0.13

Figure 22: Information ratio for different signal combinations

The best signal: Even if no combination produced positive results on the period May 2009 - December 2024, we observe that Carry to Risk still represent the best predictor for the 10 Years Yield.

To choose between the 10 years and the 5 years windows we look at the correlation matrices.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Eurozone	1.00						
UK	0.55	1.00					
Australia	0.40	0.46	1.00				
US	0.46	0.70	0.51	1.00			
Canada	0.47	0.70	0.58	0.80	1.00		
Japan	0.04	-0.07	-0.02	-0.13	-0.12	1.00	
Combined	0.70	0.85	0.73	0.85	0.87	0.03	1.00

Figure 23: 5 years Carry to Risk

The 10 years widow still displays the best returns to risk ratio, so we choose it as the best predictor. The correlation matrix shows a high correlation among all countries. The only exception, in line with Bridgewater research [5], is Japan which confirms to be is an incredible country to diversify the portfolio, with close to zero correlation.

In the following table we report the main of trading the 10y bonds based on the 5 years Carry to Risk value:

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Annualised Return %	0.65	2.92	-0.01	2.04	0.20	-0.69	0.78
Annualised Volatility %	4.51	5.73	4.86	5.30	4.85	2.09	2.84
Tracking Error Volatility %	4.53	5.70	4.81	5.32	4.86	2.09	2.84
Alpha Generated %	0.20	1.77	-2.62	0.70	-1.25	-0.64	-0.38
Expectancy %	0.09	0.09	0.04	0.24	0.07	-0.10	0.12
Max Drawdown %	-17.87	-39.27	-19.68	-31.01	-15.95	-13.06	-14.23
Information Ratio	0.04	0.31	-0.55	0.13	-0.26	-0.31	-0.13
Sharpe Ratio	0.04	0.31	-0.54	0.13	-0.26	-0.31	-0.13
Hit Ratio %	52.13	51.60	48.94	60.64	50.53	40.43	53.72

We observe the following aspects of the results:

- UK and US delivered the strongest annualized returns, likely benefiting from steeper yield curves and effective carry signals during rate-hike cycles or post-QE normalization. Eurozone (0.65%) and Combined portfolio (0.78%) showed modest gains, reflecting diversification benefits but diluted regional strengths. Australia (-0.01%) and Japan (-0.69%) underperformed, with Japan's negative returns aligning with its ultra-low yield environment and flat curve.
- UK, US and Eurozone outperformed the risk free , suggesting the carry signal added value in a market with cyclical rate adjustments. On the other hand Australia (-2.62%) and Canada (-1.25%) struggled with negative alpha, indicating poor adaptation to commodity driven economic cycles or flattening curves.
- Japan's negative expectancy (-0.10%) and low hit ratio (40.43%) reflect the inefficacy of carry strategies in the last period.
- Sensitivity to commodity price swings (e.g., post-2014 oil crash, China slowdown) may have disrupted yield curve dynamics, reducing carry effectiveness. ECB's prolonged accommodative stance (negative rates, QE) flattened curves, limiting carry potential.
- Mediocre aggregate returns highlight regional divergences. Diversification muted volatility but failed to overcome structural weaknesses (e.g., Japan's drag).

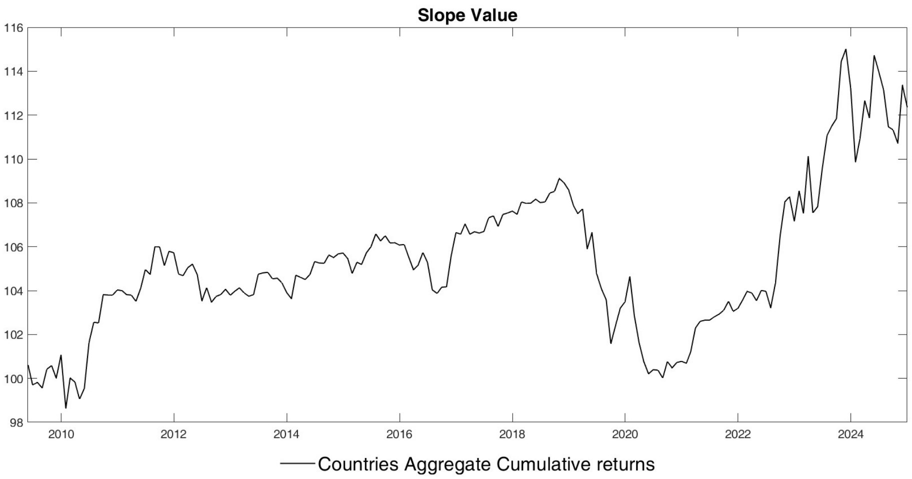


Figure 24: 10 Years Carry to Risk signal cumulative returns

Figure 24 reveals an interesting insight. The cumulative returns of the combined portfolio performed well until the onset of the downward trend in interest rates. During that period, returns were significantly compressed before recovering alongside the recent upward trend. This clearly suggests that the strategy struggles in a low-yield environment, as evidenced by Japan's weak performance.

1.7.3 Results 2nd Set of Countries

Emerging markets shows really negative performances for this strategy

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Carry								
3y	-0.63	-0.66	-1.71	-0.37	-0.11	-0.47	-0.57	-1.21
5y	-0.62	-0.48	-1.57	-0.40	-0.04	-0.48	-0.56	-1.03
10y	-0.72	-0.60	-2.30	-0.58	-0.04	-0.62	-0.72	-1.20
Carry to Risk								
3y	-0.66	-0.77	-1.87	-0.32	0.03	-0.75	-0.57	-1.37
5y	-0.67	-0.52	-1.79	-0.29	-0.09	-0.74	-0.55	-1.16
10y	-0.73	-0.67	-2.59	-0.43	0.02	-0.80	-0.60	-1.28

Table 12: Information Ratio for different signal combinations

Despite of the poor results we have identified the two most performing strategies: the 5Y Carry and the 5Y carry to Risk. The only country that displays decent values is Switzerland, which has a small but positive return to risk ratio for the 3Y and 5Y Carry to Risk signals., mainly due to the negative value of the risk free rate over the period.

The best signal: Even if no combined portfolio combination produced positive results on the period May 2009 - December 2024, we choose the best signal based on the correlations between the countries:

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
China	1.00							
Brazil	0.22	1.00						
India	0.00	0.06	1.00					
South Korea	-0.10	-0.17	0.14	1.00				
Switzerland	-0.02	0.10	0.13	-0.08	1.00			
South Africa	0.02	0.17	-0.06	0.08	-0.08	1.00		
Indonesia	0.10	0.29	0.05	-0.09	-0.06	0.32	1.00	
Combined	0.26	0.74	0.23	0.12	0.32	0.56	0.55	1.00

Figure 25: 5 years Carry to Risk

The correlation matrices once again confirm the superior predictive power of Carry to Risk compared to Carry. Therefore, we will select the 5-year Carry to Risk signal to analyze the combined strategy, which displays an average correlation of just 0.14. The results for this signal are presented in the table below.

	China	**Brazil**	**India**	**South Korea**	**Switzerland**	**South Africa**	**Indonesia**	**Combined**
Annualised Return %	-1.55	0.60	-0.72	0.17	-0.82	-0.61	1.51	0.05
Annualised Volatility %	2.89	13.86	3.81	4.73	5.49	9.81	7.12	2.92
Tracking Error Volatility %	2.89	13.99	3.75	4.73	5.51	9.84	7.07	2.96
Alpha Generated %	-1.93	-7.29	-6.72	-1.37	-0.52	-7.29	-3.91	-3.42
Expectancy %	-0.17	0.09	0.03	0.03	-0.03	0.03	-0.03	0.07
Max Drawdown %	-14.53	-35.26	-17.60	-9.83	-10.62	-20.89	-22.25	-8.30
Information Ratio	-0.67	-0.52	-1.79	-0.29	-0.09	-0.74	-0.55	-1.16
Sharpe Ratio	-0.67	-0.53	-1.76	-0.29	-0.10	-0.74	-0.55	-1.17
Hit Ratio %	42.50	53.33	50.83	50.83	48.33	50.83	48.33	52.50

We observe the following aspects of the results:

- The markets with the highest volatility has also shown positive returns , such as Brazil (0.60%) and Indonesia (1.51%), while SOuth Africa displays negative returns with a high volatility.
- There are no regions with a positive alpha generated indicating that the strategy would have not been profitable in the period January 2015 - December 2024.
- Hit ratios are really close to 50% with expectancy close to zero indicating that while the 10y-3m carry signal might work under certain conditions, it did not consistently generate favorable risk–reward opportunities during this period. This could reflect periods of muted term premiums or market noise that obscured the signal.
- Aggregating across these markets results in a low overall volatility (2.92%) and a relatively benign maximum Drawdown (–8.30%), suggesting that diversification reduced risk exposure. However, the overall negative return and negative risk-adjusted performance highlight that the benefits of diversification are not sufficient to generate profits. The combined performance implies that the economic environments across these regions post-QE have generally been less favorable for a pure carry-based strategy.

1.8 Real Yield Relative Value

In the western economies real yields have been on a downward trend since 1980s. The longevity of the downward yield trend means that, although the present negative real yields in major bond markets surely presage disappointing returns ahead, we can have little confidence about when the probable reversion to higher yields will occur. Accordingly any duration strategy based narrowly on mean reversion in real yields would have been rather unsuccessful, while a relative value strategy that invests in the continuation of the trend could have been profitable. For example, overweighting government bond markets with high real yields relative to those with low real yields would have generated solid returns since 1980s. On this line we structured our relative value strategy. We decided to go long on the 10 years bond of the countries with higher real yield and short on the 10 years bond of the countries with lower real yield. why this choice?

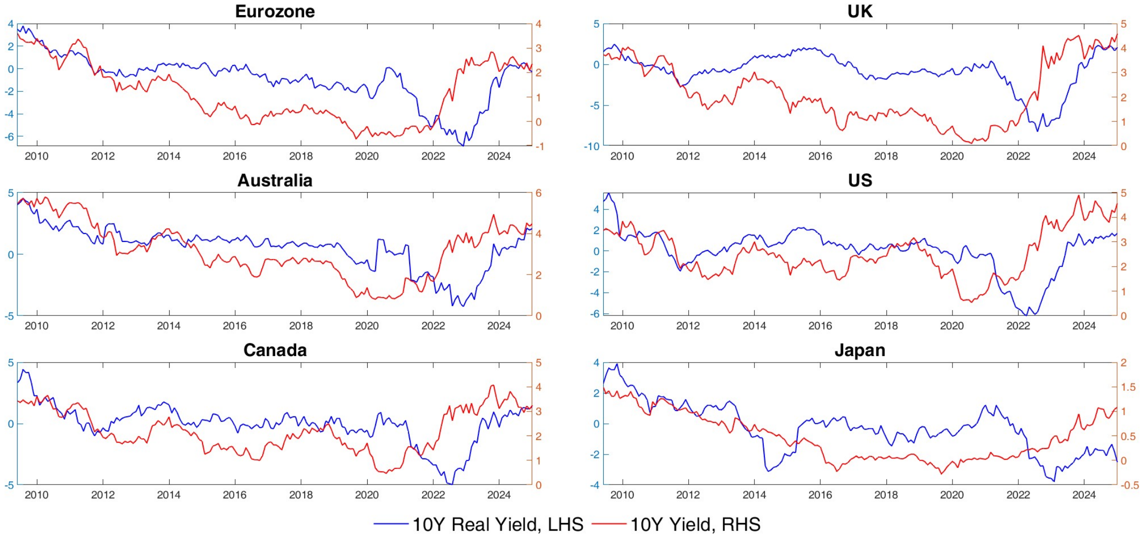


Figure 26: Real Yield of the Western Economies

Real yields represent the return on an investment after adjusting for inflation. When an asset offers a high real yield, it signals that investors are receiving a significant return above inflation. This suggests that the asset is more valuable in terms of preserving and increasing purchasing power. By going long (buying) on assets with higher real yields, you're betting that these assets will continue to offer attractive returns. As market conditions improve or as the factors supporting the high real yield persist, the price of these assets may rise further, so the yield will fall. In this way our long position on duration would be profitable. Moreover assets with higher real yields are often seen as compensating investors more adequately for the risk they suffer. This means they might be underpriced relative to their risk-adjusted potential. Conversely, assets with lower real yields provide less compensation over inflation. This can indicate that such assets are less attractive investments from a real return perspective. By shorting these assets, you're betting that these assets will underperform or lose value relative to those with higher real yields. If market corrections occur the prices of the low real yield assets might fall, enhancing our duration short position returns. The idea is that any temporary mispricing or divergence between high and low real yield assets will eventually correct. By shorting the low-yield assets, you aim to profit from the convergence when the market revalues these assets downward.

1.8.1 The signal

The real yield signal is exploited in the following way:

- for each period we estimate the real yield as:

$$r_t = y_t - i_{t-1,t}$$

where:

- r_t is our approximation of the real yield at time t;
- y_t is the 10 years yield observe at time t;
- $i_{t-1,t}$ is the annual inflation rate observe at time t;

- for each period we order the real yield of each country of the set in ascending order;
- we assign value 1 to the country with the highest real yield, which corresponds to a full long position;
- we assign value -1 to the country with the lowest real yield, which corresponds to a full short position;
- we linearly scaled all the other positions based on the relative value of their real yield.

The position can be express with the function:

$$\text{Position}(t,n) = \begin{cases} 1 & \text{if } r_{t,n} = \max(r_{t,n}) \\ -1 & \text{if } r_{t,n} = \min(r_{t,n}) \\ 2 \cdot (\frac{(r_{t,n} - \min(r_n))}{\max(r_n) - \min(r_n)}) - 1 & \text{otherwise} \end{cases}$$

Where:

- $r_{t,n}$ is the real yield for the n-th country and t-th period;
- $\max(r_{t,n})$ and $\min(r_{t,n})$ are the maximum and minimum values of the real yield in the t-th period.

With the linear scaling we are able to weigh the position depending on the intensity of the signal: stronger is the signal and stronger is the position, in both directions. This more nuanced approach gives us more flexibility in interpreting the signal.

1.8.2 Results 1st Set of Countries

Unlike other trading strategies, the implementation of the real yield signal was singular, so there are no different combinations to evaluate. In the table below are summed up the results for the western economies:

	Eurozone	**UK**	**Australia**	**US**	**Canada**	**Japan**	**Combined**
Annualised Return %	1.97	3.12	2.41	1.28	0.14	-0.13	1.35
Annualised Volatility %	4.06	7.44	6.10	6.12	4.29	2.06	1.82
Tracking Error Volatility %	4.06	7.43	6.07	6.15	4.31	2.05	1.85
Alpha Generated %	1.52	1.98	-0.21	-0.06	-1.31	-0.08	0.20
Expectancy %	0.23	0.14	0.21	0.04	0.05	0.00	0.24
Max Drawdown %	-27.57	-52.85	-39.26	-34.77	-15.79	-15.11	-21.14
Information Ratio	0.37	0.27	-0.03	-0.01	-0.30	-0.04	0.11
Sharpe Ratio	0.37	0.27	-0.03	-0.01	-0.31	-0.04	0.11
Hit Ratio %	56.38	51.60	55.32	46.28	46.81	44.15	56.91

Some interesting features:

- UK has registered the best performance with an annual return of 3.12% and an alpha generated of 1.98%. This leads to a positive information ratio, but a huge Drawdown (-52.85%). Eurozone registered good ratio performance thanks to the low vale of the benchmark risk free (annual returns are just 1.98%).
- Volatility levels range from 2.06% in Japan to 7.44% in the UK. The moderate volatility implies that the strategy's exposure is relatively controlled.

- The generation of positive alpha in some markets hints that inefficiencies in the real yield or term structure were captured effectively, while negative alphas elsewhere may point to challenges like policy-induced distortions or different yield dynamics that we did not fully account for.

- Overall, the strategy shows regional variability, with better risk-adjusted performance in the Eurozone and UK. However, the significant Drawdowns and negative alpha/information ratios in several markets point to challenges in capturing the intended relative value from the real yield signal consistently across different economic environments.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Eurozone	1.00						
UK	0.22	1.00					
Australia	-0.33	-0.35	1.00				
US	-0.25	0.19	0.19	1.00			
Canada	-0.21	-0.18	0.28	0.61	1.00		
Japan	-0.11	-0.28	0.01	-0.30	-0.07	1.00	
Combined	0.08	0.47	0.36	0.75	0.58	-0.20	1.00

Figure 27: Correlation matrix with heat map

Correlation matrix shows the correlations of this strategy are very low. The most notable data concerns a fairly inverse correlation between Japan and UK (-0.55%) not economically relevant. Due to the really close nature of the countries also US and Canada have relevant correlations. This low interdependency of the strategy between the country enhance the performance of our signal: on one hand the return to risk ratio demonstrate the strategy was not very profitable compared to the benchmark, on the other hand low correlations is telling us that the combined portfolio is well diversified.

1.8.3 Results 2nd Set of Countries

Emerging economies still displays ad results. Also a relative value strategy on the real yield was not able to beat the locals risk free in any country. In the table below are summed up the results for the emerging markets. We can observe the following:

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Annualised Return %	-0.88	-1.10	0.29	-0.52	-1.01	-0.93	1.64	0.17
Annualised Volatility %	1.80	19.54	2.57	3.03	3.48	9.63	6.90	3.07
Tracking Error Volatility %	1.81	19.52	2.65	3.09	3.51	9.63	6.86	3.09
Alpha Generated %	-1.25	-8.98	-5.71	-2.06	-0.71	-7.62	-3.77	-3.29
Expectancy %	-0.17	0.11	-0.09	0.09	-0.06	0.04	0.07	0.04
Max Drawdown %	-9.63	-57.90	-10.68	-9.12	-10.77	-22.28	-29.43	-11.75
Information Ratio	-0.69	-0.46	-2.15	-0.67	-0.20	-0.79	-0.55	-1.06
Sharpe Ratio	-0.69	-0.46	-2.22	-0.68	-0.20	-0.79	-0.55	-1.07
Hit Ratio %	39.17	50.00	42.50	49.17	43.33	47.50	48.33	47.50

- Except for Indonesia and India, the other 10-year bonds performed poorly under the strategy, failing to generate positive annual returns.

- South Africa and Brazil experienced high return volatility, but this did not translate into positive outcomes. In contrast, Indonesia's high volatility resulted in strong profits.

- The strategy failed to deliver a positive return-to-risk ratio in both negative and positive return environments. Notably, India recorded the worst results in terms of information ratio

(-2.15) despite being one of the only two countries with a positive annual return. This outcome is largely influenced by the country's high risk-free rate during the period (5.71%).

- Maximum Drawdowns were generally low, except for Brazil (-57.90%), confirming its highly risky environment.
- The underwhelming hit ratios indicate that this strategy is not well-suited for this country set. Even the combined portfolio failed to reach the 50% threshold.
- Overall, the strategy underperformed, with an information ratio of -1.06, relatively high volatility (3.07%), and an unsatisfactory annual return.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
China	1.00							
Brazil	0.27	1.00						
India	0.01	-0.07	1.00					
South Korea	0.13	-0.09	0.08	1.00				
Switzerland	0.12	-0.01	-0.03	0.55	1.00			
South Africa	0.19	0.22	0.00	-0.22	-0.28	1.00		
Indonesia	0.11	0.14	0.01	-0.30	-0.24	0.36	1.00	
Combined	0.40	0.84	0.03	0.14	0.21	0.49	0.35	1.00

Figure 28: Correlation matrix with heat map

The correlation matrix indicates generally low correlations. The most notable relationship is the strong interdependence between the signals from Switzerland and South Korea.

Considering Switzerland as a proxy for developed economies, we observe an extremely low correlation with South Africa and Brazil. However, the connection between South Africa and Brazil is relatively strong (-0.49).

The countries in the Asian region (India, China, and Indonesia) show a moderate level of correlation among themselves, with correlation values around 0.30.

1.9 The Combined Strategy

In this section, we present a present a combined strategy for trading duration throw the locals 10 years zcb using the six signals described before. For consistency, we have studied all the signals on the same period, even if a longer frame of returns was available. So the period of analysis of the combined signal will be from May 2009 to December 2024 fot he 1st set of countries and January 2015 to December 2024 for the 2nd set of countries. All the signals are rebalanced on the last working day of the month (i.e. one day after the release of the Global PMI).

1.9.1 The signal

The combined strategy has been performed as an equal weighed combination of each strategy position. We then calculate the return for each country of the derived position time series and the aggregate return across all the countries.

Figure 29 shows the correlation of returns on the six signals for the 1st and 2nd set of countries. The key point is that the returns on each signal are not very highly correlated with each other, underlining the diversification benefit of combining the bets. By far the highest correlation is between the economic signals (ERR Momentum and CLI Momentum) and equity momentum; in sample, each of these signals captures similar information. Against that, the real yield and the slope are either uncorrelated or slightly negatively correlated with all the others, illustrating the familiar benefit of combining relative value, value and momentum signals.

1st set of countries

	Equity Mom.	Bond Mom.	Slope Value	Real Yield Rel. Value	CLI Mom.	ERR Mom
Equity Mom.	1.00					
Bond Mom.	0.21	1.00				
Slope Value	0.25	-0.10	1.00			
Real Yield	-0.17	0.19	-0.30	1.00		
CLI Mom.	0.60	0.21	0.20	-0.21	1.00	
ERR Mom	0.27	0.14	0.13	-0.03	0.26	1.00

2nd set of countries

	Equity Mom.	Bond Mom.	Slope Value	Real Yield Rel. Value	CLI Mom.	ERR Mom
Equity Mom.	1.00					
Bond Mom.	-0.10	1.00				
Slope Value	0.20	-0.22	1.00			
Real Yield	0.11	-0.12	0.25	1.00		
CLI Mom.	0.64	-0.05	0.30	0.14	1.00	
ERR Mom	-0.04	0.13	0.00	0.04	-0.02	1.00

Figure 29: Correlation matrices of the duration signals

1.9.2 Results 1st Set of Countries

The six signals described before for the 1st set of countries are:

1. Equity prices, using 12-month momentum in each local equity market.
2. 1-month bond Bond momentum.
3. The 1-month Combined change in OECD Composite Leading Indicator Index of G20.
4. The 1-month change in the earnings revision ratios for both MSCI World and local markets.
5. Carry to risk i.e. the 10-year to 3-month slope, relative to realized bond market volatility with a look-back window of 10 years.
6. Real Yield relative value.

Table 13 shows the return to risk of each signal for each country. The last column shows the return to risk for each signal in all six countries combined, while the last row shows the return to risk for each country using an equally weighted combination of all six signals. The principal message this table give us is the diversification benefit of trading a range of signals in combination. Trading all six markets based on all six signals would have generated a return to risk of 0.72, net of transactions costs, far above the average return to risk for each signal, of 0.29. Similarly, the performance of the signals in Eurozone bonds is somewhat disappointing, with a return to risk of

0.25 for all six signals together, against an average of 0.63 of all the other countries. This drags down the performance of the strategy across the six markets combined since the euro bonds are relatively correlated with its returns elsewhere. In Table 13 , we combine the six signals using equal weights, i.e. with the same average absolute position size for each signal. Is it possible to improve performance by altering the weight of each signal?

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Equity momentum	0.00	0.74	-0.12	0.05	0.42	0.24	0.28
Bond momentum	-0.27	0.56	1.71	-0.13	1.09	0.47	0.83
ERR Change Momentum	0.12	0.13	0.21	-0.05	-0.07	0.15	0.07
CLI Change Momentum	0.46	0.56	0.46	0.67	0.58	0.72	0.61
Slope Value	0.04	0.31	-0.55	0.13	-0.26	-0.31	-0.13
Real Yield Relative Value	0.37	0.27	-0.03	-0.01	-0.30	-0.04	0.11
Combined	0.25	0.99	0.67	0.37	0.69	0.50	0.72

Table 13: Information Ratio for different signals

To answer this question we implement to different improvement:

- we empirically change the weights to guarantee good diversification and, possibly, a boost in the return to risk ratio, allowing the look-ahead bias of knowing which signals performed best over the period;
- we performed an optimization to reach the theoretical maximum information ratio, given the returns distribution of each signals.

The empirical relocation of weights (Figure 30) accords the highest weight by far to the bond momentum signal, which offers the best performance, then CLI momentum, and roughly similar weights to the other signals. The only exception is Slope, to which we assign just a 5.00%, since the strategy does not perform well in this last period. Instead the optimal placement of weights has seen a huge weights accorded to the bond momentum and to the CLI Momentum, while the other signals just received the minimum given by the lower boundary of the optimization. This results surely given by the huge different of the information ratio results of the singles strategies, which performs very good or very badly.

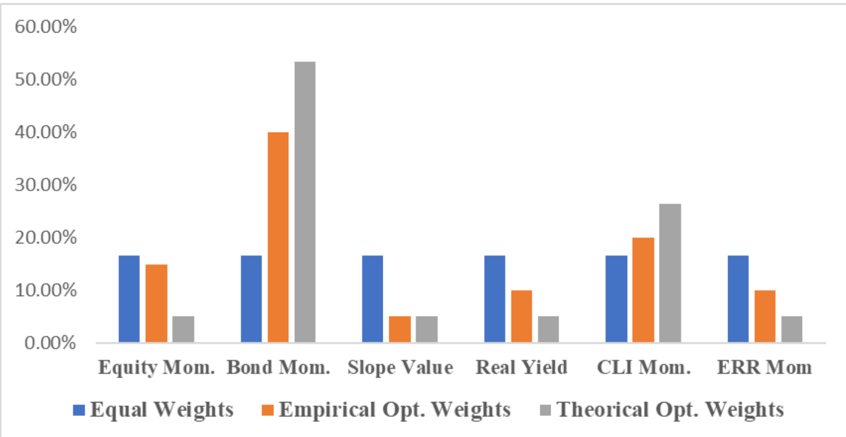


Figure 30: Weights of each signal

In the next table (Table 14) we can see both the have given a boost to the return to risk ratio. While both variations led to a substantial improvement in the ratio (≈ 0.3), there was no significant difference in returns between the discretionary and systematic optimizations. A 0.05 improvement in the combined ratio does not justify the considerable loss of diversification caused by the theoretical optimization.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Equal Weights	0.25	0.99	0.67	0.37	0.69	0.50	0.72
Empirica Optimum weights	0.06	0.96	1.32	0.23	1.05	0.63	0.94
Theorical Optimum weights	0.02	0.85	1.51	0.22	1.12	0.66	0.99

Table 14: Information Ratio for different Weight Optimizations

Table 15 summarizes the results for the empirical combination of weights of the six signals since 2009.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Annualised Return %	0.69	5.37	8.41	2.21	5.56	0.90	3.30
Annualised Volatility %	3.55	4.42	4.40	3.80	3.92	1.51	2.29
Tracking Error Volatility %	3.57	4.41	4.40	3.85	3.93	1.51	2.28
Alpha Generated %	0.23	4.22	5.80	0.87	4.11	0.95	2.15
Expectancy %	0.21	0.31	0.47	0.20	0.40	0.17	0.43
Max Drawdown %	-17.69	-55.61	-72.58	-31.44	-58.33	-15.04	-40.41
Information Ratio	0.06	0.96	1.32	0.23	1.05	0.63	0.94
Sharpe Ratio	0.06	0.95	1.32	0.23	1.05	0.63	0.94
Hit Ratio %	51.60	59.57	71.28	50.53	65.96	48.94	68.62

Table 15: Optimized weighed combination of the signals results

Here some key features:

- The results are certainly strong, with a combined information ratio of 0.94 and a hit ratio close to 69%.
- We achieved solid performance in terms of returns (3.30%) while maintaining relatively low risk, as evidenced by an annual volatility of just 2.29%.
- While the maximum Drawdown is notably close to -40%, the expectancy remains strongly positive, with a monthly expected return of 0.43%.
- It is interesting to note that the worst-performing region was the Eurozone. This makes the analysis conducted in the second chapter even more relevant. Given a return-to-risk ratio of just 0.06, it becomes crucial to assess whether it is more beneficial to trade other yield curves that, as shown, exhibit significantly better returns, even if this entails exposure to exchange rate fluctuations.

1.9.3 Results 2nd Set of Countries

The six signals described before for the 1st set of countries are:

1. Equity prices, using 12-month momentum in each local equity market.
2. 1-month bond Bond momentum.
3. The 1-month change in the G20 OECD Composite Leading Indicator Index.
4. The 1-month change in the earnings revision ratios for the MSCI World Index.
5. Carry to risk i.e. the 10-year to 3-month slope, relative to realized bond market volatility with a look-back window of 5 years.
6. Real Yield relative value.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Equity momentum	-0.10	-0.27	-1.32	0.04	-0.09	-0.41	-0.47	-0.66
Bond momentum	1.42	0.33	-0.88	-0.43	-0.26	-0.56	-0.59	-0.42
ERR Change Momentum	0.47	-0.42	-0.60	-0.42	0.79	-0.81	-0.55	-0.49
CLI Change Momentum	-0.07	-0.28	-1.11	0.03	-0.21	-0.64	-0.91	-0.70
Slope Value	-0.67	-0.52	-1.79	-0.29	-0.09	-0.74	-0.55	-1.16
Real Yield Relative Value	-1.10	0.29	-0.52	-1.01	-0.93	1.64	0.17	-1.06
Combined	0.31	-0.39	-2.57	-0.36	0.13	-1.06	-1.18	-1.23

Table 16: Information ratio with different signals weights

Table 16 shows the return to risk of each signal for each country. The last column shows the return to risk for each signal in all seven countries (plus Eurozone) combined, while the last row shows the return to risk for each country using an equally weighted combination of all six signals. A significant insight emerges immediately: in this case, diversification appears to work against the strategy. The combined information ratio stands at -1.23, compared to an average of -0.75 of all the other signals.

How can we explain this divergence? The issue lies in the nature of the return-to-risk ratio. On one hand, the signals fail to generate an excess return over the benchmark. On the other, the diversification of duration signals reduces return volatility.

Indeed, this dynamic plays out differently depending on whether the excess return is positive or negative:

- When the strategy generates positive excess returns, reducing volatility is beneficial, as it leads to higher profit per unit of risk.
- However, when the excess return is negative (i.e., a loss), higher volatility is preferable. In this scenario, the ratio reflects how much you're losing relative to the risk you're taking, and a greater volatility can help "dilute" the loss, making it less damaging in relative terms.

In short, diversification in this case reduces volatility but does not compensate with higher returns—ultimately worsening the return-to-risk tradeoff.

The performance of the signals in India bonds is totally disappointing, with a return to risk of -2.57 for all six signals together. This clearly indicates that the strategy failed to capture the key drivers of movements in the local fixed income market. A similar argument can be made for South Africa as well. China and Switzerland, instead, show modest performances with a combined information ratio of 0.31 and 0.13.

In Table 16 , we combine the six signals using equal weights, i.e. with the same average absolute position size for each signal. Is it possible to improve performance by altering the weight of each signal?

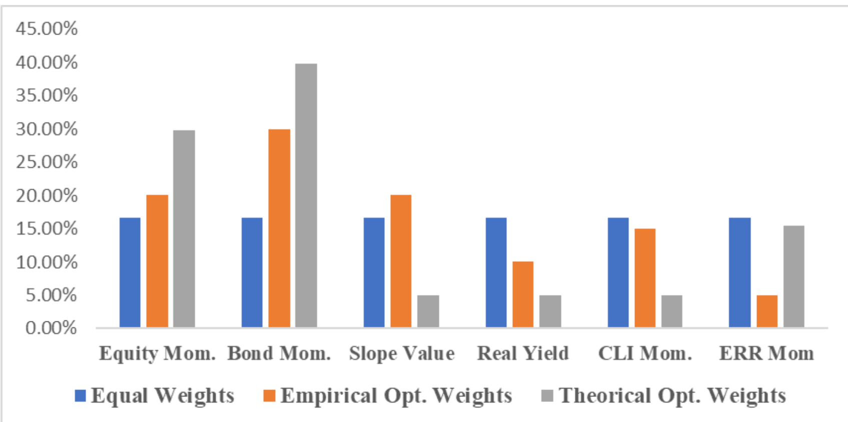


Figure 31: Weights of each signal

In the next table (Table 17) we can see that, unlike the previous case where the two optimizations yielded nearly identical results, this time only the theoretical optimization led to a substantial improvement in the return-to-risk ratio ($\approx +0.3$). Our discretionary reallocation of weights, on the other hand, managed to improve the ratio by just +0.05.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Equal Weights	0.31	-0.39	-2.57	-0.36	0.13	-1.06	-1.18	-1.23
Empirica Optimum weights	0.52	-0.14	-2.56	-0.29	-0.15	-0.98	-1.12	-1.17
Theorical Optimum weights	0.90	0.02	-1.70	-0.24	0.09	-0.90	-0.99	-0.93

Table 17: Information Ratio for different Weight Optimizations

Table 18 summarizes the results for the theoretical optimized combination of weights of the six signals since 2015.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Annualised Return %	2.51	8.05	1.17	0.70	-0.03	-0.21	-0.11	1.41
Annualised Volatility %	2.37	9.58	2.81	3.49	3.04	7.59	5.53	2.18
Tracking Error Volatility %	2.37	9.73	2.83	3.49	3.07	7.63	5.58	2.21
Alpha Generated %	2.13	0.16	-4.82	-0.84	0.26	-6.89	-5.53	-2.05
Expectancy %	0.18	0.33	0.15	0.06	0.06	0.01	0.03	0.25
Max Drawdown %	-23.31	-55.89	-14.76	-14.09	-8.97	-22.66	-21.55	-15.44
Information Ratio	0.90	0.02	-1.70	-0.24	0.09	-0.90	-0.99	-0.93
Sharpe Ratio	0.90	0.02	-1.72	-0.24	0.09	-0.91	-1.00	-0.94
Hit Ratio %	55.83	65.00	54.17	48.33	48.33	45.83	46.67	60.00

Table 18: Theoretical Optimized weighed combination of the signals results

Some key facts:

- The first thing that stands out is a clear divergence between profitability, predictive capability, and risk-adjusted returns. In the combined strategy, we observe a significantly positive hit ratio, which, however, did not translate into substantial profits. The high risk-free interest rates across various regions exceeded the combined annual return by nearly 2% (alpha combined -2.05%), ultimately weighing down performance.
- The combined return of 1.41% suggests moderate profitability, though it varies significantly across regions. Brazil (8.05%) and China (2.51%) stand out with strong performance, while other markets, especially South Africa (–0.21%) and Indonesia (–0.11%), struggled.
- The strategy appears to be more effective in higher-yielding emerging markets (e.g., Brazil, China), where fixed-income instruments typically offer higher carry. Poor performance in South Africa and Indonesia suggests that local economic conditions, monetary policy shifts, or liquidity constraints may have weakened the strategy's effectiveness.
- Brazil (9.58%) and South Africa (7.59%) exhibit the highest volatility, while China (2.37%) and Switzerland (3.04%) are relatively stable. The combined volatility of 2.18% indicates an overall conservative risk profile, but regional disparities suggest varying levels of market uncertainty.
- Emerging markets naturally exhibit higher volatility due to inflation fluctuations, interest rate shifts, and geopolitical risks.
- China (2.13%) and Switzerland (0.26%) generated positive alpha, while India (–4.82%), South Africa (–6.89%), and Indonesia (–5.53%) significantly underperformed. Negative alpha in some markets indicates the presence of systematic inefficiencies that the model fails to account for.
- High Drawdowns in emerging markets (e.g. Brazil with –55.89%), point to market crises or sharp reversals in macroeconomic trends that the strategy could not adapt to.

- Brazil (0.02%) and Switzerland (0.09%) had near-neutral information ratios, indicating weak but not disastrous risk-adjusted returns, while China (0.90%) had the only strong information ratio, suggesting efficient risk-taking. India (–1.70%), South Africa (–0.90%), and Indonesia (–0.99%) exhibited poor risk-adjusted returns, indicating inefficiencies in these regions.
- Brazil (65.00%) and China (55.83%) had the highest hit ratios, meaning the majority of trades were profitable. Positive expectancy aligns with the hit ratios, with Brazil (0.33%) and China (0.18%) leading.
- South Africa (45.83%) and Indonesia (46.67%) were below 50%, implying more losing trades than winning ones.
- To sum up, the strategy performs best in Brazil and China, where both absolute and risk-adjusted returns are relatively strong, suggesting that these markets respond well to the chosen combination of signals. In contrast, India, South Africa, and Indonesia consistently underperform, likely due to structural inefficiencies, market shocks, or weak correlation between the model's signals and bond price movements.

2 FX Risk Management

While the first chapter provided an indication of the effectiveness of the model we developed, the results obtained remain partial. Since this is an international strategy, it is unlikely that profits will be kept within their respective countries or maintained in local currencies. For an investor—particularly a European one—there is the necessity to convert profits into their home currency, introducing currency risk. [7] In this second part of the paper we are going to deal with the FX risk management.

When dealing with exchange rate risk in bond asset allocation, two key aspects must be considered:

1. *Currency Return Risk*: This refers to the appreciation or depreciation of foreign currencies over time, which directly impacts the final returns when converting profits back into the base currency. Even if the bond strategy itself is profitable in local terms, unfavorable exchange rate movements can erode—or even nullify—those gains.

2. *Currency Volatility Risk*: Exchange rate fluctuations introduce additional uncertainty and variability to the performance of the strategy. Even if the underlying bond investments are relatively stable, currency movements can amplify overall portfolio volatility, potentially leading to unintended risk exposure.

Effectively managing these risks is crucial for ensuring that the returns generated by the bond strategy are not significantly diminished by exchange rate fluctuations. In the following sections, we will explore potential hedging techniques and strategic considerations that can help mitigate the impact of currency risk on fixed-income investments. We will analyze the implications of foreign investing, trying to reproduce as faithful as possible the behavior of the strategies in three different environments:

- Firstly, we will look at the combined returns of the strategies in the case of open exchange rates.

- Secondly, we will look at the combined returns of the strategies in the case of closed exchange rates. We full hedge the positions with a rolling strategy of 1-month forward contracts.

- Thirdly, we will develop a simple empirical model to forecast the movement of the FX rates to decide whether to hedge the position or remain 'at the market'.

In this case, we decided to evaluate the trading strategy using the Sharpe ratio as the benchmark. For the risk-free rate, we applied the 1-month Eurozone rate. We applied a transaction cost of 0.005% per trade, which seems quite conservative given the high liquidity of the FX markets.

2.1 Open FX Rates Model

Evaluating an international trading strategy on bonds with open FX rates and no hedging presents a multifaceted challenge in the modern financial landscape. The period from 2009 to 2024 has been characterized by significant economic events that have deeply influenced both bond yields and currency movements. Monetary policies evolved a lot during this time, contributing to the unpredictability of FX fluctuations. The lingering aftershocks of the global financial crisis added complexity to risk management practices. Shifts and evident alignment of the central bank's policies around the world further compounded the difficulty of forecasting exchange rate movements and finding a good diversification.

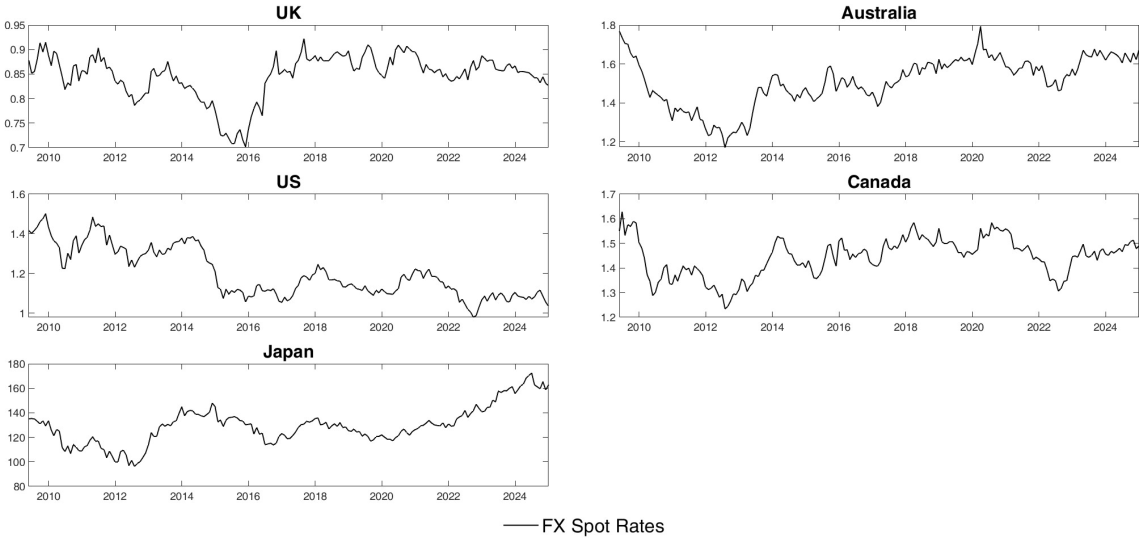


Figure 32: FX Spot Rates trajectories, form Datastream

Emerging market bonds, in particular, exhibited heightened sensitivity to changes in investor sentiment and global liquidity conditions. Political uncertainties and trade disputes also played a crucial role in driving FX volatility. Economic recovery periods were frequently interrupted by episodes of market turbulence, amplifying the potential for losses. Despite the potential for higher returns, the unhedged exposure often magnified both gains and losses. The period underscored the importance of integrating comprehensive FX risk assessments into international bond trading strategies. Market participants were forced to balance the allure of elevated yields with the inherent risks of currency volatility. The experience from 2009 to 2024 has provided valuable insights into the challenges of operating without a hedging mechanism.

2.1.1 Currencies Returns 1st Set of Countries

The following table shows the returns of the pure long only position on currencies reduced by the transaction costs. The period of analysis is still May 2009 - December 2024.

	EUR/GBP	EUR/AUD	EUR/USD	EUR/CAD	EUR/JPY	Combined
Annualised Return %	-0.79	-0.88	-1.99	-0.67	0.79	-0.52
Annualised Volatility %	6.77	8.30	8.64	7.23	10.64	5.61
Alpha Generated %	-1.25	-1.34	-2.45	-1.13	0.33	-0.98
Expectancy %	-0.14	-0.10	-0.16	-0.05	0.24	0.03
Max Drawdown %	-24.71	-34.79	-38.43	-25.39	-40.96	-22.76
Sharpe Ratio	-0.18	-0.16	-0.28	-0.16	0.03	-0.17
Hit Ratio %	47.34	48.40	46.81	50.00	57.98	52.13

Table 19: Currencies Returns 2009 - 2024

Some observations:

- The negative annualized returns against GBP (-0.79%), AUD (-0.88%), USD (-1.99%), and CAD (-0.67%) suggest that the euro has weakened against these currencies over the period.
- The positive return against JPY (0.79%) indicates that the euro has strengthened relative to the yen. This aligns with Japan's long-standing ultra-loose monetary policy, where the Bank of Japan maintained negative interest rates for much of the period.
- The highest volatility is against JPY (10.64%) and USD (8.64%), reflecting periods of sharp exchange rate movements, likely influenced by monetary policy divergence and risk sentiment.
- Maximum Drawdowns are significant across all pairs highlighting extreme periods of euro weakness.
- The hit ratio is below 50% for most pairs suggesting that the euro's movements lacked a strong consistent trend, except against the yen.
- The euro's long-term depreciation against USD, GBP, AUD, and CAD and relative strength against JPY against the JPY reflect:
  - The European Central Bank's (ECB) prolonged low-interest-rate policies, especially in the post-2008 and post-COVID periods.
  - The relative strength of commodity-driven business cycle and the US economy's resilience.
  - Brexit uncertainties surely played a role in the euro's movements against GBP.
  - Europe's stronger inflation compared to Japan, reducing the relative attractiveness of the yen.

2.1.2 Model Results 1st Set of Countries

We now examine how our 10 year zcb forecasting model perform in a open exchange rates environment. Below are reported the Information Ratio reached by each strategy taking into account FX fluctuations. For each strategy are used the combinations of signals described in the section of the combined Signal.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Equity momentum	0.00	0.46	-0.15	0.02	0.36	-0.72	0.00
Bond momentum	-0.27	0.49	1.50	-0.27	1.17	-1.17	0.47
ERR Change Momentum	0.12	-0.11	0.27	-0.22	-0.11	-0.03	-0.03
CLI Change Momentum	0.46	0.40	0.28	0.09	0.29	-0.39	0.28
Slope Value	0.04	0.16	-0.55	0.05	-0.41	-0.17	-0.26
Real Yield Relative Value	0.37	0.15	-0.17	0.12	-0.07	-0.05	0.09
Combined	0.06	0.66	1.14	-0.12	0.96	-1.12	0.43

Table 20: Information Ratio of signals with Open FX Rates

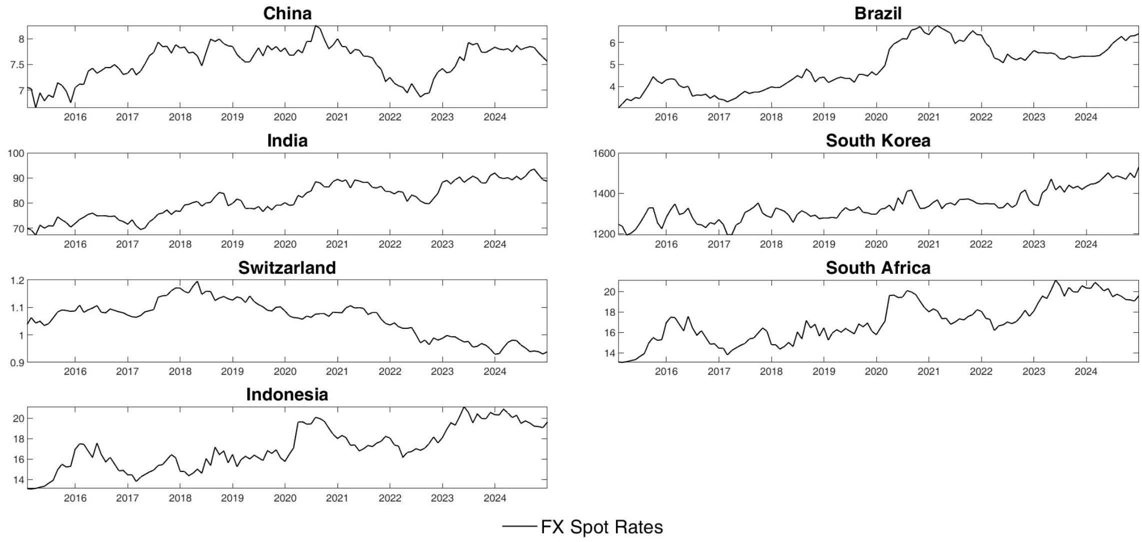
There is a clear deterioration in all profitability ratios, partly due to negative returns of the currencies and partly due to the increase in volatility. Combined strategy returns for aggregate countries decrease from 3.30% of the pure strategy (first chapter results) to 2.43%. Volatility increases from 2.29% to 2.94%. The hit ratio has also been significantly impacted, dropping from 68.62% to 57.45%. It is important to notice that the model remain profitable even taking into account FX risks, enhancing the strength of the predictions.

Observing the ratios on a country-by-country basis, we can confirm that trading foreign yield curves is generally favorable, except for the US and Japan. This suggests that, despite the profitability of the EUR/JPY exchange rate, the strategy failed to generate sufficient profits. While this result may seem surprising and contradictory to our previous findings on exchange rate performance (as the yen had a positive return), it becomes clear when analyzing the strategy's average positioning. The combined signal presents a duration positioning as shown in Table 21. There is a clear short bias that pulls down the exchange rate returns.

Eurozone	UK	Australia	US	Canada	Japan	Combined
39.74	42.31	50.32	36.22	39.10	37.82	40.92

Table 21: combined signal % of long positions to the total number of trades

2.1.3 Currencies Returns 2nd Set of Countries



The following table shows the returns of the pure long only position on currencies reduced by the transaction costs. The period of analysis is still January 2015 - December 2024.

	EUR/CNY	EUR/BRL	EUR/INR	EUR/KRW	EUR/CHF	EUR/ZAR	EUR/IDR	Combined
Annualised Return %	-0.20	6.03	1.14	1.11	-2.72	2.46	2.46	1.74
Annualised Volatility %	6.43	13.74	7.73	7.54	6.43	13.16	13.16	6.73
Alpha Generated %	-0.66	5.57	0.68	0.65	-3.18	2.00	2.00	1.28
Expectancy %	-0.09	0.35	0.15	0.32	-0.09	0.15	0.15	0.35
Max Drawdown %	-18.20	-51.76	-25.91	-20.31	-23.02	-32.85	-32.85	-25.24
Sharpe Ratio	-0.10	0.41	0.09	0.09	-0.49	0.15	0.15	0.19
Hit Ratio %	45.83	56.67	51.67	55.83	45.83	51.67	51.67	56.67

Table 22: Currencies Returns 2015 - 2024

Some topics:

- The highest annualized return is observed in EUR/BRL (6.03%), indicating a significant depreciation of the euro against the Brazilian real, followed by EUR/ZAR and EUR/IDR at 2.46%. Conversely, the euro appreciated strongly against the Swiss franc (EUR/CHF: –2.72%), reflecting Switzerland's safe-haven status.
- The Sharpe ratios indicate that most currencies provided low or negative risk-adjusted returns when measured against the European risk-free rate, with EUR/BRL (0.41) showing the best performance.
- High volatility is evident in emerging market currencies, particularly EUR/BRL (13.74%) and EUR/ZAR (13.16%), suggesting substantial fluctuations driven by macroeconomic and political factors.
- The expectancy values suggest that trades in EUR/BRL and EUR/KRW were relatively more profitable on average, while EUR/CHF was least favorable. The hit ratios, with EUR/BRL

and the combined strategy at 56.67%, suggest that momentum or trend-following strategies could be more effective in certain pairs. The maximum drawdowns highlight significant downside risks, especially in EUR/BRL (–51.76%), which reflects high market turbulence.

- The combined strategy delivers a moderate return (1.74%) with an improved Sharpe ratio (0.19), suggesting diversification benefits. Overall, the euro's performance was weak against high-yielding emerging market currencies but stronger against defensive ones like the Swiss franc.

2.1.4 Model Results 2nd Set of Countries

We now examine how our 10 year zcb forecasting model perform in a open exchange rates environment. Below are reported the Information Ratio reached by each strategy taking into account FX fluctuations. For each strategy are used the combinations of signals described in the section of the combined Signal.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Equity momentum	0.38	0.13	-0.38	0.45	-0.11	-0.26	0.30	0.19
Bond momentum	0.83	-0.60	-0.51	-0.45	-0.57	-1.36	-0.97	-1.24
ERR Change Momentum	0.02	-0.61	-0.67	-0.33	0.46	-0.78	-0.53	-0.64
CLI Change Momentum	0.05	-0.23	-0.59	0.14	-0.27	0.07	-0.05	-0.19
Slope Value	-0.30	0.06	-0.79	-0.01	0.13	-0.48	-0.08	-0.39
Real Yield Relative Value	-0.56	-0.12	-1.36	-0.55	0.16	-0.50	-0.29	-0.68
Combined	0.40	0.09	-0.54	0.38	-0.11	-0.43	0.17	-0.04

Table 23: Information Ratio of signals with Open FX Rates

In Table 24 are displayed the positioning of the combined signal. There is a clear short bias that pulls down the exchange rate returns.

China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
39.81	57.87	39.81	35.19	34.26	41.20	50.46	41.36

Table 24: combined signal % of long positions to the total number of trades

2.2 Fully Hedged Model

Reducing volatility is a goal of hedging international bonds. As Figure 33 shows, the hedge return itself has been less volatile over time than foreign currency return. The figure demonstrates that a foreign investor can never access only the underlying international bond returns in local terms; an additional return component, the currency return or the hedge return, will always exist. The low level of interest rates and the highly correlated monetary policies of central banks have flattened returns on forward contracts. Notably, there has been a significant spike in profits in Japan in recent years, as the upward movement in Eurozone interest rates was not accompanied by a corresponding increase in BoJ interest rates.

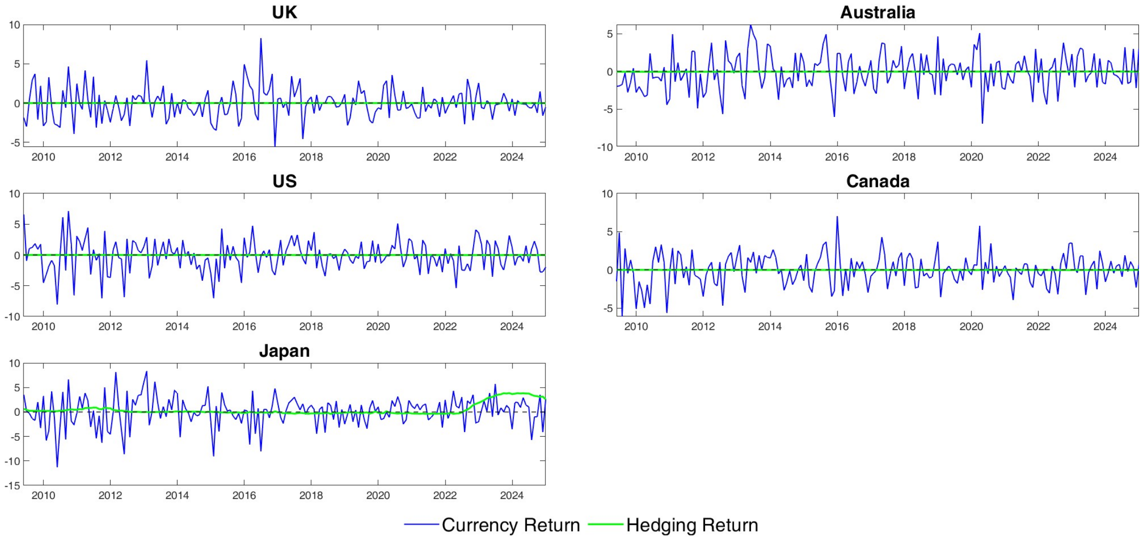


Figure 33: Spot Results and Hedging Costs

By hedging that currency risk, bond investors can reduce a portfolio's volatility over time. However, investors may not be aware of the potential effect on longer-term returns of the hedging activity itself. Currency hedging often involves the use of contracts that effectively "lock in" an exchange rate, eliminating the volatility of currency movements from a portfolio. By locking in an exchange rate, investors are now exposed to the return from hedging. No matter how the currency moves, the investor will receive (or pay) :

$$\begin{cases} Cost\ of\ Hedging = \frac{Farward_{t,t+1} - Spot_t}{Spot_t} \\ \\ Forward_t = Spot_t \cdot e^{(i_{d,t} - i_{f,t}) \cdot T} \end{cases}$$

Where:

- $Forward_{t,t+1}$ is the "forward" rate reflected in the contract with Maturity in *t+1*.
- $Spot_t$ the exchange rate in force when the hedge was initiated
- T is the time period expressed in years (for one month, $T = \frac{1}{12}$ if using annualized rates),
- $i_{d,t}$ and $i_{f,t}$ are the annualized short term interest rates for the domestic and foreign currencies respectively.

For small time periods (and modest interest rates), this can be approximated as:

$$Cost\ of\ Hedging = (i_{d,t} - i_{f,t}) * T$$

This "hedge return" is part of the investor's total return, and it effectively replaces the currency return that an investor would otherwise receive.[7]

2.2.1 Hedging Costs 1st set of countries

The following table shows the hedging costs region by region. Alserda, Thompson and Warren (2020) show that "*the interest rate differential between the currencies is by far the largest contributor to currency hedging costs* " [4], so we didn't apply transaction costs to these calculations.

	EUR/GBP	EUR/AUD	EUR/USD	EUR/CAD	EUR/JPY	Combined
Annualised Return %	-0.69	-2.14	-0.89	-1.00	0.52	-0.84
Annualised Volatility %	0.17	0.32	0.31	0.20	0.37	0.14
Alpha Generated %	-1.15	-2.60	-1.35	-1.46	0.06	-1.30
Expectancy %	-0.08	-0.10	-0.06	-0.08	-0.02	-0.09
Max Drawdown %	-10.75	-28.67	-14.31	-14.65	-7.66	-12.44
Sharpe Ratio	-6.93	-8.05	-4.39	-7.11	0.16	-9.45
Hit Ratio %	11.17	0.00	22.46	11.17	49.46	3.72

Table 25: Hedging Cost KPI

As expected, the returns on most of the covered currencies are negative due to the very low interest rates in Europe compared to those in other countries. The only exception is Japan, which exhibits positive performance. The attractive return on the yen hedge likely reflects Japan's historically low interest rates relative to Europe, resulting in positive forward points. In contrast, hedges on other currencies may incur a cost when the home currency (euro) offers a higher interest rate than the hedged currency. As we can expect the worst performance has been provide by the hedging on the EUR/AUD due to the very high interest rates of Australia.

These results underscore the importance of selective or tailored hedging strategies. Instead of a one-size-fits-all approach, European investors might consider hedging currencies on a case-by-case basis, weighing the benefits of positive carry (as seen with the yen) against the costs and risks associated with other currencies. We will develop this approach later.

2.2.2 Model Results 1st Set of Countries

We now examine how our 10 year zcb forecasting model perform in a closed exchange rates environment. Below are reported the Information Ratio reached by each strategy taking into account hedging costs. For each strategy are used the combinations of signals described in the section of the combined Signal. Just a quick clarification on the methodology. For an investor that deals with international bonds, hedging costs change sign based on whether the position is long or short because the underlying exposure to currency risk reverses. When holding a long position, the investor owns the foreign bond, exposing them to adverse currency movements; thus, hedging typically involves paying a premium linked to the interest rate differential between the euro and the foreign currency. In contrast, a short position means the investor is effectively borrowing or selling the bond, which reverses the exposure and can lead to receiving a premium instead of paying one.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Equity momentum	0.00	0.77	-0.03	0.11	0.48	0.09	0.33
Bond momentum	-0.27	0.56	1.65	-0.12	1.09	0.45	0.81
ERR Change Momentum	0.12	0.13	0.20	-0.05	-0.08	0.18	0.07
CLI Change Momentum	0.46	0.57	0.47	0.67	0.57	0.57	0.61
Slope Value	0.04	0.39	-0.61	0.25	-0.15	-0.10	-0.05
Real Yield Relative Value	0.37	0.28	-0.33	-0.11	-0.38	-0.17	-0.11
Combined	0.06	0.98	1.27	0.25	1.05	0.55	0.93

Table 26: Information Ratio of signals with Closed FX Rates

The strategy shows slitly worsened results compared to profitability without FX management, indicating that hedging costs have negatively impacted the model's overall performance.In particular, Japan's performance worsened (the information ratio dropped from 0.63 to 0.55) despite hedging contributing positively to returns. As we mentioned earlier, this seemingly contradictory outcome becomes clear when taking into account the significant short bias in the model (approximately 70% short positions). The model remains basically as profitable as the pure strategy increasing the performance with respect to a open exchange rates approach.

There is a fundamental point to highlight at this stage: except for the case of Japan, in every other scenario, it would have always been beneficial to invest in international bonds following the model we developed in this paper. This is evident from the combined information ratio results, which show that all markets outperformed the Eurozone.

2.2.3 Hedging Costs 2nd Set of countries

	EUR/CNY	EUR/BRL	EUR/INR	EUR/KRW	EUR/CHF	EUR/ZAR	EUR/IDR	Combined
Annualised Return %	0.09	-7.25	-5.41	-1.08	0.76	-6.05	-4.86	-3.44
Annualised Volatility %	0.48	1.12	0.58	0.22	0.23	0.35	0.72	0.39
Alpha Generated %	-0.37	-7.71	-5.87	-1.54	0.30	-6.51	-5.32	-3.90
Expectancy %	-0.26	-0.37	-0.37	-0.31	0.08	-0.37	-0.37	-0.37
Max Drawdown %	-6.69	-52.55	-42.34	-10.53	-7.21	-46.17	-38.79	-29.28
Sharpe Ratio	-0.78	-6.91	-10.09	-6.97	1.32	-18.35	-7.34	-10.00
Hit Ratio %	23.33	0.00	0.83	13.33	97.50	0.00	0.00	0.00

Table 27: Hedging Cost KPI

2.2.4 Model Results 2nd Set of countries

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Equity momentum	0.04	-0.15	-0.31	0.41	0.05	-0.23	-0.41	-0.22
Bond momentum	1.49	0.25	-0.99	-0.42	-0.24	-0.59	-0.62	-0.48
ERR Change Momentum	0.49	-0.42	-0.63	-0.42	0.79	-0.79	-0.53	-0.48
CLI Change Momentum	-0.21	-0.28	-1.12	-0.01	-0.26	-0.60	-0.91	-0.71
Slope Value	-0.73	-0.50	-2.36	-0.22	-0.16	-0.79	-0.78	-1.30
Real Yield Relative Value	-0.62	-0.81	-2.38	-0.55	-0.35	-1.12	-0.88	-1.55
Combined	0.08	-0.20	-0.68	0.32	0.05	-0.41	-0.59	-0.48

Table 28: Information Ratio of signals with Closed FX Rates

Here are the key observations:

- The combined information ratio in the non-hedged environment is –0.04 compared to –0.48 when fully hedged, indicating that for this set of signals, leaving FX exposure unhedged generally leads to better overall performance.
- Equity momentum performs notably better without hedging (combined IR of 0.19 versus –0.22 with hedging), suggesting that beneficial FX moves may enhance equity-driven returns.
- While bond momentum shows a strong positive signal in China with hedging (1.49 vs. 0.83), the non-hedged environment markedly improves the Real Yield Relative Value (combined IR improves from –1.55 to –0.68) and Slope Value (from –1.30 to –0.39), implying that FX exposure adds value to these signals.
- The CLI Change Momentum signal is considerably more favorable in the non-hedged case (combined IR of –0.19 versus –0.71), while ERR Change Momentum also shows a modest improvement, indicating that hedging may strip away positive currency comp
- Improvements in non-hedged signals are more pronounced in markets like Brazil, Switzerland, and Indonesia, reflecting that FX risk can contribute useful information for these strategies, whereas in some cases (e.g., China's bond momentum) partial hedging may still be beneficial.
- Overall, the benefits of retaining FX exposure can outweigh the protection offered by full hedging, though the optimal approach may vary by market and signal type.

2.3 Hedging Strategy Model

Let's now analyze the results obtained by applying an empirical strategy to determine whether, and to what extent, exchange rate risk should be hedged.

2.3.1 The Hedging Model

We have developed a decision-making model based on three factors:

- The level of interest rate differential
- The momentum of the currency
- The relative value of the interest rate differential

This approach allows us to leverage the benefits of differentiating three distinct types of signals: a value signal, a momentum signal, and a relative value signal.

Each of the three factors will determine, for each period, the percentage of the exchange rate risk to hedge: the closer the signal is to 1, the higher the hedge ratio should be. Then to calculate the aggregated percentage of hedging for each period I apply a weighed average with constant weights.

Interest Rate Differential Value The strategy based on the interest rate differential relies on a simple concept: a high and negative interest rate differential implies a high hedging cost, so a lower percentage of the position will be hedged. On the other hand a high and positive interest rate differential implies a profit form the hedging, so i bigger percentage of the position will be hedged. To calibrate the hedge ratio according to the signal's intensity, I use the same function developed for the slope strategy described in Chapter One. The hedge level will therefore be determined as follows:

$$\%Hedging = Perc.(i_{d,t} - i_{f,t})$$

where:

- $i_{d,t}$ is the domestic 1 month Interest rate at time t.
- $i_{f,t}$ is the domestic 1 foreign Interest rate at time t.
- *Perc()* is a function that calculate the Percentile of the interest rate differential at time t relative to the previous 10 years.

Currencies Momentum This second strategy is also very intuitive: since we are assuming the role of a European investor, each currency will be quoted as a "certain-to-uncertain quotation." When investing in foreign currency and needing to convert profits back to the local currency, we want to protect ourselves from the appreciation of the euro against the foreign currency. In the case of an appreciation of the euro, we would receive fewer units of foreign currency per unit of foreign exchange. The appreciation of the euro, in the case of the certain-to-uncertain quotation, translates into an increase in the exchange rate. Therefore, we will apply a momentum strategy that will trigger the hedging in the case of a descending trend in the exchange rate; otherwise, we will remain in the market. From a practical point of view, the decision to hedge or not is represented by a boolean function defined as follows:

$$\text{Momentum} = \text{spot rate}_t - \frac{1}{n}\sum_{i=t-1-n}^{t-1} \text{spot rate}_i$$

$$\%Hedging = \begin{cases} 1 & \text{if } Momentum < 0 \\ 0 & \text{Otherwise} \end{cases}$$

We used a Moving Average of 6 periods.

Interest Rate Differential Relative Value For the third signal, we used a relative value strategy. The idea is similar to what was described for the first signal, but with a mean reverting approach: the more negative the interest rate differential, the more we hedge. We apply this concept through a cross-country strategy that will hedge less in countries with a more negative interest rate differential and hedge more where the differential is higher. The intuition is that differentials will converge in the long run. This idea is applied using a linear function of the type:

$$\%Hedging(t,n) = \begin{cases} data_{t,n} = i_{d,(t,n)} - i_{f,(t,n)} \\ 1 - \frac{(data_{t,n} - \min(data_n))}{\max(data_n) - \min(data_n)} & \text{otherwise} \end{cases}$$

This function assign a full hedge where the differential is min, zero hedge where is max and apply a value to the other countries which is linearly scaled with respect to the max and the min.

2.3.2 Strategy performance 1st set of countries

Below are summarized the results of the currency trading strategy using the model outlined above.

	EUR/GBP	EUR/AUD	EUR/USD	EUR/CAD	EUR/JPY	Combined
Annualised Return %	1.18	0.14	0.73	1.42	3.29	1.20
Annualised Volatility %	4.34	2.87	5.15	4.26	7.96	2.76
Alpha Generated %	0.72	-0.32	0.27	0.96	2.83	0.74
Expectancy %	0.05	-0.03	0.05	0.07	0.32	0.27
Max Drawdown %	-21.53	-18.86	-13.32	-25.58	-48.33	-21.52
Sharpe Ratio	0.16	-0.11	0.05	0.23	0.36	0.27
Hit Ratio %	44.68	40.43	44.68	45.74	58.51	55.85

Table 29: FX Strategy Results

We note that, despite Japan historically having the lowest interest rates compared to the Eurozone, the strategy manages to generate profit even in countries with historically higher rates, thanks to the strategy's effectiveness in identifying trends of exchange rate. All ratios are enhanced, even if the strategy did not managed to perform positively in Australia, where the interest rate differential if too high.

2.3.3 Model Results 1st set of countries

The results are certainly encouraging, but we need to consider an important factor. This strategy is designed for a long-only positioning, meaning its goal is to hedge against an expected appreciation of the euro while remaining unhedged in case of a depreciation of the local currency. However, in the previous sections, we observed that our model is heavily influenced by a short bias in its positions. Intuitively, to achieve favorable results, we should reverse the strategy's approach—since an appreciation of the euro would actually be beneficial when taking short positions on international bonds. In this case, to close a short position, we would need to buy dollars and sell euros, making the currency movement work in our favor. Therefore, when applying the results of the strategy to the returns of our forecasting model, we will revert the directionality of the exchange rate forecasting strategy as follows:

$$\%Hedging = 1 - Perc.(i_{d,t} - i_{f,t})$$

$$\%Hedging = \begin{cases} 0 & \text{if } Momentum < 0 \\ 1 & \text{Otherwise} \end{cases}$$

$$\%Hedging(t,n) = \begin{cases} data_{t,n} = i_{d,(t,n)} - i_{f,(t,n)} \\ \frac{(data_{t,n} - \min(data_n))}{\max(data_n) - \min(data_n)} & \text{otherwise} \end{cases}$$

Below are reported the results we achieved applying this strategy to the forecasting model.

	Eurozone	UK	Australia	US	Canada	Japan	Combined
Equity momentum	0.00	0.74	-0.05	0.26	0.53	-0.21	0.36
Bond momentum	-0.27	0.53	1.58	-0.17	1.21	-0.55	0.78
ERR Change Momentum	0.12	0.00	0.24	-0.17	-0.14	0.18	0.02
CLI Change Momentum	0.46	0.52	0.37	0.44	0.49	0.28	0.55
Slope Value	0.04	0.33	-0.58	0.24	-0.20	0.18	-0.06
Real Yield Relative Value	0.37	0.32	-0.38	-0.10	-0.31	-0.21	-0.15
Combined	0.06	0.89	1.22	0.15	1.09	-0.32	0.87

Table 30: Information Ratio of Model Signals Strategy Hedged

The strategy we proposed managed to outperform the scenario of not hedging currency risk, but it failed to outperform an "always hedge" strategy. This confirms two fundamental points:

1. The importance of always implementing a risk management framework when dealing with international bond trading.
2. The extreme difficulty of effectively forecasting currency movements due to the numerous factors influencing FX rates.

All the countries are strongly positive, except of Japan, even if its ratio has been improved.

2.3.4 Strategy performance 2nd set of countries

Below are summarized the results of the currency trading strategy using the model outlined above.

	EUR/CNY	EUR/BRL	EUR/INR	EUR/KRW	EUR/CHF	EUR/ZAR	EUR/IDR	Combined
Annualised Return %	1.76	1.76	-0.76	2.18	-0.21	1.69	2.39	1.18
Annualised Volatility %	4.71	6.74	3.59	5.02	4.33	7.02	6.87	3.31
Alpha Generated %	1.30	1.30	-1.22	1.72	-0.67	1.23	1.93	0.72
Expectancy %	0.14	0.07	0.00	0.28	0.14	0.03	0.03	0.21
Max Drawdown %	-22.95	-27.73	-9.90	-24.41	-13.96	-22.64	-25.20	-15.16
Sharpe Ratio	0.28	0.19	-0.34	0.34	-0.15	0.18	0.28	0.22
Hit Ratio %	46.67	43.33	40.00	53.33	46.67	41.67	41.67	50.00

Table 31: FX Strategy Results

Also for this group of regions the strategy provide good results. The Sharpe Ratio against the European risk free shows a positive value, except for India and Switzerland. Volatilities are moderates across the set with a combined annual volatility of 3.31%. EUR/KRW is the only pair with a winning ratio above 50%, while the combined strategy shows a 50%, well above the 44.7% average of the countries aggregated. A positive combined expectancy confirms the profitability of the strategy.

The main objective of this strategy is to reduce the volatility without totally eroding the profitability, as it happens with a full hedge. We think the strategy accomplished its target.

2.3.5 Model Results 2nd set of countries

As we mentioned earlier, the strategy is optimized for a long positioning on currency. Therefore, its application to the forecasting model requires reversing the signals, as the second set of countries also exhibits a short bias, albeit to a lesser extent. Below we show the results of applying the FX hedging strategy to our forecasting model.

	China	Brazil	India	South Korea	Switzerland	South Africa	Indonesia	Combined
Equity momentum	0.18	0.00	-0.26	0.47	0.04	-0.27	-0.02	0.01
Bond momentum	1.28	-0.23	-0.83	-0.49	-0.44	-1.07	-0.82	-0.99
ERR Change Momentum	0.30	-0.60	-0.73	-0.43	0.72	-0.84	-0.57	-0.66
CLI Change Momentum	-0.09	-0.29	-0.91	0.02	-0.27	-0.29	-0.43	-0.51
Slope Value	-0.26	-0.27	-1.59	-0.04	0.09	-0.68	-0.51	-0.88
Real Yield Relative Value	-0.45	-0.63	-2.01	-0.40	0.15	-1.09	-0.77	-1.31
Combined	0.22	-0.07	-0.53	0.37	0.06	-0.48	-0.21	-0.29

Table 32: Information Ratio of Model Signals Strategy Hedged

Some observations:

- The dynamic FX hedging model reduces some of the adverse impact of currency fluctuations on the bond momentum strategy, leading to a noticeable improvement (nearly 40% relative improvement in the information ratio).
- China's performance improves markedly with FX hedging—likely because hedging reduces the volatility and adverse currency moves that can otherwise dilute the positive bond or equity momentum signals. Brazil's individual signals are volatile (e.g., bond momentum swings from positive 0.25 to negative –0.23), the optimized signal shows less negative performance when hedging is applied.
- India's Combined IR improves from –0.68 of the non hedged strategy to –0.53 and South Korea from -0.32 to -0.37. Both markets benefit modestly, suggesting that FX fluctuations have been a drag on these signals, and hedging helps mitigate that. In Switzerland, FX risk appears to be less material, so the hedging model does not have a large impact. South Africa worsens slightly (from –0.41 to –0.48), while Indonesia improves from –0.59 to –0.21.
- In most cases (e.g., China and South Korea), the IR for equity momentum improves when FX hedging is applied (China: from 0.04 to 0.18; South Korea: from 0.41 to 0.47). Equity momentum signals are sensitive to currency moves, so hedging helps to isolate the pure equity effect.
- For China, the bond momentum IR decreases slightly (from 1.49 to 1.28), while for other markets it remains negative or becomes slightly more negative. Since bond momentum can be affected by both interest rate differentials and FX fluctuations, hedging sometimes dampens positive signals (as in China) but generally serves to moderate the noise.
- Although the overall information ratios remain negative in both approaches (indicating that, on average, the strategies are underperforming on a risk-adjusted basis), the FX hedging approach consistently improves the performance. The fact that hedging yields a less negative (i.e., improved) information ratio suggests that FX risk is an important drag on international bond momentum strategies.

Chapter 3

Conclusions

Appendix

Below are reported the MATLAB codes we developed in this paper:

Codes Chapters 1 and 2

Main

```
clc;
clear;
close all;
%% Variables settings
simulation = 2; %simulation 1 is 1st set of countries
%simulation 1 is 2nd set of countries
if simulation == 1; load Data_thesis_developed.mat; else; load Data_thesis_emerging.mat; end
plot_if = 0; % set == 1 to plot graphs
save_if = 0; % set == 1 to save plots in folder
inv_curve = Rate_10Y; % set the curve you are using as the investiment target
inv_duration = 10; % duration of the target curve
bench_inv_curve = Rate_1M; % benchmark curve
funding_curve = Rate_1M; %set the funding curve
apply_fundig_cost = ’No’; % Set ’Yes’ or ’No’ if you want to apply funding cost
FX_hedge_str = ’Neutral’; % Set to:
%’Open’ if you want no hedging
% Closed’ if you want total hedging
% ’Strategy’ if you want strategy hedging
% ’Neutral’ if you want pure strategies returns
%% Preliminary calculations and assignment
if simulation == 1
trans_cost = 0.01; %1 bps = transaction costs to be applied per trade
trans_cost_bench = 0.005; %0.5 bps = transaction costs to be applied per trade on the benchmark
per_ana_starting_ind = 125; % index where to start the results analysis
per_ana_end_ind = 312; % index where to end the results analysis
Countries = {”Eurozone”, ”UK”, ”Australia”, ’US’, ”Canada”, ”Japan”}; %countries of the dataset
elseif simulation == 2
trans_cost = 0.04; %1 bps = transaction costs to be applied per trade
trans_cost_bench = 0.01; %0.5 bps = transaction costs to be applied per trade on the benchmark
per_ana_starting_ind = 97; % index where to start the results analysis
per_ana_end_ind = 216; % index where to end the results analysis
Countries = {”Eurozone”, ”China”, ”Brazil”, ’India’, ”South Korea”, ”Switzarland”, ”South Africa”, ”Indonesia”}; %countries of the dataset
end
% Fill missing values with Spline Interpolation
x = (1:size(Rate_10Y,1))’;
for i = 1 : size(Rate_10Y,2)
missingIdx = isnan(Rate_2Y(:,i)); % Find NaN indices
knownIdx = ~missingIdx; % Find valid indices
% Only interpolate if there are missing values
if any(missingIdx) & any(knownIdx)
Rate_2Y(missingIdx, i) = interp1(x(knownIdx), Rate_2Y(knownIdx, i), x(missingIdx), ’spline’);
end
%Choose if apply funding costs or not
if strcmp(apply_fundig_cost, ’Yes’)
funding_cost = (((1 + funding_curve(:,2:end)/100).^(1/12))-1)*100 ;
elseif strcmp(apply_fundig_cost, ’No’)
```

```
funding_cost = zeros(size(Rate_1M(:,2:end),1), size(Rate_1M(:,2:end),2));
else
error('computeValue:InvalidInput', "Set a correct value: 'Yes' or 'No'");
end
per_analysis = [dates(per_ana_starting_ind,1) dates(per_ana_end_ind,1)];
per_ana_dim = {'per_ana_starting_ind:per_ana_end_ind, :'};
n_countries = size(Rate_10Y, 2)-1;
%% Cash Long Only Strategy: Benchmark Returns
% benchmark return obtained from a long only strategy with buy and hold
% approach
benchmark_returns = (((1 + bench_inv_curve(:,2:end)/100).^(1/12))-1)*100; %benchmark returns
benchmark_returns = [benchmark_returns, sum(benchmark_returns,2) * 1/(size(bench_inv_curve,2)-1)];
% Print results
printres('Benchmark', ret_analysis(benchmark_returns(per_ana_starting_ind:per_ana_end_ind,:), benchmark_returns(per_ana_starting_ind:per_ana_end_ind,:)), per_analysis, Countries);
str_benchmark = benchmark_returns(per_ana_starting_ind:per_ana_end_ind,:);
a = ret_analysis(benchmark_returns(per_ana_starting_ind:per_ana_end_ind,:), benchmark_returns(per_ana_starting_i
%% FX Risk Management
%Evaluatio of forward rates
rate1M_diff = Rate_1M(:,2) - Rate_1M(:,3:end);
fwd_rate = FX_Spot(:,2:end) .* exp((Rate_1M(:,2)/100 - Rate_1M(:,3:end)/100)*1/12);
%Evaluation of currency returns
ret_spot = [zeros(1,size(fwd_rate,2));log(FX_Spot(2:end,2:end) ./ FX_Spot(1:end-1,2:end))*100 - 0.005];
ret_spot = [zeros(size(ret_spot,1),1), ret_spot, sum(ret_spot,2)/size(ret_spot,2)];
ret_spot_ana = ret_analysis(ret_spot(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
%Evaluation the cost of hedging
cost_hedging = (Rate_1M(:,2)/100 - Rate_1M(:,3:end)/100) .* (1/12) * 100; %calculate annual ret of hedging and then make it monthly
cost_hedging = [zeros(size(cost_hedging,1),1), cost_hedging, sum(cost_hedging,2,'omitnan')/size(cost_hedging,2)];
ret_forward_ana = ret_analysis(cost_hedging(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
%evaluate returns with a systematic strategy to decide on FX Hedging
hedgingg_perc = FX_strategy('Inverse', FX_Spot,Rate_3M, Rate_1M, Rate_infl);
fx_str = hedgingg_perc.perc .* cost_hedging(:,1:end-1) + (1-hedgingg_perc.perc) .* ret_spot(:,1:end-1) - 0.005 .* (hedgingg_perc.perc .* cost_hedging(:,1:end-1) + (1-hedgingg_perc.perc) .* ret_spot(:,1:end-1)~=0);
fx_str = [fx_str, mean(fx_str,2)];
fx_str_ana = ret_analysis(fx_str(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
% plot FX results
plot_FX_res(plot_if, save_if, FX_Spot, fwd_rate, ret_spot, cost_hedging, fx_str, dates, Countries, per_ana_starting_ind, per_ana_end_ind)
% Print FX results
printres('Spot FX', ret_spot_ana, per_analysis, Countries);
printres('Hedging Costs', ret_forward_ana, per_analysis, Countries);
printres('FX Srategy',fx_str_ana , per_analysis, Countries);
%Set the variables to apply returns to the strategies
if strcmp(FX_hedge_str, 'Closed')
FX_ret_str = cost_hedging(:,1:end-1);
fprintf('The following results are obtained with always-hedged exchange rate.\n\n')
elseif strcmp(FX_hedge_str, 'Open')
FX_ret_str = ret_spot(:,1:end-1);
fprintf('The following results are obtained with open exchange rates.\n\n')
elseif strcmp(FX_hedge_str, 'Strategy')
FX_ret_str = fx_str(:,1:end-1);
```

```
fprintf(’The following results are obtained with exchange rates hedged through an FX strategy.\n\n’)
elseif strcmp(FX_hedge_str, ’Neutral’)
FX_ret_str = zeros(size(ret_spot,1), size(ret_spot,2)-1);
fprintf(’The following results are obtained without applying exchange rate variations.\n\n’)
else
error(’computeValue:InvalidInput’, ”Set a correct value: ’Open’, ’Closed’, ’Strategy’ or ’Neutral’”);
end
%% Equity momentum Strategy
Eq_ind = log(Eq_ind); %uniform data with log
ma_eq_mom = 12; %moving average window
upper_treshold = 0.01; %tresholds to avoid false signals due to data noise
lower_treshold = -0.01;
%strategy evaluation
equity_momentum = eq_mom_strgy(ma_eq_mom, inv_curve, inv_duration, Eq_ind,upper_treshold,lower_treshold, trans_cost, funding_cost, FX_ret_str); %0 for non-filtered data,1 for filtered data
%strategy analysis
eq_mom_ana = ret_analysis(equity_momentum.strategy_return(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
%strategy plots
plot_equity_momentum(plot_if, save_if, Countries, equity_momentum, Eq_ind, inv_curve, dates, per_ana_starting_ind, per_ana_end_ind);
% Print results
printres(’Equity Momentum Strategy’, eq_mom_ana, per_analysis, Countries);
%% Bond return momentum Strategy
%first of all we build an index that tracks the bond local returns
bond_index = bond_ret_idx(Eq_ind,Rate_2Y, Rate_5Y, Rate_7Y, Rate_10Y, Rate_20Y, Rate_30Y, Rate_3M, Rate_infl);
ma_bd_mom = 1; %moving average window
upper_treshold = 0.01; %tresholds to avoid false signals due to data noise
lower_treshold = -0.01;
%strategy evaluation
bond_momentum = bd_mom_strgy(ma_bd_mom, inv_curve, inv_duration, bond_index, upper_treshold, lower_treshold, trans_cost, funding_cost, FX_ret_str);
%strategy analysis
bd_mom_ana = ret_analysis(bond_momentum.strategy_return(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
%strategy plots
plot_bond_momentum(plot_if, save_if, Countries, bond_momentum, bond_index, inv_curve, dates, per_ana_starting_ind, per_ana_end_ind);
% Print results
printres(’Bond Momentum Strategy’, bd_mom_ana, per_analysis, Countries);
%% IBES earnings estimates Strategy
lag = 1;
%strategy evaluation
IBES_change = IBES_momentum(’Global’, lag, inv_curve, inv_duration, IBES_ERR, IBES_ERR_Glo, trans_cost, funding_cost, FX_ret_str);
%strategy analysis
IBES_change_ana = ret_analysis(IBES_change.strategy_return(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
%strategy plots
plot_IBES(plot_if, save_if, inv_curve, IBES_ERR, IBES_ERR_Glo, IBES_change, Countries, dates, per_ana_starting_ind, per_ana_end_ind)
% Print results
```

printres('IBES Earnings Revision Ratio Change Strategy', IBES_change_ana, per_analysis, Countries);
%% Slope
Window_size_s = 60; %number of months
%strategy evaluation
term_spread = term_spread('Carry to Risk', 'GARCH', inv_curve, inv_duration, Rate_10Y, Rate_3M, Window_size_s, Rate_10Y_daily, dates_daily, trans_cost, funding_cost, FX_ret_str);
%strategy analysis
term_spread_ana = ret_analysis(term_spread.strategy_return(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
%strategy plots
plot_slope(plot_if, save_if, inv_curve, term_spread, Countries, dates, per_ana_starting_ind, per_ana_end_ind)
% Print results
printres('Slope Strategy' , term_spread_ana, per_analysis, Countries);
%% Real Yield
Real_Yield = Rate_10Y - Rate_infl;
%strategy evaluation
Real_yield_relval = real_yield_relval(Real_Yield, inv_curve, inv_duration, trans_cost, funding_cost, FX_ret_str);
%strategy analysis
Real_yield_relval_ana = ret_analysis(Real_yield_relval.strategy_return(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
%strategy plots
plot_real_yield(plot_if, save_if, inv_curve, Rate_infl, Real_Yield, Real_yield_relval, Countries, dates, per_ana_starting_ind, per_ana_end_ind)
% Print results
printres('Real Yield Momentum Strategy', Real_yield_relval_ana, per_analysis, Countries);
%% Leading Indicator index change strategy
lag = 1;
%strategy evaluation
li_change = leading_index_str('Global', lag, inv_curve, inv_duration, Comp_lead_idx, Comp_lead_idx_glo, trans_cost, funding_cost, FX_ret_str);
%strategy analysis
li_change_ana = ret_analysis(li_change.strategy_return(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
%strategy plots
plot_leading_mom(plot_if, save_if, inv_curve, Comp_lead_idx, Comp_lead_idx_glo, li_change, Countries, dates, per_ana_starting_ind, per_ana_end_ind)
% Print results
printres('Leading Indicator index Change Strategy', li_change_ana, per_analysis, Countries);
%% Combination of signals
%Uniform data in block matrices
returns = cat(3,equity_momentum.strategy_return, bond_momentum.strategy_return, term_spread.strategy_return, Real_yield_relval.strategy_return,li_change.strategy_return, IBES_change.strategy_return);
positions = cat(3,equity_momentum.position,bond_momentum.position,term_spread.position, Real_yield_relval.posi li_change.position, IBES_change.position);
% Strategy evaluation
comb_str = comb_strategy('Theoretical', inv_curve, inv_duration, returns, positions, trans_cost, funding_cost, FX_ret_str);
% Strategy analysis
comb_str_ana = ret_analysis(comb_str.strategy_return(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
comb_str_ana_opt = ret_analysis(comb_str.strategy_return_opt(per_ana_starting_ind:per_ana_end_ind,:), str_benchmark);
% Strategy plots
plot_comb_str(plot_if, save_if, inv_curve, comb_str, Countries, dates, per_ana_starting_ind, per_ana_end_ind);

```
% Print results
printres('Combined Strategy', comb_str_ana, per_analysis, Countries);
printres('Combined Strategy with optimum weights', comb_str_ana_opt, per_analysis, Countries);
```

Equity Momentum Strategy

```
function y=eq_mom_strgy(ma, inv_curve, duration, data, t1, t2, trans_cost, funding_cost, FX_ret)
    data = data(:,2:end);
    inv_curve = inv_curve(:,2:end);
    n_countries = size(inv_curve,2);
    mov_av1 = movmean(data,ma,1,"includenan",Endpoints="discard"); %evaluate moving average
    mov_av1 = mov_av1(1:end - 1,:);
    data = data(ma+1:end,:); %resize data
    %% Strategy Evaluation
    ctr1 = (data - mov_av1); %signal
    dummy = zeros(size(ctr1));
    dummy(ctr1 ¿ t1) = -1;
    dummy(ctr1 ¡ t2) = 1;
    dummy = [NaN(ma,n_countries);dummy];
    str_ret = calc_str_return(dummy, inv_curve, duration, FX_ret, trans_cost, funding_cost);
    %% Cumulative retunrs
    cum_str = ones(size(str_ret,1),n_countries+1);
    cum_str(1,:) = 100;
    str_ret(isnan(str_ret)) = 0;
    for j = 1 : n_countries+1
    for i = 2 : size(str_ret,1)
    cum_str(i,j) = cum_str(i-1,j) * (1+str_ret(i-1,j)/100);
    end
    end
    %% OUTPUTS
    y.position = dummy;
    y.strategy_return = str_ret;
    y.moving_avg = [NaN(ma,size(mov_av1,2));mov_av1];
    y.treshold_levels = [t1;t2];
    y.signals = ctr1;
    y.cumulative_returns = cum_str;
    y.long = sum(dummy == 1, 1)/size(dummy,1)*100;
    end
```

Bond Momentum Strategy

```
function y=bd_mom_strgy(ma, inv_curve, duration, data, t1, t2, trans_cost, funding_cost, FX_ret)
    inv_curve = inv_curve(:,2:end);
    n_countries = size(inv_curve, 2);
    mov_av1 = movmean(data,ma,1,"includenan",Endpoints="discard"); %evaluate moving average
    mov_av1 = mov_av1(1:end - 1,:);
    data = data(ma+1:end,:);
    %% Strategy Evaluation
    ctr1 = (data - mov_av1);
    dummy = zeros(size(ctr1));
    dummy(ctr1 ¿ t1) = -1;
    dummy(ctr1 ¡ t2) = 1;
    dummy = [NaN(ma,n_countries);dummy];
```

```
str_ret = calc_str_return(dummy, inv_curve, duration, FX_ret, trans_cost, funding_cost);
%signal hit rate
sig_h_r = sum((dummy(1:end-1,:) == -1 & inv_curve(2:end,:) ¿ inv_curve(1:end-1,:)) — (dummy(1:end-1,:) == 1 & inv_curve(2:end,:) ¡ inv_curve(1:end-1,:))) ./ (size(dummy,1));
%% Cumulative retunrs
cum_str = ones(size(str_ret,1),n_countries+1);
cum_str(1,:) = 100;
str_ret(isnan(str_ret)) = 0;
for j = 1 : n_countries+1
for i = 2: size(str_ret,1)+1
cum_str(i,j) = cum_str(i-1,j) * (1+str_ret(i-1,j)/100);
end
end
%% OUTPUTS
y.signals = ctr1;
y.strategy_return = str_ret;
y.position = dummy;
y.moving_avg = [NaN(ma,size(mov_av1,2));mov_av1];
y.treshold_levels = [t1;t2];
y.signal_hit_rate = sig_h_r;
y.cumulative_returns = cum_str;
y.long = sum(dummy ¿ 0, 1)/size(dummy,1) * 100;
end
```

IBES ERR Change Strategy

```
function y = IBES_momentum(region, lag, inv_curve, duration, ERR, ERR_Glo, trans_cost, funding_cost, FX_ret)
%region variable indicates if you want to take a local perspective or a
%combined signal
data = ERR(:,2:end);
data_global = ERR_Glo(:,2:end);
inv_curve = inv_curve(:,2:end);
n_countries = size(data,2);
dummy = zeros(size(data,1)-lag, n_countries);
if strcmp(region,'Local')
dummy(data(lag+1:end,:) ¿ data(1:end-lag,:))= -1;
dummy(data(lag+1:end,:) ¡ data(1:end-lag,:))= 1;
elseif strcmp(region,'Global')
dummy(data_global(lag+1:end,:) ¿ data_global(1:end-lag,:))= -1;
dummy(data_global(lag+1:end,:) ¡ data_global(1:end-lag,:)) = 1;
dummy(:,2:end) = repmat(dummy(:, 1), 1, n_countries - 1);
elseif strcmp(region,'Combined')
dummy(data_global(lag+1:end,:) ¿ data_global(1:end-lag,:) & data(lag+1:end,:) ¿ data(1:end-lag,:))= -1;
dummy(data_global(lag+1:end,:) ¡ data_global(1:end-lag,:) & data(lag+1:end,:) ¡ data(1:end-lag,:))= 1;
else
error('computeValue:InvalidInput', "Insert a valid model: 'Local', 'Global' or 'Combined'");
end
dummy = [NaN(lag, n_countries); dummy];
str_ret = calc_str_return(dummy, inv_curve, duration, FX_ret, trans_cost, funding_cost);
%signal hit rate
sig_h_r = sum((dummy(1:end-1,:) == -1 & inv_curve(2:end,:) ¿ inv_curve(1:end-1,:)) — (dummy(1:end-1,:) == 1 & inv_curve(2:end,:) ¡ inv_curve(1:end-1,:))) ./ (size(dummy,1)-1);
%% Cumulative retunrs
```

```
cum_str = ones(size(str_ret,1),n_countries+1);
cum_str(1,:) = 100;
str_ret(isnan(str_ret)) = 0;
for j = 1 : n_countries+1
for i = 2: size(str_ret,1)+1
cum_str(i,j) = cum_str(i-1,j) * (1+str_ret(i-1,j)/100);
end
end
%
y.position = dummy;
y.strategy_return = str_ret;
y.long = sum(dummy == 1, 1)/size(dummy,1) * 100;
y.Correlations = corr(dummy);
y.signal_hit_rate = sig_h_r;
y.cumulative_returns = cum_str;
end
```

OECD CLI Change Strategy

```
function y = leading_index_str(region, lag, inv_curve, duration, data, data_global, trans_cost, funding_cost, FX_ret)
data = data(:,2:end);
data_global = data_global(:,2:end);
inv_curve = inv_curve(:,2:end);
n_countries = size(data, 2);
dummy = zeros(size(data,1)-lag, n_countries);
%% Strategy Evaluation
if strcmp(region,'Local')
dummy(data(lag+1:end,:) ¿ data(1:end-lag,:))= -1;
dummy(data(lag+1:end,:) ¡ data(1:end-lag,:))= 1;
elseif strcmp(region,'Global')
dummy(data_global(lag+1:end,:) ¿ data_global(1:end-lag,:))= -1;
dummy(data_global(lag+1:end,:) ¡ data_global(1:end-lag,:))= 1;
dummy(:,2:end) = repmat(dummy(:, 1), 1, n_countries - 1);
elseif strcmp(region,'Combined')
dummy(data_global(lag+1:end,:) ¿ data_global(1:end-lag,:) & data(lag+1:end,:) ¿ data(1:end-lag,:))= -1;
dummy(data_global(lag+1:end,:) ¡ data_global(1:end-lag,:) & data(lag+1:end,:) ¡ data(1:end-lag,:))= 1;
else
error('computeValue:InvalidInput', "Insert a valid model: 'Local', 'Global' or 'Combined'");
end
dummy = [NaN(lag, n_countries); dummy];
str_ret = calc_str_return(dummy, inv_curve, duration, FX_ret, trans_cost, funding_cost);
%signal hit rate
sig_h_r = sum((dummy(1:end-1,:) == -1 & inv_curve(2:end,:) ¿ inv_curve(1:end-1,:)) — (dummy(1:end-1,:) == 1 & inv_curve(2:end,:) ¡ inv_curve(1:end-1,:))) ./ (size(dummy,1)-1);
%% Cumulative retunrs
cum_str = ones(size(str_ret,1),n_countries+1);
cum_str(1,:) = 100;
str_ret(isnan(str_ret)) = 0;
for j = 1 : n_countries+1
for i = 2: size(str_ret,1)+1
cum_str(i,j) = cum_str(i-1,j) * (1+str_ret(i-1,j)/100);
end
end
```

```
%% OUTPUTS
y.position = dummy;
y.strategy_return = str_ret;
y.long = sum(dummy == 1, 1)/size(dummy,1) * 100;
y.Correlations = corr(dummy);
y.signal_hit_rate = sig_h_r;
y.cumulative_returns = cum_str;
end
```

Term Spread

```
function y = term_spread(variable, model, inv_curve, duration, yield_long_term, yield_short_term,
delay, daily_rate_10y, dates_daily, trans_cost, funding_cost, FX_ret)
inv_curve = inv_curve(:,2:end);
yield_long_term = yield_long_term(:,2:end);
yield_short_term = yield_short_term(:,2:end);
n_countries = size(inv_curve, 2);
%evaluate the realized volatility with the selected model
realized_volatility = real_vola(model, daily_rate_10y, dates_daily);
% carry and carry to risk
carry = yield_long_term - yield_short_term;
carry(carry == 0) = 1e-6;
ctr = carry ./ realized_volatility;
if strcmp(variable, 'Carry to Risk')
data = ctr;
elseif strcmp(variable, 'Carry')
data = carry;
else
error('computeValue:InvalidInput', "insert a valid Variable: 'Carry to Risk' or 'Carry'");
end
%% Strategy evaluationo
signal = zeros(size(data,1)-delay,size(yield_long_term,2));
dur_pos = zeros(size(data,1)-delay,size(yield_long_term,2)); %preacllocate position array, whose
values span -1 to 1
for j = 1 : n_countries
for i = 1 : size(data,1)-delay
tmp = data(i:delay+i-1,j);
rank = rank_perc(data(i+delay,j),tmp);
signal(i,j) = 2 * (rank - 0.5);
if signal(i,j) ¿ 0.02 —— signal(i,j) ¡ -0.02
dur_pos(i,j) = 2 * (rank - 0.5);
else
dur_pos(i,j) = 0;
end
end
end
dur_pos = [NaN(delay, n_countries);dur_pos];
str_ret = calc_str_return(dur_pos, inv_curve, duration, FX_ret, trans_cost, funding_cost);
%% Cumulative retunrs
cum_str = ones(size(str_ret,1),n_countries+1);
cum_str(1,:) = 100;
str_ret(isnan(str_ret)) = 0;
for j = 1 : n_countries+1
for i = 2: size(str_ret,1)+1
cum_str(i,j) = cum_str(i-1,j) * (1+str_ret(i-1,j)/100);
end
```

```
end
%% Outputs
%y.garch_parameters = garch_parameters;
y.garch_volatility = realized_volatility;
y.carry = carry;
y.carry_to_risk = ctr;
y.strategy_return = str_ret;
y.position = dur_pos;
y.signals = [NaN(delay,size(dur_pos,2));signal];
y.cumulative_returns = cum_str;
y.long = sum(dur_pos ¿ 0, 1)/size(dur_pos,1)*100;
end
```

Real Yield

```
function y = real_yield_relval(data, inv_curve, duration, trans_cost, funding_cost, FX_ret)
data = data(:,2:end);
inv_curve = inv_curve(:,2:end);
n_countries = size(inv_curve,2);
%% strategy evaluation
%dummy = -1 for data behind the median, short on low real yield bond
%dummy = 1 for data over the median, long on high real yield bond
%dummy = 0.5*(data ¡ median(data,2)) + 0.5;
min_data = min(data, [], 2);
max_data = max(data, [], 2);
range = max_data - min_data;
range(range == 0) = 1;
dummy = 2 * (data - min_data) ./ range - 1;
str_ret = calc_str_return(dummy, inv_curve, duration, FX_ret, trans_cost, funding_cost);
%% Cumulative retunrs
cum_str = ones(size(str_ret,1),n_countries+1);
cum_str(1,:) = 100;
str_ret(isnan(str_ret)) = 0;
for j = 1 : n_countries+1
for i = 2: size(str_ret,1)+1
cum_str(i,j) = cum_str(i-1,j) * (1+str_ret(i-1,j)/100);
end
end
%% Outputs
y.strategy_return = str_ret;
y.position = dummy;
y.cumulative_returns = cum_str;
y.long = sum(dummy ¿ 0, 1)/size(dummy,1)*100;
end
```

Combined Strategy

```
function y = comb_strategy(weight, inv_curve, duration, returns, positions, trans_cost, funding_cost,
FX_ret)
% we linearly combine the 6 positions for each countriy with equal weights,
% and then we optimize
inv_curve = inv_curve(:,2:end);
n_countries = size(returns,2) - 1;
%% Strategy evaluation with fixed weights
w_eq = 1/6;
w_b_mom = 1/6;
```

```
w_slope = 1/6;
w_ry = 1/6;
w_li = 1/6;
w_IBES = 1/6;
w = [w_eq, w_b_mom, w_slope, w_ry, w_li, w_IBES];
w_3d = reshape(w,[1,1,length(w)]);
valid_ret_boolean = ~isnan(positions);
valid_w = w_3d .* valid_ret_boolean;
norm_w = valid_w ./ sum(valid_w,3);
str_position = sum(positions .* norm_w,3, 'omitnan');
str_ret = calc_str_return(str_position, inv_curve, duration, FX_ret, trans_cost, funding_cost);
%% Strategy evaluation with optimized weights
if strcmp(weight,'Empirical') & n_countries == 6
w_eq = 0.15;
w_b_mom = 0.4;
w_slope = 0.05;
w_ry = 0.1;
w_li = 0.2;
w_IBES = 0.1;
opt_w = [w_eq, w_b_mom, w_slope, w_ry, w_li, w_IBES];
elseif strcmp(weight,'Empirical') & n_countries ~= 6
w_eq = 0.2;
w_b_mom = 0.30;
w_slope = 0.20;
w_ry = 0.10;
w_li = 0.15;
w_IBES = 0.05;
opt_w = [w_eq, w_b_mom, w_slope, w_ry, w_li, w_IBES];
elseif strcmp(weight,'Theoretical')
opt_w = optimize_weights(inv_curve, duration, positions, trans_cost, funding_cost, FX_ret);% Weights optimiiation
else
error('computeValue:InvalidInput', "Insert a valid model: 'Empirical' or 'Theoretical'");
end
%strategy evaluation with optimum weights
w_3d = reshape(opt_w, [1, 1, length(opt_w)]);
valid_pos_boolean = ~isnan(positions);
valid_w = w_3d .* valid_pos_boolean;
norm_w = valid_w ./ sum(valid_w,3);
str_position_opt = sum(positions .* norm_w,3, 'omitnan');
str_ret_opt = calc_str_return(str_position_opt, inv_curve, duration, FX_ret, trans_cost, funding_cost);
%% Cumulative retunrs
cum_str_opt = ones(size(str_ret,1),n_countries+1);
cum_str_opt(1,:) = 100;
cum_str = ones(size(str_ret,1),n_countries+1);
cum_str(1,:) = 100;
str_ret_opt(isnan(str_ret_opt)) = 0;
str_ret(isnan(str_ret)) = 0;
for j = 1 : n_countries+1
for i = 2: size(str_ret,1)+1
cum_str(i,j) = cum_str(i-1,j) * (1+str_ret(i-1,j)/100);
cum_str_opt(i,j) = cum_str_opt(i-1,j) * (1+str_ret_opt(i-1,j)/100);
end
end
%% calculate correlation between strategies returns
```

ret_agg = squeeze(returns(:,n_countries+1,:)); %matrix of countries aggregate returns for each strategy
%% OUTPUTS
y.strategy_return = str_ret;
y.strategy_return_opt = str_ret_opt;
y.str_correlations = corr(ret_agg);
y.long = sum(str_position ¿ 0, 1)/size(str_position,1)*100;
y.str_position = str_position;
y.str_position_opt = str_position_opt;
y.strategy_cumu_return = cum_str;
y.strategy_cumu_return_opt = cum_str_opt;
y.weights = w;
y.optimal_weights = opt_w;
end

Function: Daily Realized Volatility

function y = real_vola(model, daily_rate_10y, dates_daily)
daily_rate_10y = daily_rate_10y(:,2:end)/100;
adj_daily_rate = daily_rate_10y;
adj_daily_rate(adj_daily_rate == 0) = 1e-6;
n_countries = size(adj_daily_rate,2);
daily_ret = [zeros(1,n_countries);(adj_daily_rate(2:end,:)-adj_daily_rate(1:end-1,:)) ./ adj_daily_rate(1:end-1,:)];
%% volatility estimation
if strcmp(model, 'EWMA')
lambda = 0.97;
var = [daily_ret(1,:) .2̂; zeros(size(daily_ret,1)-1,n_countries)];
var(2:end,:) = lambda * var(1:end-1,:) + (1-lambda) * daily_ret(1:end-1,:).2̂;
elseif strcmp(model, 'GARCH')
mdl = garch(1,1);
var = zeros(size(daily_ret,1), n_countries);
for j = 1 : size(daily_ret,2)
est_garch = estimate(mdl,daily_ret(:,j),'Display', 'off');
var(:,j) = infer(est_garch, daily_ret(:,j));
end
else
error('computeValue:InvalidInput', "insert a valid model: 'EWMA' or 'GARCH'");
end
[yearMonth, ˜, groupIdx] = unique(year(dates_daily) * 100 + month(dates_daily)); % Unique year-month values
monthly_real_var = zeros(length(yearMonth), n_countries); % Preallocate
for i = 1 : n_countries
monthly_real_var(:, i) = splitapply(@(x) sum(x), var(:, i), groupIdx);
end
monthly_real_volatility = sqrt(monthly_real_var) * sqrt(12)*100;
%% OUTPUT
y = monthly_real_volatility;
end

Function: Returns Analysis

function y=ret_analysis(returns, benchmark_ret)
per_len_y = size(returns,1)/12; %years of investment
%set trasnaction cost = 1 if ypou want to subtract transaction cost,
%otherwise, if they are already computed set it different from 1

```
%Expectancy
%hit ratio
pos_real = sum(returns ¿ 0,1,'omitnan'); %positive realizations
neg_real = sum(returns ¡ 0,1,'omitnan'); %negative realizations
h_r = pos_real./(pos_real+neg_real);
av_trade_x_year = (pos_real+neg_real)./per_len_y;
av_win = mean(returns(returns¿0),1);
av_loss = mean(returns(returns¡0),1);
exp = av_win* h_r + av_loss * (1-h_r);
%Annual return and volatility
a_ret = zeros(1, size(returns,2));
a_vola = zeros(1, size(returns,2));
tev = zeros(1, size(returns,2));
max_draw_down = zeros(1, size(returns,2));
for i = 1 : size(returns,2)
valid_ret = returns(:, i)./100;
valid_bench = benchmark_ret(:, i)./100;
zero_idx = (valid_ret == 0);
valid_ret(zero_idx) = [];
valid_bench(zero_idx) = [];
if ˜isempty(valid_ret)
len = size(valid_ret,1)/12;
cum_ret = prod(1 + valid_ret,"omitnan"); % Compounding without zero periods
a_ret(i) = ((cum_ret ˆ(1/len))-1)*100; %Annaulized Return
a_vola(i) = std(valid_ret,1)*sqrt(12)*100; %Annaulized Volatility
tev(i) = std(valid_ret - valid_bench,1)*sqrt(12)*100; %Tracking Error Volatility
cum_ret_md = cumprod(1 + valid_ret);
runningMax = max(cum_ret_md(:));
max_draw_down(i) = ((min(cum_ret_md) - runningMax) ./ runningMax) * 100; %Maxdraw-down
else
a_ret(i) = NaN;
a_vola(i) = NaN;
max_draw_down(i) = NaN;
tev(i) = NaN;
end
end
%Benchmark Annual return
len = size(benchmark_ret,1)/12;
cum_ret = prod(1 + benchmark_ret/100);
a_ret_bench = (((cum_ret).ˆ(1/len))-1)*100;
%Alpha Generated
alpha = a_ret - a_ret_bench; % Excess return over the benchmark
%sharpe ratio
s_r = alpha./a_vola;
%tracking error volatility anad information ratio
i_r = alpha./tev;
%% OUTPUTS
y.annualized_return = a_ret;
y.annualized_volatility = a_vola;
y.sharpe_ratio = s_r;
y.number_trades = sum(returns ˜= 0,1);
y.alpha = alpha;
y.Tracking_Error_Volatility = tev;
y.Information_ratio = i_r;
y.expectancy = exp;
```

```
y.hit_ratio = h_r;
y.max_draw_down = max_draw_down;
y.av_trade_per_year = av_trade_x_year;
y.correlations = corr(returns);
y.print = [a_ret;a_vola;tev;alpha;exp;max_draw_down;i_r;s_r;h_r*100];
end
```

Function: Rank Perc

```
%% This function return the percentile of a given number (target) given an array.
% If 'target' is not present in the array, the function retunr the percentile as a linear interpolation
function y = rank_perc(target,data)
data = sort(data(ĩsnan(data)),1,"ascend");
if isempty(data)
y = NaN(1,1);
return
else
if isnan(target)
y = NaN(1,1);
return
elseif target  data(1)
y = 0;
return
elseif target  = data(end)
y = 1;
return
else
for i = 1 : size(data,1)-1
if data(i) == target && data(i+1) == target
y = ((2 * i + 1) / 2) / size(data,1);
return;
elseif data(i) == target
y = i / size(data,1);
return;
elseif data(i + 1)  target && data(i)  target
tmp = data(i + 1) - data(i);
y = ((i) * (target - data(i)) / tmp + (i + 1) * (data(i + 1) - target) / tmp) / size(data,1); %linear interpolation
return;
end
end
end
end
end
```

Codes Chapter 3

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