Department of Economics and Finance

Chair of Fixed Income, Credit and Derivatives

Global Fixed Income Duration Timing Strategies

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INTRODUCTION

This work aims to furnish a systematic set of rules to manage portfolio duration efficiently. The idea is to develop a model able to generate reasonable predictions about changes in long term bond yields. The paper contains two main sections: yield curve analysis and duration timing strategies.

The first part begins with the analysis of the concept of yield curve and its evolution over time. A considerable focus will be on the bond risk premium, its theories and estimation methods, and the impact of convexity on expected bond returns. The contents in this section are the basis from which starts the empirical analysis.

The second part describes the strategies that a portfolio manager could implement to trade duration on a monthly basis. Key points are: variables identification and their relationships with the forecast that is object of this paper; model description; empirical application.

A large focus will be on an innovative variable, which is gaining a lot of attention from both investors and policymakers: the Financial Conditions Index. It results in being extremely powerful with concern to the prediction of changes in future interest rates.

The analysis will develop across the so-called G-4 countries (U.S., Germany, U.K. and Japan) to prove that the thesis is robust globally speaking. The observation period, on average, is from the end of the ’90s to the end of 2019. A focus will be on 2012, which corresponds to the stopping year of another empirical research from which this dissertation took inspiration. Indeed, one of the reasons behind this work was to study the so-called signal strategy and extend and implement it with unique ideas.

The entire work is out-of-the-sample, meaning that the analysis and the strategies are truthful to what it could have happened if the investor followed these rules (i.e., working only with available data at the decision time, without looking to the future).

The strategy will be tested on each country (hence creating four different portfolios.), and the results are quite interesting compared to their respective benchmark. Finally, the work closes with the composition of a global government bond portfolio, which is developed both static and dynamic.

THE BOND RISK PREMIUM

Bond Risk Premium: introduction and terminologies

The following chapter starts with the description of the main terminologies and identities concerning the bond risk premium followed by its main theories and evidence and close with some notes about other determinants of the yield curve such as the Convexity Bias and how they influence the curve shape.

Suppose there is a portfolio composed of two main asset classes, stocks and bonds. The formers are reasonably considered as riskier and the latter as safer. However, even government bonds show different volatilities and risks because of their maturity and duration. The reward for such risks is the so-called bond risk premium which is the ex-ante excess return of a long-term government bond over holding a series of short-term bonds. Alternatively, the bond risk premium could be viewed as the needed reward to extend the portfolio duration.

It is crucial to distinguish between the bond risk premium (BRP from now on) from the realized excess bond return (EBR) and from the term spread (which corresponds to the yield curve steepness). While the latter two are directly observable (the term spread today, and the EBR at the time of realization) the BRP needs to be estimated.

Analysis of the BRP is typically done using government bond data because the BRP compensates for uncertainty in default-free yields (uncertain discount rates). Other bond yields also reflect issuers' uncertain creditworthiness or otherwise uncertain cash flows as well as possible illiquidity premia.[1]

Two components determine the bond return over a given holding period: the bond yield and the capital gain or loss from any change in interest rates.

Realized and expected (excess) bond return

Two components determine the bond return over a given holding period: the bond yield and the capital gain or loss from any change in interest rates:

$$H_{10} \approx \; Y_{10} - \text{Duration}_{10} * \Delta Y_{10} \qquad (1.1)$$

Subtracting the short-term asset rate and taking expectations, is it possible to obtain the bond risk premium associated with near term returns:

$$BRP_H \equiv E\,[EBR] \approx \; (Y_{10} - Y_1) - \text{Duration}_{10} * E[\Delta Y_{10}] \qquad (1.2)$$

Where, EBR= Excess Bond Return over the riskless rate for the next year

[1] Anti Ilmanen, *Expected returns: An Investor's Guide to Harvesting Market Rewards* (London: John Wiley & Sons, 2011), 153.

Bond yield

Bond yields incorporate both the markets' rate expectations of interest rates and the risk premium factor.

Consider the Forward Rates (or Break-even rates) that are a series of future short-term rates computed in a way that, if rolled over time, would give the same return as a long term bond yield. Under risk-neutrality, these forward rates correspond to the investors' expectations and the long-term bond yield (Y_{10}) perfectly match what is going to be the average of the future short rates $\mathrm{E[avgY_1]}$. Nevertheless, if the current long term yields are high and the short term rates are expected to be low, then there is the evidence of the existence of a risk premium factor. The word "risk premium" comes from the fact that the investor requires an extra remuneration to bear a "long-term-kind risk."

$$\mathrm{Y_{10} \approx E[avgY_1] + BRP_Y} \tag{1.3}$$

Hence, for example, the 10-year bond yield can be written as the sum of the expected average of the 1-year bond yield, from today to the next ten years, and the bond risk premium factor.

There is a slight difference between the BRP expressed in (1.2) and (1.3). The latter ($\mathrm{BRP_Y}$) simply refer to the average of the expected future of the former ($\mathrm{BRP_H}$) for each year "(a 10-year bond's $\mathrm{BRP_H}$ for the coming year, 9-year bond's $\mathrm{BRP_H}$ for the following year, etc.)[2]".

The expected average of the short-term yield corresponds to the sum of the expected average inflation and real interest rate:

$$\mathrm{E[avgY_1] = E[avg. Inflation] + E[avg. R_1]} \tag{1.4}$$

By merging the equations (1.3) and (1.4), it is possible to obtain the three factors decomposition of the long term rate:

$$\mathrm{Y_{10} \approx E[avg. Inflation] + E[avg. R_1] + BRP_y} \tag{1.5}$$

The curve steepness also embeds the bond risk premium factor:

$$\begin{aligned} \mathrm{YC} &\equiv \mathrm{Y_{10} - Y_1} \\ &= \mathrm{[E[avg. Y_1] - Y_1] + BRP_Y} \\ &= \mathrm{E[\Delta avg. Y_1] + BRP_Y} \end{aligned} \tag{1.6}$$

[2] Anti Ilmanen, *Expected returns: An Investor's Guide to Harvesting Market Rewards*, 154.

And by rearranging with (1.2), the yield curve steepness question becomes:

$$\text{YC} \approx \text{Duration}_{10} * \text{E}[\Delta\text{Y}_{10}] + \text{BRP}_{\text{H}} \tag{1.7}$$

As Ilmanen stated: “A steep curve reflects either market expectations of rising yields or high required bond risk premia—or, more likely, some combination of the two. The rate expectation component can be expressed either in terms of expected multi-year changes in the 1-year yield over the next decade or, alternatively, as the expected next-year change in the 10-year yield, scaled by its (end-of-horizon) duration.[3]”

Theories Behind the Bond Risk Premium

This paragraph answers the question of what theories state concerning the bond risk premium, their main assumptions and results.

Several theories discuss very differently about the predictions of the bond risk premium and aim to identify its system of determinants. However, despite the fact that the approaches followed in the various studies are profoundly dissimilar to each other, the pluriform profile of the bond risk premium allows to provide analysis tools only concerning its probable sign, its shape in the different maturities, and its constancy over time. Hence the bond risk premiums’ potential “magnitude “remains a factor to be understood.

In this paragraph is briefly explained the evolution of the main theories concerning the Bond Risk Premium. For the purposes of the analysis, the theories are distinguished between two macro-categories: the classic term structure, which defines the BRP according to the time horizon of investment and the type of investor; the modern asset theories pricing, which instead estimates the BRP using as reference determinants the amount of risk and its price.

Classic term structure hypotheses:

I. THE PURE EXPECTATION HYPOTHESIS (PEH) states that the “term” or bond risk premium is zero across all maturities. This means that the influence of all agents (who are risk-neutral) drives the expected returns of all medium- and long-term government bonds to be equal to the short-term riskless rate. In a technical way: “More specifically, it holds that any long-term interest rate simply represents the geometric mean of current and future one-year interest rates expected to prevail over the maturity of the issue.[4]”

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[3] Anti Ilmanen, *Expected returns: An Investor's Guide to Harvesting Market Rewards*, 155.
[4] Reilly, Frank K., and Keith C. Brown, *Investment Analysis & Portfolio Management* (Boston: South-Western Cengage Learning, 2012), 650.

In this scenario, any yield differences between the bonds arise only from expectations about future interest rate changes, in order to offset the expected capital gains or losses and to make all bonds yield the same return.

The yield curve can assume different shapes and three are the possible scenarios: A flat yield curve; an upward or downward sloping yield curve and a humped yield curve

(i) The Flat YC: is the less probable scenario to observe, interest rates are equal across all maturities reflecting any investor's expectation about future fluctuations.

(ii) Upward & Downward sloping YC: Is the most common scenario, upward means that the bonds yields increase with their maturities. Investors expect that long-term bonds will experience a capital loss because interest rates are going to rise and, because of that, securities with higher duration are rewarded with an higher yield. The opposite is for the downward sloping YC.

(iii)Concave & Convex YC (humped YC): The concave YC come across when market expects the curve to be flat in the future. Therefore, if today's curve is upward sloping and the expectation is that it is going to flatten, then bullet and barbell portfolios[5] are going to behave differently in term of performance and the YC concavity is to offset this discrepancy (in this case barbell portfolio outperforms the bullet). The opposite occurs when it is convex.

II. THE RANDOM WALK HYPOTHESIS (or risk premium hypothesis) states that long-term bonds comprise a risk premium factor as a reward for the increased volatility of theirs returns. Hence it states the opposite extreme assumption of the PEH. For example an upward-sloping yield curve only reflects the additional yield for duration extension risk and does not give any useful information concerning the market's rate expectations of future short term rates.[6] The underlying idea of this concept is that investors do not like short-term returns' fluctuations, hence they are risk adverse and have a short investment horizon.

An alternative and more reliable argument states that "most investors have a vague investment horizon. If the horizon is so uncertain that it does not guide an investor's decision making and if he is more averse to price risk than to reinvestment risk, he is likely to bias the portfolio toward a short duration. Public accountability makes many investors more adverse to price risk than to reinvestment risk. Erring toward a too-short duration exposes an investor "only" to reinvestment risk, which is akin to an opportunity cost. Erring toward a too-long duration exposes an investor to price risk, which is visible and, if realized, is more likely to cause public outcry[7]".

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[6] Anti Ilmanen, *Expected returns: An Investor's Guide to Harvesting Market Rewards*, 156.
[7] Ilmanen, Antti. "Does Duration Extension Enhance Long-Term Expected Returns?" (Understanding the Yield curve: part 3). New York: Salomon Brothers, (July 1995): 2

In other words, the compensation requested to hold long-term securities may depend on both the amount of risk and the price of the latter, which may change over time due to fundamental variables:

III. THE PREFERRED HABITAT HYPOTHESIS: states that the duration is the main factor that affects any increase or decrease of excess returns. Many institutional investors, such as pension funds and life insurance companies, consider a long exposure in the duration as less risky than short one to avoid the so-called asset-liability mismatch. Because of that, these long-horizon investors are willing to accept a lower yield for the long-term bond than for the short-term asset. Even if each investor has its horizon and risk profile, there is only a single price valuation for each security. This means that long-horizon and short-horizon investors compose together the markets' investment horizon, which offers the risk premium price. Even if it is not precisely clear the relative weights of long/short-horizon investors, the long oriented ones should represent a less percentage of the market participants and for this reason the risk premium factor increases with the duration. However this do not exclude the same risk premium to be lower from what requested by the short-term markets' participants.

Modern Asset Pricing Theories

In this other category the investment horizon of different investors is not anymore, the main determinant of the risk premium which is, on the opposite, related to the risk concerning amount and price.

IV. PARTIAL EQUILIBRIUM (or one-factor models): states that the bond risk premium is impacted by only one macroeconomic factor, which is the return volatility. For this reason, any correlation between bond returns and other macroeconomic and financial factors is not taken into account. "Although unrealistic, one-factor models provide good approximations of the term structure if the various factors affecting interest rates are highly correlated.[8]"

V. CAPM: The Capital Asset Pricing Model, developed by William Sharpe in 1964[9] states the any assets' risk is a function of the aggregate wealth. In the model the relevant factor is the β which correspond to the asset sensitivity with respect to the performance of the market portfolio. Hence the assets' risk premium is computed by multiplying its beta with the market risk premium. Because of long-term bonds and stock market return are historically positive correlated, then both the sensitivity coefficients (β) and risk bond premium are positive. The implication is that there is a linear relationship between

[8] Corporate Finance Institute. "Equilibrium Term Structure Models". 2015 to 2020 CFI Education Inc. https://corporatefinanceinstitute.com/resources/knowledge/other/equilibrium-term-structure-models/.
[9] Sharpe, William. "*Capital Asset Prices: a theory of market equilibrium under conditions of risk*". Journal of Finance, no. 19 (1964).

the bond risk premium and duration. However, as Ilmanen claimed in his research, in reality the relationship between bond risk premium and duration is far from being linear. Precisely:

"However. these models specify a linear relation between expected returns and return volatility for beta. A linear relation between expected returns and duration only follows if yields are equally volatile across the curve (because a bond's return volatility is approximately equal to its duration times the volatility of the yield changes). Empirically, however. the short-term rates tend to be more volatile than the long-term rates, making the return volatility increase by less than one-for-one with duration. Because return volatilities are somewhat concave as a function of duration, also expected return (and bond risk premia) should be somewhat concave as a function of duration. [10]".

VI. GENERAL EQUILIBRIUM: The general equilibrium states that the bond risk premium is related to the assets' capability of obtaining positive results in bad-times and vice versa. In the first case the bond risk premium is supposed to be modest due to the lowest implicit risk.

Estimating the Bond Risk Premium

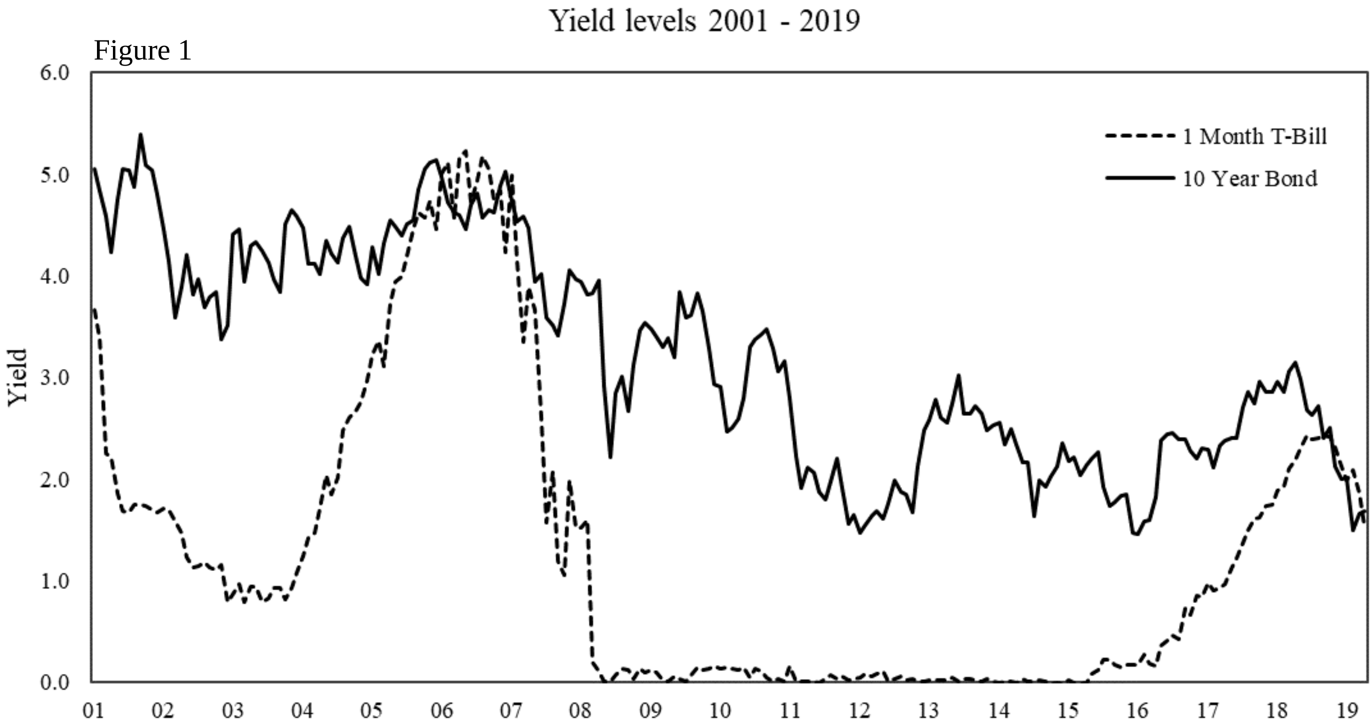
The following paragraph aims to explain what techniques are used to estimate the risk premium factor. Since the expected BRP "cannot be straight observed[11]", two approaches are used to its estimation: historical yield or return data.

Historical yields:

The first way to estimate the bond risk premium is looking at the yield curve shape. It contains useful informations to understand which was (or is) the risk premium requested from the investors. The most direct way to read the yield curve is by observing the so called Carry or Term Spread which is the differential between long-term yield (suppose a 10 years U.S. Treasury) and a short-term yield (3 months T-Bill). Obviously, the Carry is a useful explanatory factor if the expected future fluctuations of short-term interest rates are completely null in the sample timeframe. Since it is well known that often markets participants persistently expect an increase of interest rates then the Term Spread could, if inappropriately contextualized (e.g. in a small sample), produce an overestimation of the BRP.[12]

[10] Ilmanen, Antti. "Duration Extension", 4.
[11] Ilmanen, Antti. "Duration Extension", 4.
[12] Recall what Ilmanen stated in his paper: "According to the pure expectations hypothesis an upward-sloping yield curve only reflects expectations of future rate changes: there are no risk premia. The liquidity premium hypothesis makes the opposite claim: An upward-sloping yield curve reflects only required risk premia and no rate expectations. In reality, the shape of the yield curve probably reflects both rate expectations and risk premia." Ilmanen, Antti. "Duration Extension", 5.

Figure 1



The figure 1 shows the evolution of the long term and short-term rates. The sample under analysis is unique for its peculiarities and includes three main events of the global Financial Markets: The post Dot-Com Bubble; The Sub-Prime Mortgage Crisis; The Sovereign Debt Crisis. For most of the sample, the curve is upward sloping, with the exclusion of the years previous the Great Recession and at the tail of the time series.

The table reports average bond yields, their volatility and the term spread across different maturities. The yield increases across the curve but at a decreasing rate with respect to the maturity. The volatility is inverted, short-term rates exhibits high mean-reverting yields changes, even if they were set near zero for several years. The path of long terms rates results less volatile and characterized by a decreasing trend. Term spread in this case reflect both the required risk premium (before the 2007-2009 Crisis) and the expectation of a rise in interest rates (2014 on). The bond risk premium is required to bear the risk of duration extension in a sample characterized by several downturns. On the other side, expectations about a rise in short-term rates (rates have been near zero for many years) dominates the bond risk premium factor.

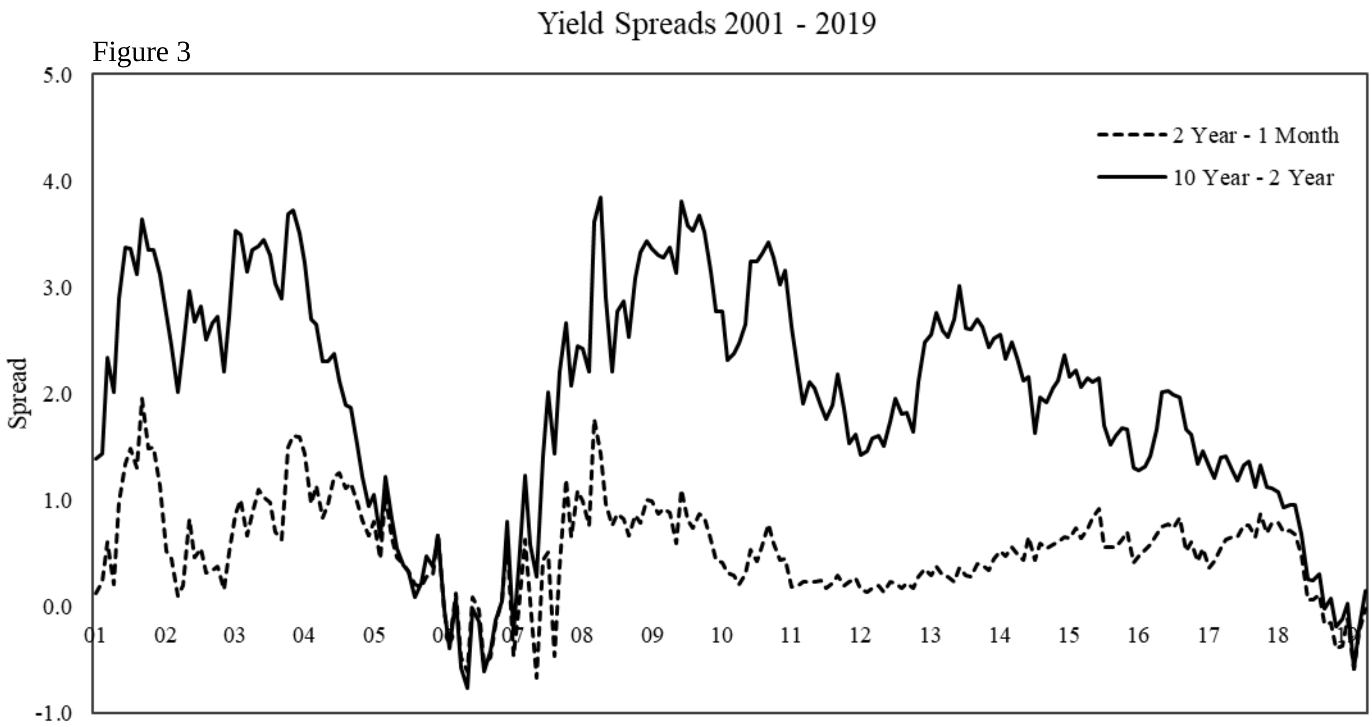
Figure 2

Bonds Yields 2001 - 2019

	1 Mo	3 Mo	2 Year	5 Year	10 Year	30 Year
Average Yield	1.28%	1.34%	1.81%	2.52%	3.21%	3.90%
Volatility of Yield Changes	1.49	1.51	1.42	1.22	1.07	0.96
Term Spread over One-Month Rate	0.00	0.06	0.53	1.24	1.94	2.62

Figures 3 represents the term spread at the end and at the beginning of the yield curve. The high level of the long-end term spread (10 Year – 2 Year) is again a confirm about how much was elevated the premium after the great recession which was a period characterized by low investors' wealth and high uncertainty about future economic and financial trends.

Figure 3



Historical Returns

The other approach to assess the bond risk premium is by studying the historical bond returns. In this case the main assumption states that the realized excess bond return (hence, ex-post returns) is composed from an expected part (the bond risk premium) and an unexpected part:

$$\text{Excess Bond Return}_t = \text{BRP}_{t-1} + \varepsilon_t \qquad (1.8)$$

where ε_t corresponds to the surprise component about future excess returns (or unexpected yield change). It can be positive or negative.

In a small sample the unexpected part dominates the bond risk premium component and because of that the expected excess bond return comes to be complex to be estimated. However, if the timeframe is stretched, the positive and negative signs related to the surprise factors tends to compensate each other and the estimation becomes more stationary[13]. This result (the complete surprise component write-off) is less likely to happen if in the sample period there is any yield trends bias. It is then important to refer to a neutral timeframe, where the yield levels remain more or less the same.

Historical Returns – Database

The following analysis refers to the period starting from 2001 to 2019. It comprehends 220 monthly observations of bond returns for various maturities (1 Month; 3 Month; 2 Year; 5 Year; 10 Year; 30 Year)[14].

The focus is immediately on the Sharpe Ratio[15] which shows how medium/long term bonds (5 Year and 10 Year) overperformed the other candidates. This was possible because the large volatility of short-term interest rates (1 Month and 3 Month) accompanied by a considerable period of yields close to zero. However, stretching too much the duration significatively decrease the Sharpe Ratio, not because of an increase in the return volatility (which is normal by increasing the duration) but instead due to a not proportional increase of the long-term yield.

Figure 4

U.S. Bond Maturity Decomposition Monthly Returns and Other Statistics 2001-2019

	1 Mo	3 Mo	2 Year	5 Year	10 Year	30 Year
Monthly Return Mean	1.27%	1.34%	1.82%	2.58%	3.36%	4.34%
Volatility	1.49	1.52	1.54	1.93	2.91	7.21
Sharpe Ratio	N/A	0.04	0.36	0.68	0.72	0.43

The figure 5 gives a quick look of what stated before. The higher steepness of the Yield Curve is on its first half, meaning that the risk-return relation of the curve is non-linear. This is still consistent with what stated by Ilmanen:" I have claimed that the long-run risk–reward relation in the Treasury market looks like a hockey stick: very steep up to two years and flat thereafter. Also, for the longer sample used here, the reward for extending the duration is highest at short maturities and decays at longer maturities.[16]".

The main difference is that in the sample analyzed, the curve is very steep up to 5 Year and starts to flatten thereafter.

[13] "In other words, this approach is valid if the markets yield forecasts are correct, on average, during the sample period, so that the average unexpected yield changes are zero." Ilmanen, Antti. "Duration Extension", 5.

[14] Source: Bloomberg

[15] Sharpe ratio is a risk-adjusted indicator. It shows how much excess return the investor could get by adding a unit of volatility.

[16] Anti Ilmanen, *Expected returns: An Investor's Guide to Harvesting Market Rewards*, 158.

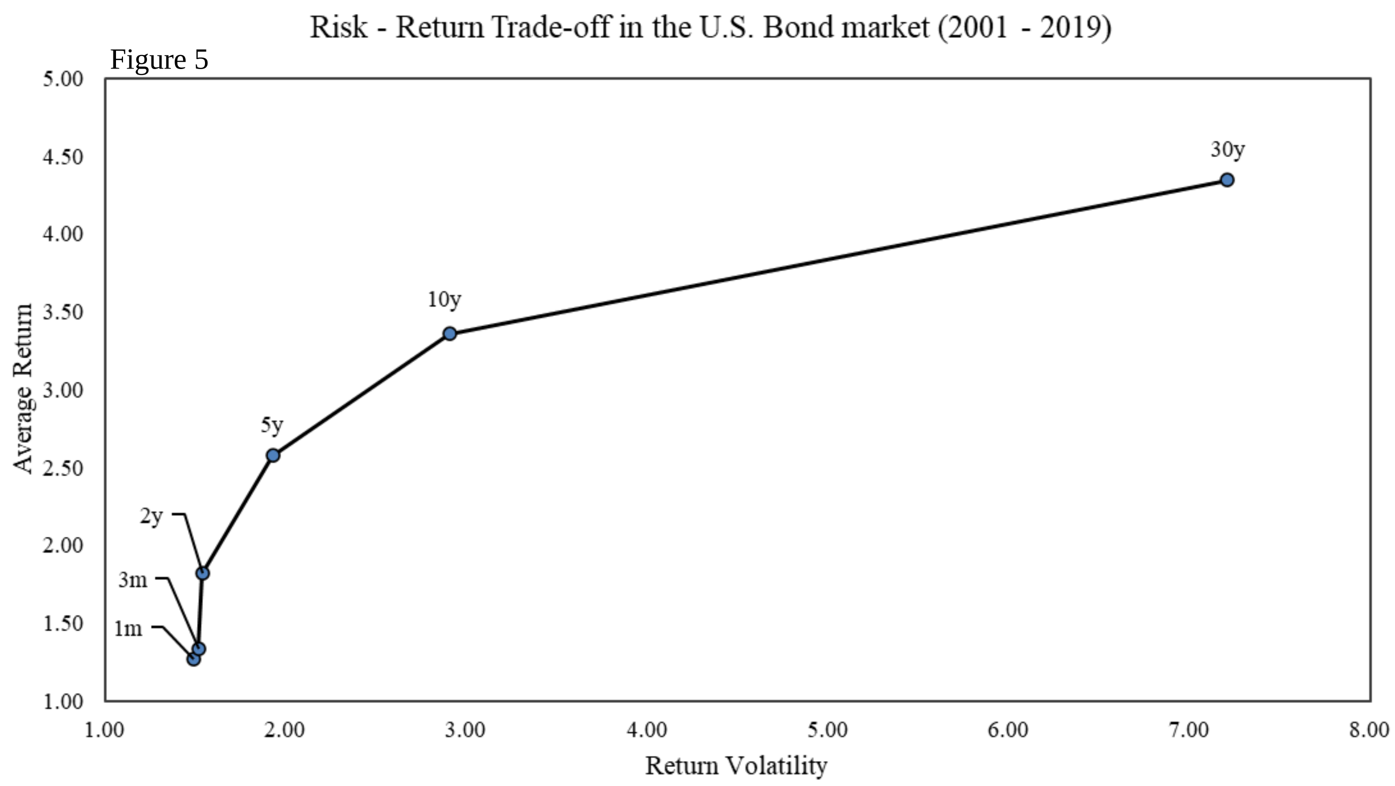


Figure 5

The sub-sample analysis (figure 6) gives an idea of the magnitude of the Sovereign Debt Crisis and its repercussions on the Bond Market, now characterized by less appetible risk-adjusted returns.

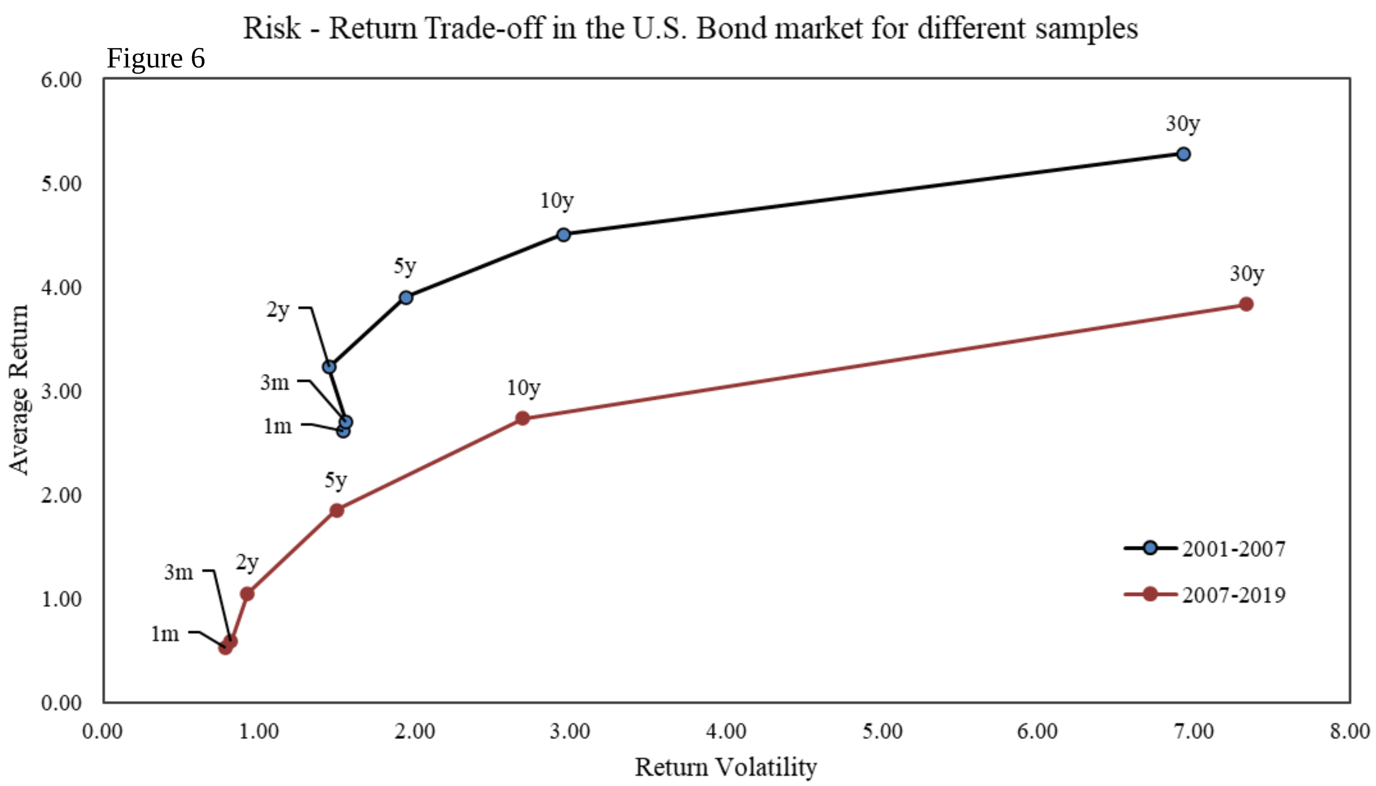


Figure 6

ALTERNATIVE EX ANTE MEASURES OF THE BRP

Regression based estimates:

"Simple regression models can produce measures of term premia. Under the joint assumption of the expectations hypothesis and rational expectations, ie expectations that are unbiased and incorporate all available information, the difference between the forward rate and the ex post realised short rate should not be forecastable with ex ante variables. If, in fact, ex ante variables help to predict this difference, it would imply the presence of a term premium or a failure of rational expectations. Adopting the former interpretation, one may use the predictable component of the rate difference resulting from the regression as a measure of the term premium.[17]"

"One reason for official reluctance to use regression-based term premium estimates is their apparent lack of robustness to the choice of the sample and regressors.[18]"

"An alternative approach to regression-based estimates of term premia is to take survey forecasts of financial market participants as a "model-free" proxy for market expectations. Unlike the in-sample regression-based premia discussed above, this measure is calculated in real time.[19]"

Survey Bond Risk Premium ("SBRP")

The survey-based bond risk premium estimation is a forecast made by financial market participants about future interest rates. These surveys give a real time information about markets' expectations and the technique is completely model-free. The expected risk premium is then given by the difference between bond future interest rate and the interest rated that comes out from the survey. The result of using surveys for the interest rates forecast is in a more accurate estimation of the bond risk premium.[20]

It is useful to conduct a back-test to have an idea of the robustness of past survey forecast about future interest rates, and then bond risk premium. Ilmanen in his book shows the following survey, made in March 2010: "Simply subtracting this measure from current long-term yield gives an estimate of the BRP. In March 2010, for example, both the 10-year Treasury yield and the survey forecast of the 2010–2020 average Treasury bill rate were near 3.5%, indicating an SBRP around zero. Apparently, the very steep YC at the time reflected only market expectations of steeply rising short rates, and no BRP was built into the curve.[21]"

Figure 7 shows the YC shape when the survey was made:

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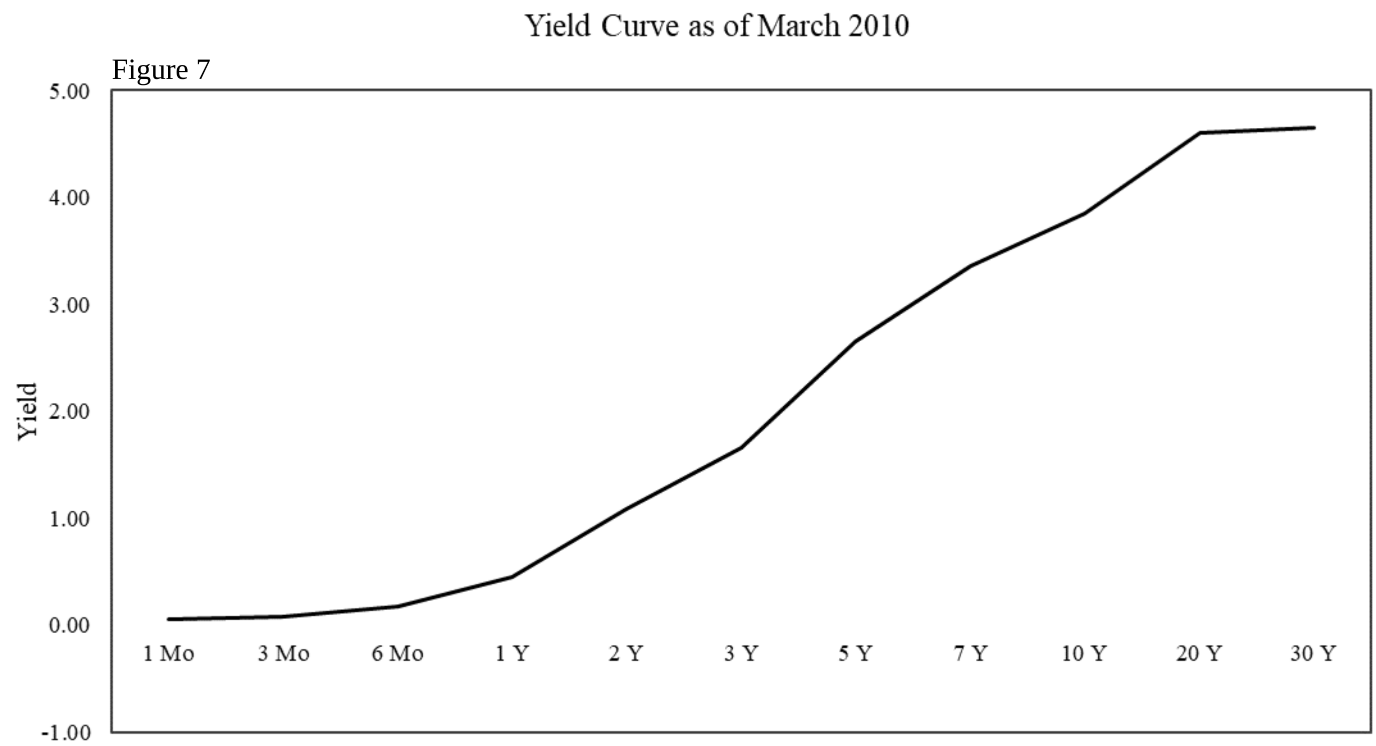
[17] Kim, Don H., and Athanasios Orphanides. "*The bond market term premium: what is it, and how can we measure it?*". BIS Quarterly Review, (June 2007): 30.
[18] Kim, Don H, "*The bond market term premium",* 31.
[19] Kim, Don H, "*The bond market term premium*", 32.
[20] Kim, Don H, "*The bond market term premium*", 36.
[21] Anti Ilmanen, *Expected returns: An Investor's Guide to Harvesting Market Rewards*, 160-161.



The survey was made in a context of null short-term yields and the pure expectation hypothesis is more than reasonable. However, the realized BRP (1.82[22]) over the time frame is not in line with the expectation about a zero SBRP.

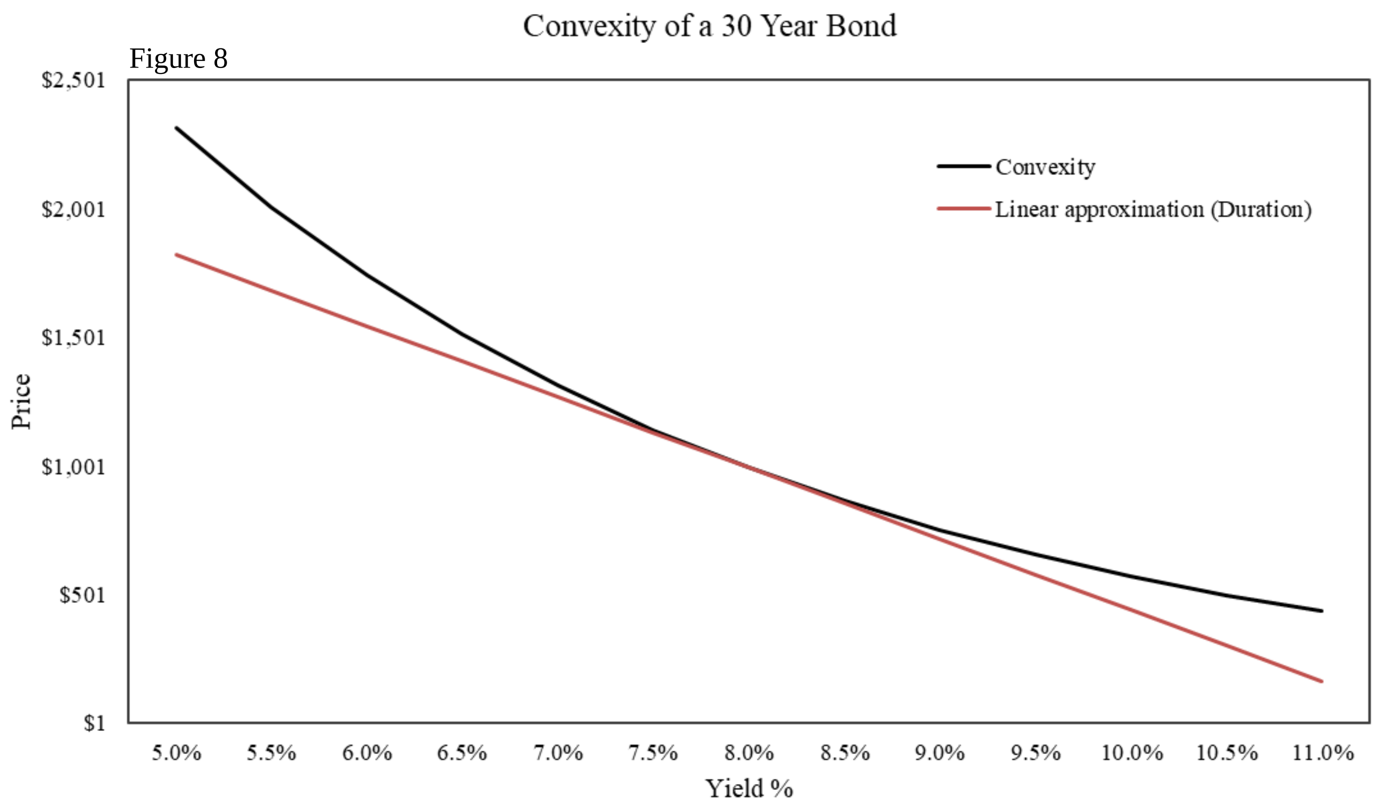
The Impact of Convexity on the Yield Curve Shape

Before going through the forecast model, it is important to say some words about the so called "Convexity Bias". Convexity is one of the main features linked to bonds, indeed it shows that there is a nonlinear relationship between bonds' price and its yield. When a bond is convex (such as all noncallable bonds) its price declines less for a given yield increase than it rises for the same yield decrease. This peculiar characteristic would be an important factor for the portfolios' performance, allowing managers to achieve better risk-adjusted returns.

Figure 8 shows the price as a function of the yield of a 30 Year ZCB in two different approaches.

[22] Computed as the arithmetic mean of the Yield differential (10 Year – 3 Month) of 2010 -2019 sample.

Figure 8



Hence computing the bonds' price-yield sensitivity with duration-based approximation tends to understate the bond price especially for large variation of interest rates. On the opposite, duration is reliable for small changes in interest rates.

It is possible to use both the duration and the convexity in a single formula for the computation of the percentage change on bond price:[23]

$$100 * \frac{\Delta P}{P} \approx -\text{Duration} * \Delta y + \frac{1}{2} * \text{Convexity} * (\Delta y)^2 \quad (1.9)$$

Where Duration $= -\frac{100}{P} * \frac{dP}{dy}$, Convexity $= \frac{100}{P} * \frac{dP^2}{dy^2}$, Δy is the yield change.

The most important determinants of convexity are bond maturity, coupon (if any) and options embedded. For example the callable bonds (which is a structured product composed by a noncallable bond with a call option for the issuer) exhibit negative convexity because its price is given by the difference between the bond price and the call option price. Indeed the non-callable bonds gives to the issuer the right to redeem the bond if the yield decreases more than a given level (if interest rates decreases, the issuer has the incentive to write-off the current bond and to issue another bond paying a lower yield.), hence the bond price-yield relation is concave for any yield level lower than the strike yield of the call option.

[23] The equation "is based on a two-term Taylor series expansion of a bond's price as a function of its yield, divided by the price. The Taylor series can be used to approximate the bond price with any desired level of accuracy." Ilmanen, Antti. *Convexity Bias and the Yield Curve (Understanding the Yield curve: part 5)*. New York: Salomon Brothers, (July 1995), 2.

Figure 9 shows the convexity of a ZCB as a function of the duration (modified). There is a positive relationship between them and furthermore, convexity increases at a rising pace.

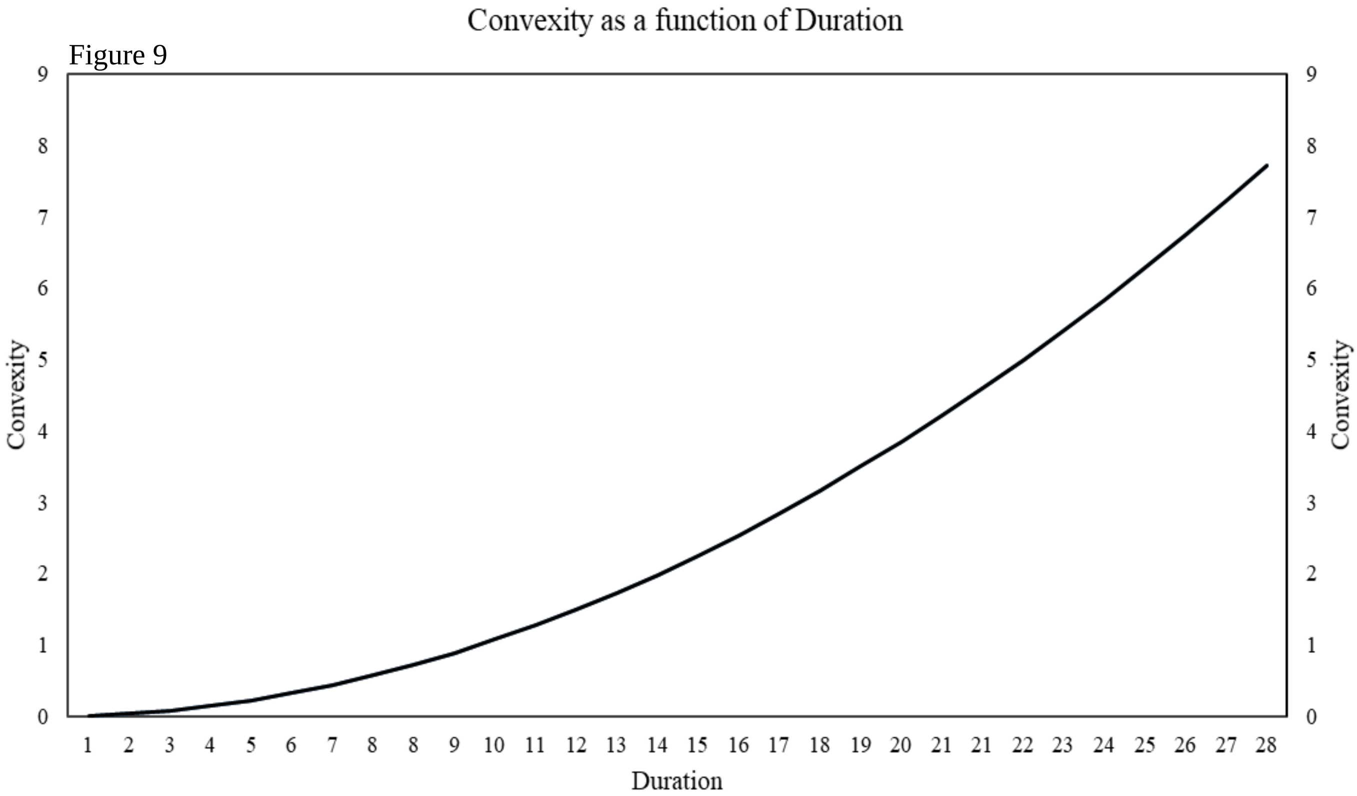


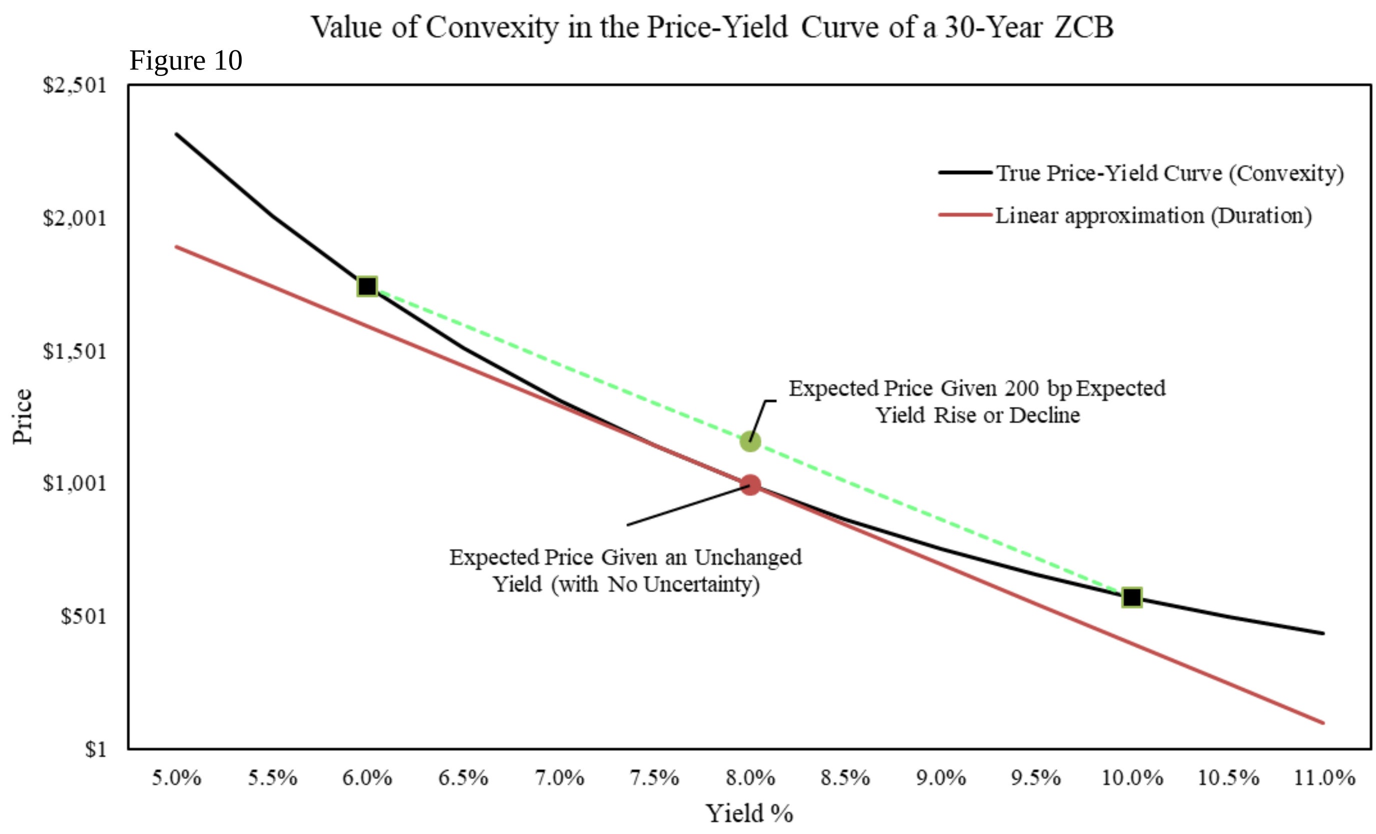
Figure 9

For what concern bullet and barbell portofolios, the barbel has more convexity because the latter increases with the square of maturity. “For zeros, a good rule of thumb is that convexity equals the square of duration (divided by 100).[24]”

To understand the real value of convexity the chart below shows the expected value of a 30-Year ZCB in a contest of certainty with respect to uncertainty. The difference between the green dot and the red dot represent the value of convexity. With no uncertainty there is no volatility about future returns and for this reason convexity has no value (investors know that the bond is going to yield suppose 8% for its entire life). The idea of uncertainty is given by the fluctuation of the interest rates. For example, suppose that the investors expect that interest rates will change by 200 basis points (with negative or positive sign) in the future, with equal probabilities (hence 6% or 10% with prob. 50% each). Note that both prices ($1,741.00 for yield = 6% and $573.00 for yield = 10%) are higher than those implied in the linear approximation. The expected ZCB price is given by the average of the two possible final prices ($E[P] = 0.5 * 1{,}741 + 0.5 * 573 = \$1{,}157.00$) and it is higher than the ZCB price given no yield change expected ($994.00 for yield = 8%). The difference between those two values is the expected value of convexity (1,157-994=$163.00). Hence the ZCB price is $163.00 higher if volatility is 200bps than if is null.

[24] Ilmanen, “*Convexity Bias*”, 4.

Figure 10



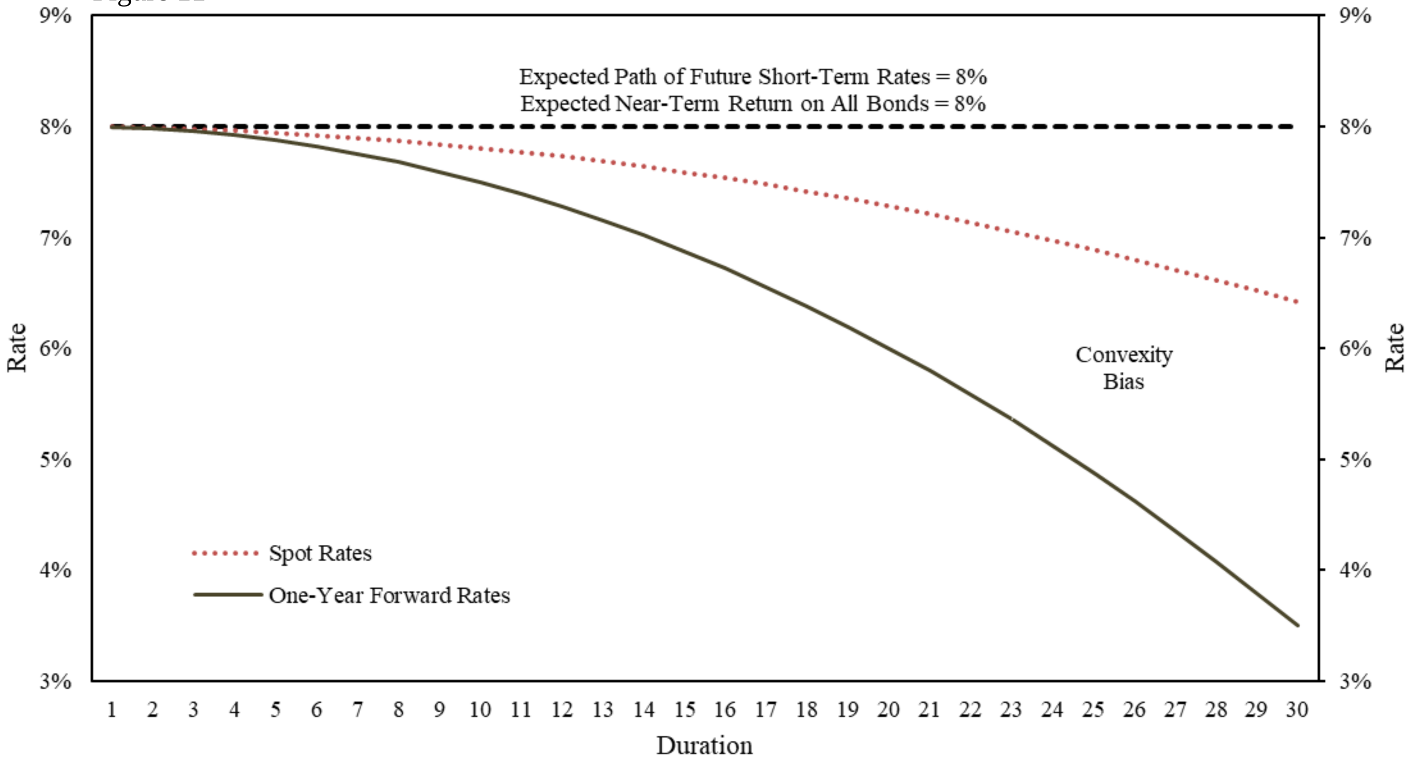
In conclusion, higher is the volatility, better is the expected performance of convex bonds with the consequence that higher is the bond convexity lower is the yield that the same bond offers with respect to less convex bonds (such as long-term vs short-term bonds).

This result is showed in the next figure (11), where is possible to touch the real impact of convexity on the yield curve shape.[25]

[25] This example is a replica (made with full passages and computations) of what Ilmanen did in: Ilmanen, "*Convexity Bias*", 5-6.

Pure Impact of Convexity on the Yield Curve Shape

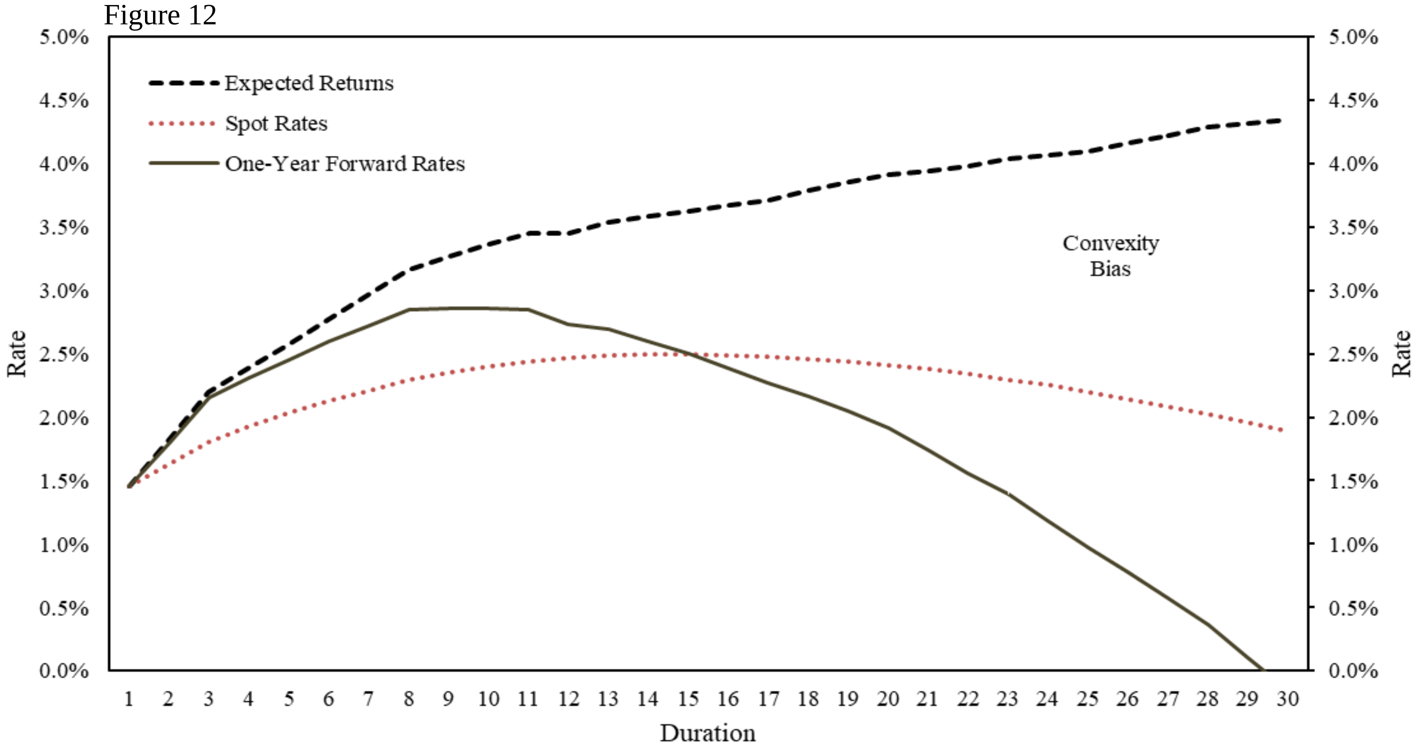
Figure 11



It is easy to see that convexity bias, by itself, makes the yield curve inverted as duration increases. However, rarely the Yield Curve is inverted such as the one showed in the graph (red dot line) and this issue arise from the assumption of equal expected returns across different maturities (8%) and same expected yield changes (100bps).

Impact of Convexity with Positive Bond Risk Premium

Figure 12



By relaxing the first assumption (figure 12), it is now assumed that the bonds expected returns are equal to the arithmetich mean of bond returns reported from 2001 to 2019. This means that it is now introduced the Bond Risk Premium Factor (which before was supposed to be zero). In this case the convexity bias is of different magnitude: at the front-end of the curve is so small that it does not delete the impact of the Bond Risk Premium; as duration becomes higher the convexity bias completely offsets the risk premium factor and makes long-term yield lower than medium-ones (humped yield curve).

In conclusion Convexity has a significant impact on long-term expected bond returns, expecially in a high-volatility environment.

DURATION TIMING STRATEGIES

Introduction

In the previous chapter was introduced and explained the concept of Bond Risk Premium and its main theories. It was also highlighted why and how long-term bonds generate higher returns with respect to the short-term bonds with the consequence that differences in yields are not only due to interest rate expectations.

Now the focus is on the drivers (or better, variables) that are going to be used into a signal model to predict changes in long-term interest rates. The aim of this chapter is then to prove the variables' predictive power for what concerns changes in interest rates and how to construct a profitable strategy to trade duration in a systematic way over time.

Which variables forecast changes in Long-Term interest rates?

Literature Review

In 1995 Anti Ilmanen introduced a first set of variables in his paper entitled *"Forecasting U.S. Bond Returns"*. He described that it is possible to forecast periods characterized by an extremely high/low required premium for duration extension. The idea is then to search for indicators that help the investor to make expectations about one-period-ahead Excess Bond Returns. The variables were the followings:

- The Term Spread: the differential between the long-term and the short-term yields gives immediate information about the yield curve shape and its steepness. A positive term spread and an upward sloping yield curve is the standard and most often observed scenario. If the investors have no expectations about changes in interest rates, then the term spread full represents the required premium to hold a long-term government bond.
- Inverse Wealth: The term spread alone is not sufficiently stable to predict changes in interest rates. The inverse wealth variable represents the wealth-depended risk aversion of markets' participants. Its formula is the weighted average of past stock market returns where recent prices have more weight.
- Real Yield: In addition to the aggregate risk-aversion variable, the investors are also concerned about the inflation rate. Real yield incorporates the inflation premium in the forecasting model.
- Bond Momentum: The last predictive variable is the so-called bond momentum. Although bond momentum has been proved to be not sufficiently reliable, it still represents a useful variable to be added to the model. In fact, it tends to move in countertendency with the other variables, and hence it compensates the magnitude of erroneous forecasts.

In 2012 Seamus Mc Gorain introduced an evolved set of variables in his working paper entitled *"Simple rules to trade duration"*. These variables, being more modern, reflect better the current contest and, consequently, their ability in forecasting long term interest rates changes.

The variables are then signals used to trade duration through 10-year government bond futures. Futures are often used to increase or decrease portfolio duration for several reasons: when the market is particularly illiquid, if there are restrictions about the portfolio composition, or because of their low transaction costs[26]. Hence bond futures are an easy and flexible way to adjust bond portfolio duration[27]. However, in the following analysis, the portfolio will be cash-based, meaning that standard zero-coupon bonds will substitute bond futures with no changes affecting the strategy results.

The identified set of signals is then the following:

- Manufacturing purchasing manager indices (PMIs)
- Bonds price momentum
- Stock Price Momentum
- Carry to risk, i.e., the slope of the yield curve adjusted for its volatility

Together the signals can capture changes in the long-term interest rates. A portfolio manager could use this signal strategy to manage portfolio duration and enhance its performance.

As will be discussed later, the signals reflect many influences concerning the yield curve shape, such as economic news (e.g., via the PMI) and investors' perception about risk (e.g., via Stock Momentum).

Before proceeding with the analysis of the variables, it is proper to describe the structure of the following work. Firstly, there is the description of every variable focusing on its property and the computation methodology behind it. Then it reports the performance of each variable from 2000 up to both 2012 (the stopping year in McGorain) and the end of 2019, in order to find out any potentials in terms of predictability.

In the beginning, the study aggregates the signals of the so-called G-4 (U.S., Germany, Japan, UK) into one single performance indicator while, later on, the focus will be on the spin-off of each country.

Manufacturing Purchasing Manager Indices (PMIs)

The manufacturing purchasing managers indices (PMI from now on) are monthly surveys of business conditions. The first PMI is back in the U.S. during the 1930s, and currently, this signal is worldwide

[26] CME Group. "A Simple Treasury Future Duration Adjustment". Research and Product Development, 2013. https://www.cmegroup.com.
[27] Very briefly the manager goes long future to increase portfolio duration, short otherwise.

developed in more than twenty countries. In Europe, the first country that launched this kind of signal was Germany, and its PMI "accurately replicate the true structure of the economy in miniature[28]".

The group of companies is carefully selected, and the methodology prefers to value the quality of companies instead of their quantity.

The PMIs indagate how firms react to changes in business conditions, such as demand, sales, output, employment. The collection of these indices is various and includes the following: Manufacturing Purchasing Manager Indices (PMI), German IFO manufacturing business, Global PMI, and many more.

How effective is a Local PMI as a duration signal? The figure 13 shows the G-2 (Japan and U.K. excluded) return of a trading rule, which goes long duration if the Local PMI fells over the average of its previous 3-months and short otherwise.

Despite negative results at the beginning of the window, the PMI proved to be a profitable duration timing indicator. The time-series comprehend just U.S. and Germany's PMIs because Japan and U.K. started their business indicator only in the last years (2017). For this reason, when this paper will go through the country strategy, the U.K. and japan local PMIs will be substituted with Local FCIs.

Figure 13

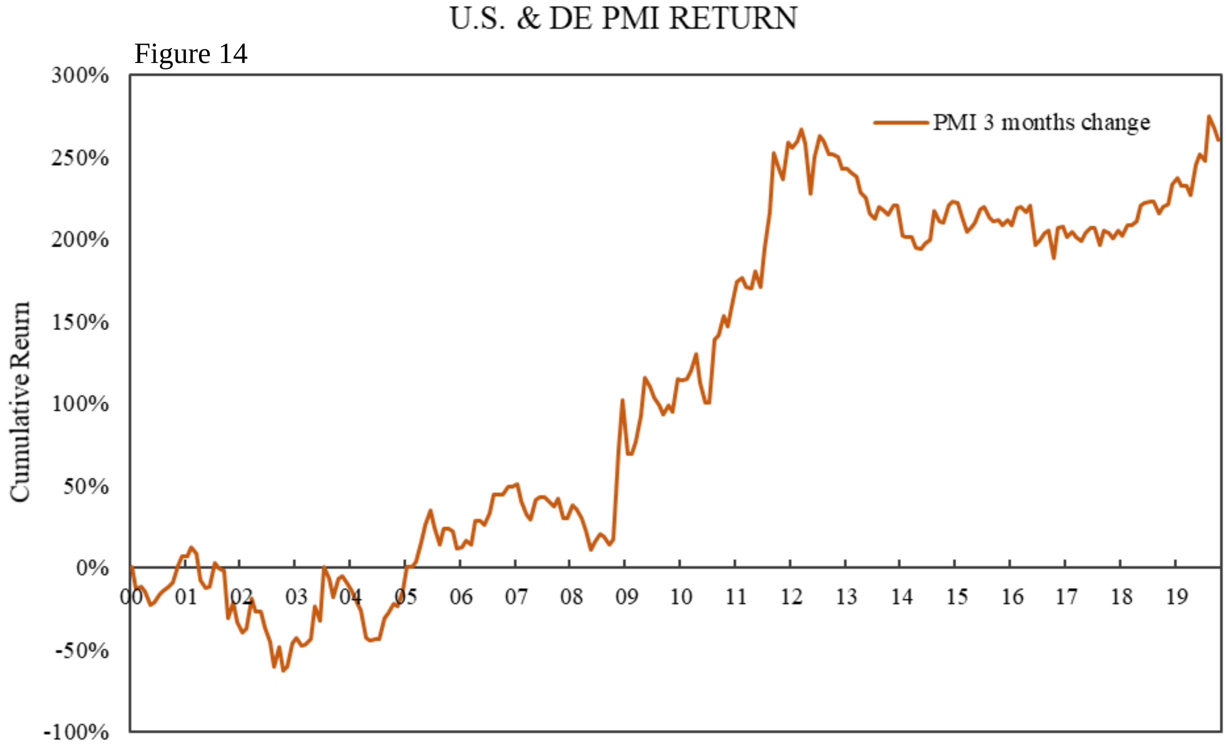
PMI 3 months change

	2000-2012	2012-2019	2000-2019
Return	243,0%	10%	260,2%
Annul Return	18,7%	1,4%	13,1%
Volatility	12,0%	7,7%	10,7%
Ret. To Risk	1,56	0,19	1,23

The figure 14 shows the cumulative return over the full sample timeframe, from 2000 to 2019 of the aggregated PMIs performances. The signal was quite able to capture the upside and downside trends of the 10 years zero-coupon bond while losing some predictability power during periods of neutral trends (from 2012 to 2018).

[28] Williamson, Christopher. "*The purchasing managers' index as a leading indicator for busines users*". In Best Practice in Einkauf und Logistik, edited by Bundesverband Materialwirtschaft, Einkauf und Logistik, 467-479. Wiesbaden, 2008.

Figure 14



Bonds Momentum

In addition to economic momentum, bonds price momentum has been proved to be a successful signal for duration timing trading. Momentum strategies work under the assumption that current time-series trends will persist in a near future. The investment technique is divided into two subsets: the observation period and the investment period. The former is about how much the investor looks behind in order to exploit some price trends (e.g., bull or bear trend in the last six months). After the individuation of a bullish or bearish trend, the investor bets that the current observed time series behavior will remain the same during the investment periods (e.g., for the next month).

The length of the observation period is then crucial for the investment success. In fact, for example, a too concise lookback window could not exploit real trends and, on the opposite, a too much extended could not consider current market conditions. Hence, the lookback window must be proportional to the expected holding period (i.e., investment period). With this in mind, a useful approach to overcome potential errors could be to merge (or better, diversify) short signals with long signals.

Seamus Mac Gorain precisely engaged the latter approach: he simply merged 1-month with 12-months momentum. The strategy is then to go long if both one-month and twelve-month momentums are equal in signs and to stay neutral if they are of opposite signs.[29]

Figure 15 shows the return-to-risk results of 1-month momentum, 12-month momentum, and combined.

Figure 15

Subsample 2000-2019			
	1 month	12 months	1-12 combined
Return	133,3%	97%	28,9%
Annul Return	6,7%	4,9%	1,5%
Volatility	11,3%	15,7%	10,2%
Ret. To Risk	0,60	0,31	0,14

Subsample 2000-2012			
	1 month	12 months	1-12 combined
Return	98,8%	-9%	14,7%
Annul Return	7,6%	-0,7%	1,1%
Volatility	12,0%	16,3%	10,6%
Ret. To Risk	0,63	-0,04	0,11

Subsample 2012-2019			
	1 month	12 months	1-12 combined
Return	34,5%	103%	14,2%
Annul Return	5,0%	14,9%	2,0%
Volatility	10,1%	14,8%	9,6%
Ret. To Risk	0,49	1,00	0,21

The analysis intentionally shows the results of implementing one-month, twelve-month, or the combination of the two. One-month momentum outperforms the other two and seems to be the best candidate to use in the forecast.

However, as this paper will show later, momentum varies substantially across countries, expressing negative results in various windows. The one-twelve month combination is the best candidate because it has the lowest volatility overall and tends to move in countertrend with other signals. Indeed, the momentum signal is often of the opposite sign with respect to the other variables and, for this reason, it furnishes more equilibrium to the model. It tends to reduce the magnitude of the erroneous signals, sometimes helping the investor to stay neutral instead of engaging in the wrong position.

The figure below shows the behavior of various momentum strategies.

[29] Mac Gorain stated in his paper the following: "Specifically, the strategy goes long duration if our futures return index for each country is above its average for the past one, two, three, six or twelve months, and short otherwise. 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." Mac Gorain, Seamus. "*Simple rules to trade duration*". Investment Strategies, no. 74 (2012). J.P. Morgan.

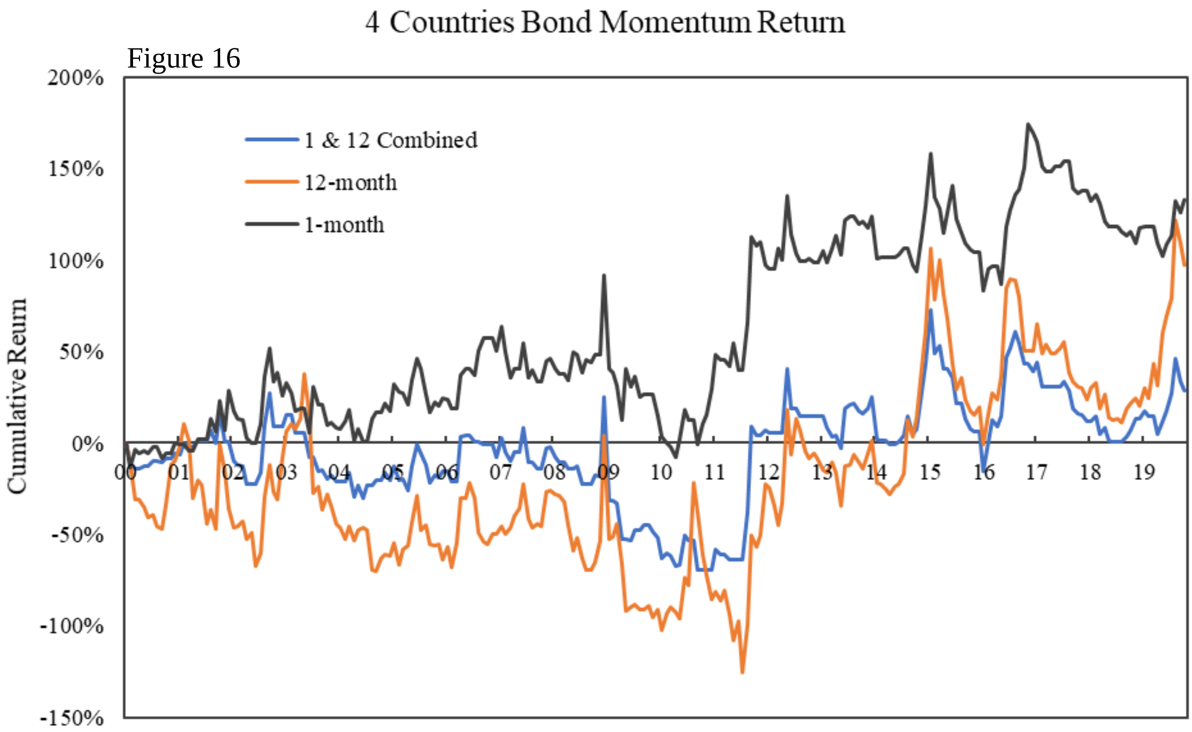


Figure 16

Stock Momentum

In addition to the bond momentum another useful variable is the stock momentum. Indeed, past equity returns are highly correlated with changes in interest rates, in particular a weak stock market tends to be followed by strong bonds returns. The reasons behind this relationship are different. First, as Ilmanen stated in his paper[30], a stock market decline corresponds to the increase in investor risk aversion (low returns are synonym of low wealth), leading the markets participants to invest in safer assets such as government bonds (thus increasing the demand and then the price). Another reason is that low and persistent stock returns are synonyms of economic cycle downturn, which is usually followed by an expansionary policy driving down short term interest rates (with an effect also on long term rates) and up the on-the-run bonds' prices.

A further and detailed description of the equity-bond relationship is the following:

"Whether strong equity returns should be expected to be followed by weak bond returns depends on what is driving both markets (i.e. what news investors are although to be underreacting to). For example, a growth slowdown, or a period of financial turbulence, would be expected to push stocks lower and bonds higher, in keeping with the rationale of wealth and risk aversion effects linking the two. On the other hand, further monetary policy easing (e.g. more QE) should benefit both stock and bond prices, other things equal.[31]"

---

[30] Time Varying Expected Returns in International Bond Markets, Journal of Finance, June 1995.

[31] Mac Gorain, "*Simple rules to trade duration*", 7

The table below (figure 17) shows the performance of a trading rule which goes long if the current stock prices are below the six-month average, and short otherwise. The returns are, also in this case, divided into subperiods to get a more concrete idea of different contests. This strategy sums the returns of the G-4 countries.

Figure 17

Stock Momentum 6-months	2000-2012	2012-2019	2000-2019
Return	378%	73,7%	448,8%
Annul Return	29,1%	10,7%	22,6%
Volatility	16,7%	13,2%	15,6%
Ret. To Risk	1,74	0,81	1,45

The aggregated performance exhibits a bull trend for the entire sample, meaning that this indicator is one of the most powerful. Obviously, the signal is not equally robust for each country, as will be discussed later.

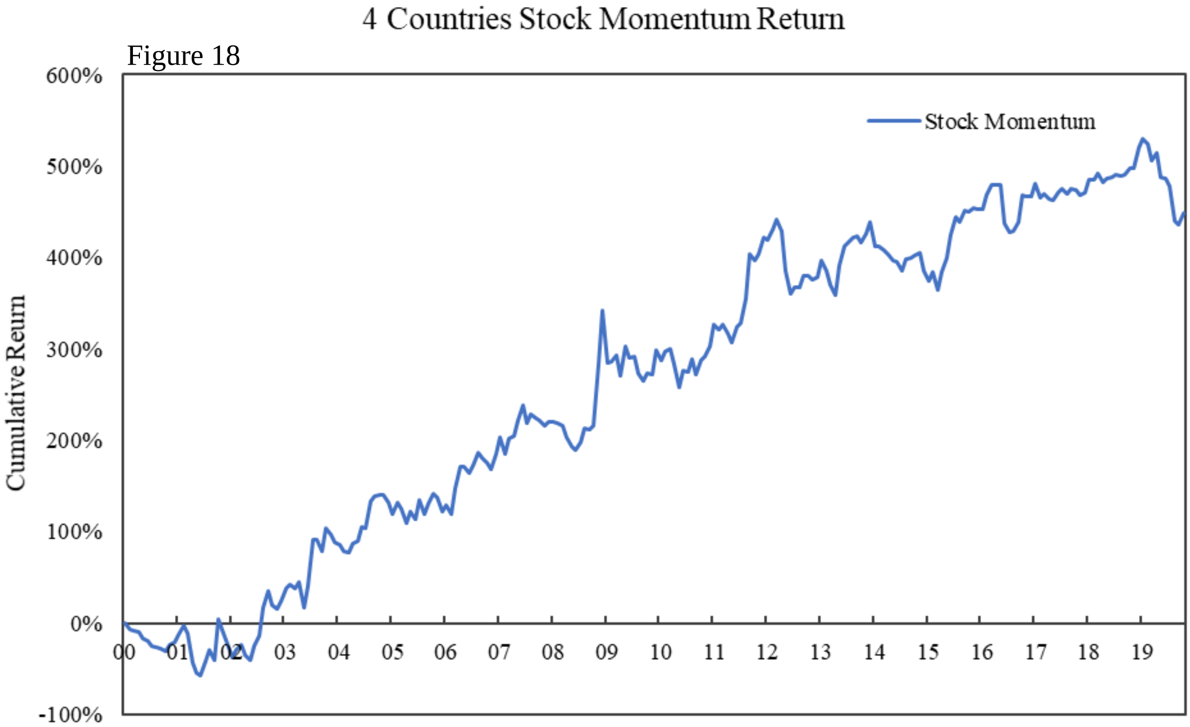


Figure 18

Yield Curve Slope (Carry)

The Carry is an indicator of value in the bond market. It represents the slope of the yield curve and is measured by the difference between long-term and short-term bond yields. Another measure of value is the real yield (the differential between the long-term bond yield and the inflation level) but, giving the current contests, it may be not so significant. In fact, real yield showed a constant negative trend during the timeframe, leading to potential erroneous results.

Hence, the Carry is a much more reliable indicator for bond expected returns. A high carry (steep yield curve) generally corresponds to a high bond risk premium and also to an expansionary monetary policy in support of the economy.

A more sophisticated measure is to scale the Carry by the volatility of 10-year bond returns. The result is then the Carry standardized for its risk and is called the carry-to-risk. The "ratio" behind the carry-to-risk approach is that investors are more willing to lengthen their portfolio duration in a scenario of low volatility.

The trading rules, in this case, is to extend duration in the proportion of how much the carry-to-risk is high with respect to the past ten years. The formula to get this measure is the following:

$$\text{Magnitude of the signal} = 4 * (\text{Percentile of carry} - 0.5) \tag{2.1}$$

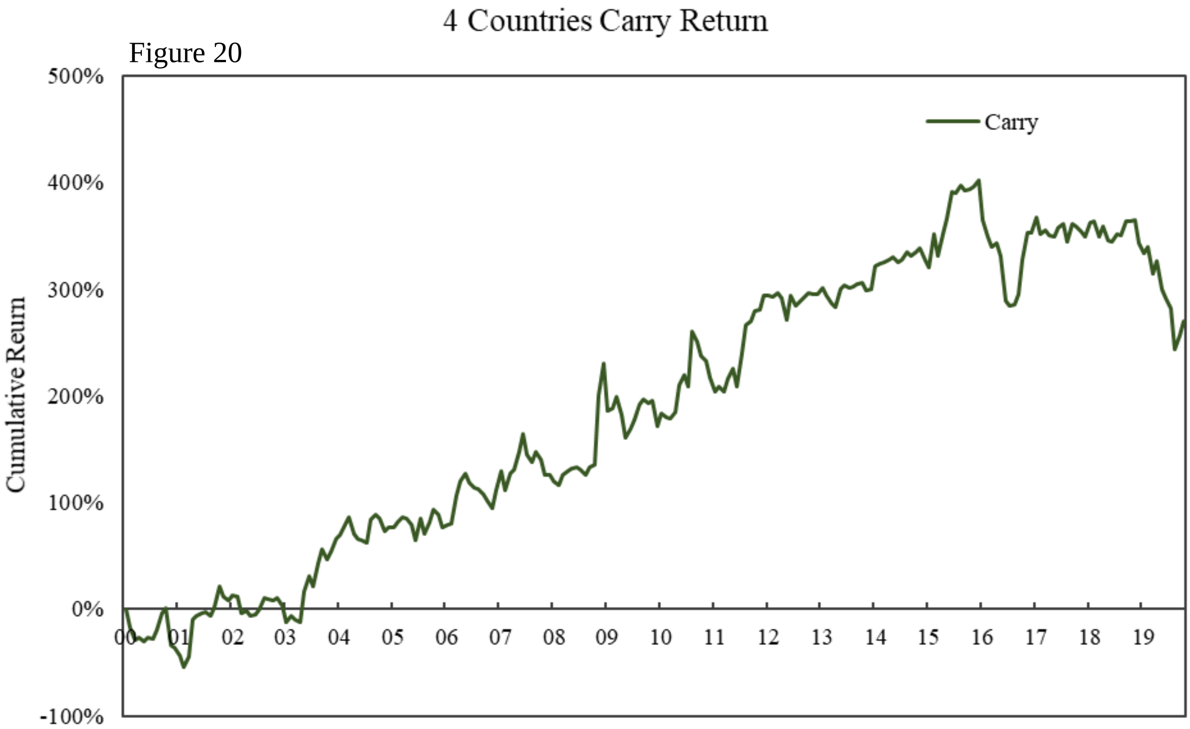
The benefit of this approach is generating a measure that is able to furnish a signal of different magnitudes. Below the figure 19 shows the results of the carry-to-risk strategy.

Figure 19

Carry-to-Risk

	2000-2012	2012-2019	2000-2019
Return	295%	-25,6%	269,9%
Annul Return	22,7%	-3,7%	13,6%
Volatility	13,9%	13,8%	13,9%
Ret. To Risk	1,64	-0,27	0,98

Figure 20



Financial Conditions Index (FCI)

A revolutionary indicator is the Financial Conditions Index (FCI from now on), which is receiving a lot of interest from both the investors and policymaker in recent years.

In the 2007 U.S. economy was severely damaged by the financial crisis and, in the following years, faced one of the most severe recession of its history. Then also the global economy reported a shocking downturn and this critical contest had brought the focus on the significance of financial conditions. Jan Hatzius (Chief Economist of Goldman Sachs) highlighted the above description in the following statement:

"Financial conditions can be defined as the current state of financial variables that influence economic behavior and (thereby) the future state of the economy.[32]"

The economic activity is defined by the supply and demand functions of financial instruments. This relationship results from the behavior of several financial variables such as prices, quantities (flows), and many more indicators. The FCI aggregates all these financial variables generating a synthetic measure of future economic conditions[33].

This paper will use the Goldman Sachs Financial Condition Index. The Goldman Sachs FCI is the weighted sum of several variables, such as short-term bond yields, long-term corporate yields, the exchange rates, and stock prices.

A more precise description of the index is the following:

"Our preferred FCI is constructed as a weighted average of short-term interest rates, long-term interest rates, the trade-weighted dollar, an index of credit spreads, and the ratio of equity prices to the 10-year average of earnings per share. We set the weights using the estimated impact of shocks to each variable on real GDP growth over the following four quarters using a stylized macro model. Moreover, we estimate the partial impact of changes in each financial variable while holding the other financial variables constant. This avoids giving too much weight to some variables—such as the short-term policy rate—whose effect on GDP actually comes via their (potentially time-varying) impact on other series such as long-term yields and the exchange rate.[34]"

---

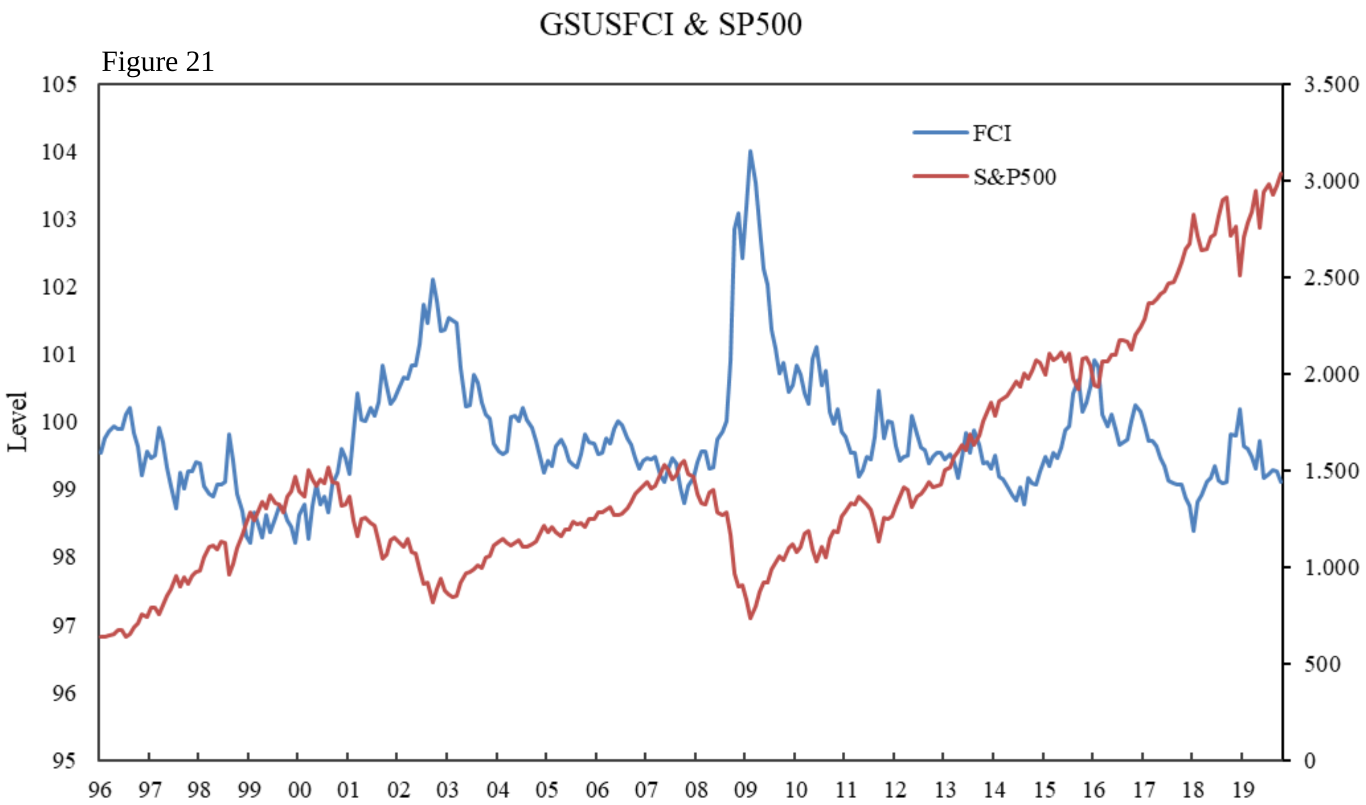
[32] Hatzius, Jan, Peter Hooper, Frederic S. Mishkin, Kermit L. Schoenholtz, and Mark W. Watson. "Financial conditions indexes: a fresh look after the financial crisis". Nber working paper series, no. 16150 (July 2010): 1-56, https://www.nber.org/papers/w16150.

[33] "Ideally, an FCI should measure financial shocks – exogenous shifts in financial conditions that influence or otherwise predict future economic activity. True financial shocks should be distinguished from the endogenous reflection or embodiment in financial variables of past economic activity that itself predicts future activity. If the only information contained in financial variables about future economic activity were of this endogenous variety, there would be no reason to construct an FCI: Past economic activity itself would contain all the relevant predictive information." Hatzius, "*Financial conditions indexes: a fresh look after the financial crisis*", 1.

[34] Hatzius, Jan, and Sven Jari Stehn. "*The case for a financial conditions index*". Global Economics Paper - Goldman Sachs, (July 2018): 1-33.

To understand how to interpret the FCI, below the figure 21 shows the relationship between the GSUSFCI and S&P500. When the FCI is above 100, the financial condition is overall weak (hence it is negatively correlated to the stock market performance).

Figure 21



Below the table shows a trading rule which goes short if the FCI falls below its 3-month average (synonym of better financial conditions) and long otherwise (financial conditions are tightening). The idea is that when financial conditions are getting worse, investors tend to invest in safer assets (such as long-term government bonds), driving down the required rate of return (i.e. yields).

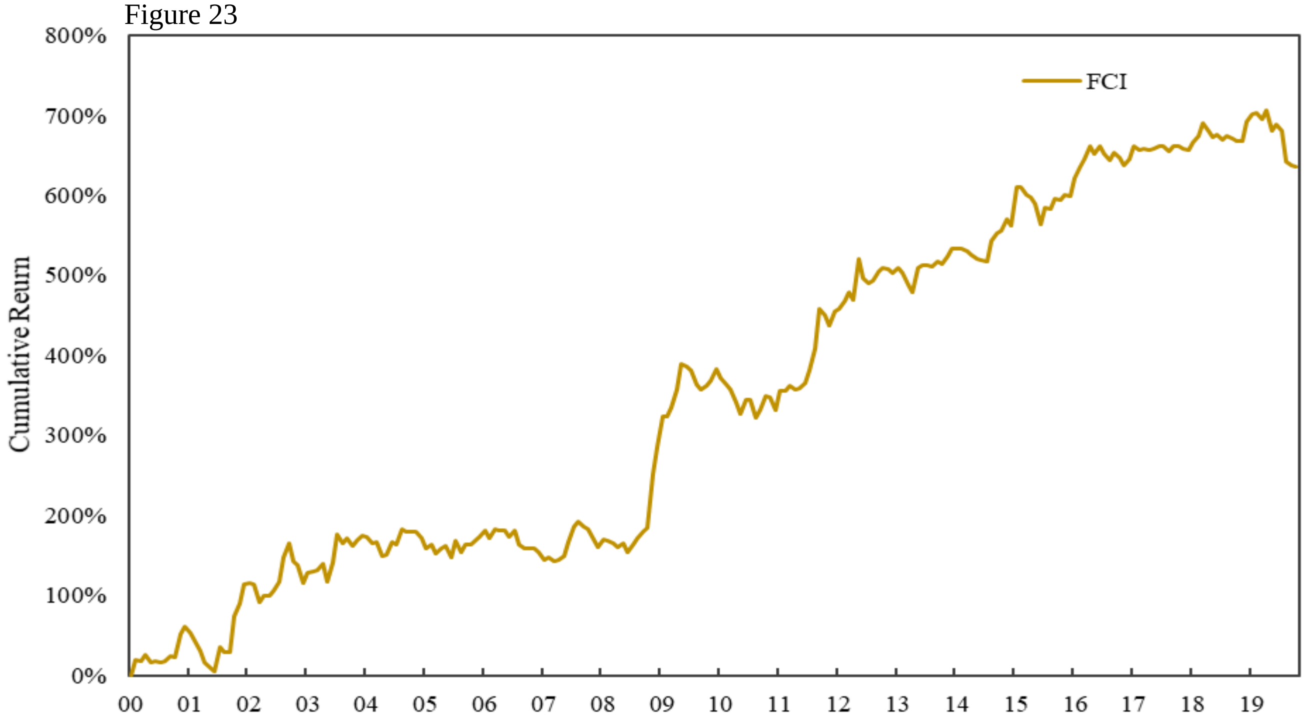
Figure 22

FCI 3-month change			
	2000-2012	2012-2019	2000-2019
Return	503%	128,2%	636,0%
Annul Return	38,7%	18,5%	32,1%
Volatility	15,0%	12,1%	14,1%
Ret. To Risk	2,58	1,53	2,28

The figure illustrates the G-4 performance over the 2000-2019 timeframe. The FCI is the most profitable and stable indicator with respect to the other measures.

4 Countries FCI Return

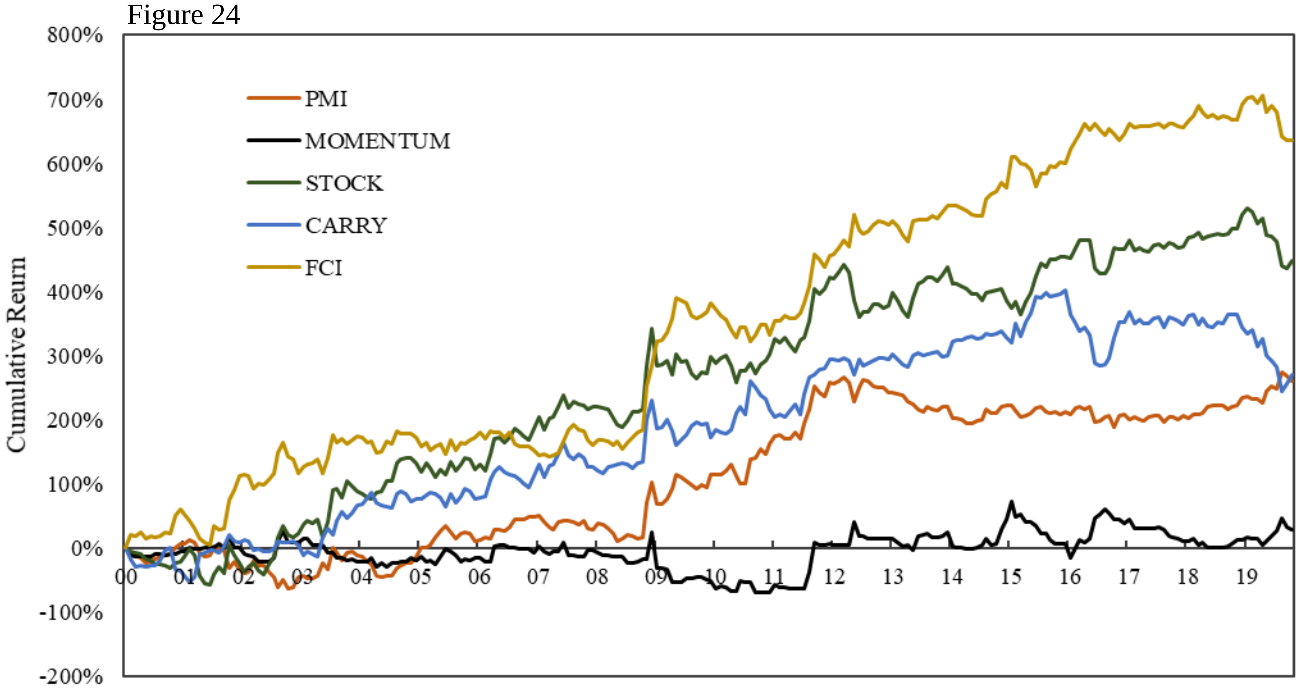
Figure 23



Below the figure compares all the signals together. Intuitively is possible to see that not always the measures move in synchrony. In the specific PMI and bond momentum seems to be quite negatively correlated with FCI, stock momentum, and carry. That does not necessarily translate in less performance if all these signals are combined; in fact, as is possible to check later, negatively correlated signals make the model more equilibrated, especially during "bad forecasts".

All Signals Returns

Figure 24



The Signal Strategy

Description

This section describes the duration timing strategy applied to each G-4 country. The analysis first reflects what Mac Gorain did his paper, then is extended both in terms of the sample period and personal intuitions. The focus is going to be on U.S., Germany, Japan and U.K.. Each country will have its duration timing strategy for a given set of variables and then will be presented the aggregated portfolio.

Given a set of indicators (Global and local PMIs, IBES revisions ratio, carry, bond momentum, and stock momentum), is it possible to generate a single trading signal. The methodology behind is the same as before: for example, the bond momentum variable tells us to go long if the current bond price is below its 1, 6, 12-month average. The same concept is for the other variables (hence to go long or short). Therefore, each month the investor has, for example, 4 signals (e.g. long(1), long(1), short(-1), neutral(0)) linked to the 4 variables (e.g. PMI, carry, bond, stock). At this point, he/she assigns to each signal the same weight (e.g., 25%) and gets the final unique signal $\left(1 * \frac{1}{4} + 1 * \frac{1}{4} - 1 * \frac{1}{4} + 0 * \frac{1}{4} = \frac{1}{4} > 0 \ \rightarrow \text{Long}\right)$. The model aims to predict changes in sign of the ten-year ZCB yield and not the precise value. Obviously, more potent is the aggregate signal (an integer 1 is better than a $\frac{1}{4}$) more probabilities there are that the forecast will correspond to the real value.

Mac Gorain proposed to use both equal and discretionary weights, but always constant in time. In this paper will be presented two main strategies:

- Mac Gorain approach: equal and constant weights (25% for the entire sample)
- Equal weights up to 2012 (Mac Gorain stopping year) and monthly rolling after that.

Concerning the second strategy, the idea is to study the behavior of the signals for a given window (keeping them constant) and then to monthly roll the weights according to the past (2 years) predictive power (in terms of numbers of correct predictions). This approach results in being not only more performing but also more truthful (in fact, an investor would never assigns the same weight to a signal that is not giving useful hints and would tend to overweight more reliable indicators).

For each country, the portfolio will be cash-based, and the trading will be done through 30 years ZCB, to enhance potential returns from interest rate fluctuations (but also increasing the volatility). Furthermore, the strategy is self-financing, meaning that when the signal tells to go long, the investor will finance himself at the country 1-month LIBOR rate and then buys the bond. On the opposite, when short, he/she will borrow the security and sells it on the market, and the cash from the transaction will be invested at the 1-month country LIBOR rate.

The performance will be compared to both a "long-only" trading strategy, which goes always long each month (basically is a bet that interest rates will always decline in the future) and to an always-bond portfolio, i.e., holding up to maturity a 3-month country T-Bill.

The analysis will start with the U.S. country, which will also be the "test country" for what concerns the explanatory power of the variables. Indeed, an univariate linear regression model will help to understand the relationship between the independent variables (i.e., the signals: PMI, Bond momentum, Stock Momentum, Carry, FCI) and the dependent variable (monthly percentage change of the long-term ZCB) in terms of both statistical significances and qualitatively.

Statistics Behind The Variables

U.S. dataset starts from April 4, 1996, to October 31, 2019, with a total of 283 monthly observations. The model aims to estimate the monthly percentage change of long-term bond yield (10 years) through the signal approach. OLS technique will be used for the time series analysis. The model is the following with Bond Momentum as an example:

$$LT\ Yield\ \%\ change_{t \rightarrow t+1} = \alpha + \beta(Bond\ Momentum_t) + \varepsilon_t \quad (2.1)$$

The linear regression analysis are developed trough the software "Matlab".

The set of signals is the following:

1) Stock Price Momentum: 6-month momentum.
2) Carry to risk: Term Premium percentage change scaled by both its past 10-year volatility and its positioning along the antecedent 10-years.
3) Bonds price momentum: 12-month momentum.
4) Manufacturing purchasing manager indices: 3-month change in the local PMI.
5) Extra: FCI 3-month change.

1) Stock Price Momentum

Stock Price Momentum works under the assumption that if stock returns decline too much and follow a momentum behavior (i.e. the negative trend is going to persist in a near future), then the investors starts to switch over safer assets, such as long-term government bond, raising the demand and lowering the yields. The coefficient from the regression confirms what stated, and the relationship is statistically significant.

```
Estimated Coefficients:
                   Estimate        SE         tStat       pValue
                  __________    __________    ________    _______

    (Intercept)   -0.0043968     0.0049649    -0.88557    0.37661
    x1            0.00014682    6.7838e-05      2.1643    0.03128


Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0802
R-squared: 0.0164,  Adjusted R-Squared: 0.0129
F-statistic vs. constant model: 4.68, p-value = 0.0313
```

Therefore, the trading rule is to go long if the current stock price fall below its 6-month average and short otherwise.

2) Carry-to-Risk

The same approach is developed with respect to the carry-to-risk. As stated earlier, this variable does not simply express the slope of the yield curve but instead scale it by its volatility of 10-years bond returns. Furthermore, it considers its ranking over the past 10-years values.

```
Estimated Coefficients:
                   Estimate          SE         tStat       pValue
                  ___________    _________    ________    ________

    (Intercept)   -0.00093545    0.0047658    -0.19628     0.84453
    x1              0.0079868    0.0034818      2.2938    0.022538


Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0801
R-squared: 0.0184,  Adjusted R-Squared: 0.0149
F-statistic vs. constant model: 5.26, p-value = 0.0225
```

The variable is statistically significant, proving how the yield curve slope is one of the most determinant indicators for predicting changes in yields.

3) Bond Momentum

Bond momentum seems not to be particularly performing both in terms of explanatory power and single signal trading approach. The regression is made with the 12-month bond momentum instead of the 1 & 12-month combination (which goes long/short only if 1-month and 12-month momentums are equal in signs, stay neutral otherwise) to overcome the large component of neutral signals. Even if the bond momentum is not statistically significant with changes in long-term yield, it still gives good equilibrium to the model, moving inversely with the other predictors.

```
Estimated Coefficients:
                   Estimate        SE         tStat      pValue
                  __________    _________    ________    _______

    (Intercept)   -0.0016827    0.0048247    -0.34876    0.72753
    x1             0.0030737    0.0048247     0.63708    0.52459


Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0808
R-squared: 0.00144,  Adjusted R-Squared: -0.00211
F-statistic vs. constant model: 0.406, p-value = 0.525
```

4) PMI

The ISM Manufacturing PMI for United States is a reliable indicator of country business conditions. The monthly change shows whether the general business condition is expanding or contracting, and it furnishes a quick look of the investor's current perception about the economic wealth.

```
Estimated Coefficients:
                   Estimate        SE         tStat      pValue
                  __________    _________    ________    _______

    (Intercept)     0.071509     0.054376      1.3151    0.18955
    x1            -0.0013834    0.0010279     -1.3459    0.17943


Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0806
R-squared: 0.0064,  Adjusted R-Squared: 0.00287
F-statistic vs. constant model: 1.81, p-value = 0.179
```

The coefficient seems not to be in line with what one should expect, in fact, an increase in PMI should correspond with an overall increase of economic wealth and less risk-averse investors. However, the window is full of unusual monetary policies which could drive interest rates out of this assumption. Furthermore, it is not always true that business conditions are the key determinants of investors' behavior. This model does not consider changes in Global PMIs and IBES revision ratios (2 key variables of economic condition in the Mac Gorain model). In any case, going long duration when the local PMI decreases and short otherwise seems to be in line with the original assumption, and more is a profitable strategy.

5) FCI

The FCI variable is also introduced to overcome the previous lack of information. As stated before, FCI is able to summarize the overall financial conditions and is getting more and more attention both from investors and policymakers. The FCI measure varies around 100, and a value above of it means that financial conditions are tightening. The FCI 3-month change is one of the best indicators both in terms of trading performance and statistical significance.

```
Estimated Coefficients:
                   Estimate        SE         tStat       pValue
                  __________    ________    ________    __________

    (Intercept)   -0.0015061    0.004671    -0.32244       0.74736
    x1             -0.079273    0.019511     -4.0631    6.2898e-05


Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0786
R-squared: 0.0555,  Adjusted R-Squared: 0.0521
F-statistic vs. constant model: 16.5, p-value = 6.29e-05
```

The coefficient is negative, meaning that an increase in the weakness of financial conditions drives down long-term interest rates.

Combining the signals

U.S.

The next step is to combine the previous trading signals into a single one indicator. Therefore, each month the investor will look to the variables and the weighted average of these will generate the duration trading signal. The aggregated performance of keeping constant the weights is worse than the previous proposed rolling strategy, as it is possible to check in the next figures. Overall, the variables are reliable indicators having a percentage of truthfulness over 50%, and the model, overall, generated a quite satisfactory percentage of correct interest rate predictions.

Figure 25

Signal Strategy with constant weights over time: always 25% for each signal

	PMI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long only
Return	71,7%	-6,9%	176,9%	161,2%	**211,5%**	232,6%
Annual Return	3,0%	-0,3%	7,5%	6,8%	**9,0%**	9,9%
Risk (std)	6,6%	7,3%	6,6%	6,5%	**6,4%**	6,6%
Ret. To Risk	0,46	-0,04	1,13	1,05	**1,40**	1,49
% True	47,6%	55,2%	56,6%	53,8%	**56,2%**	54,1%

Figure 26

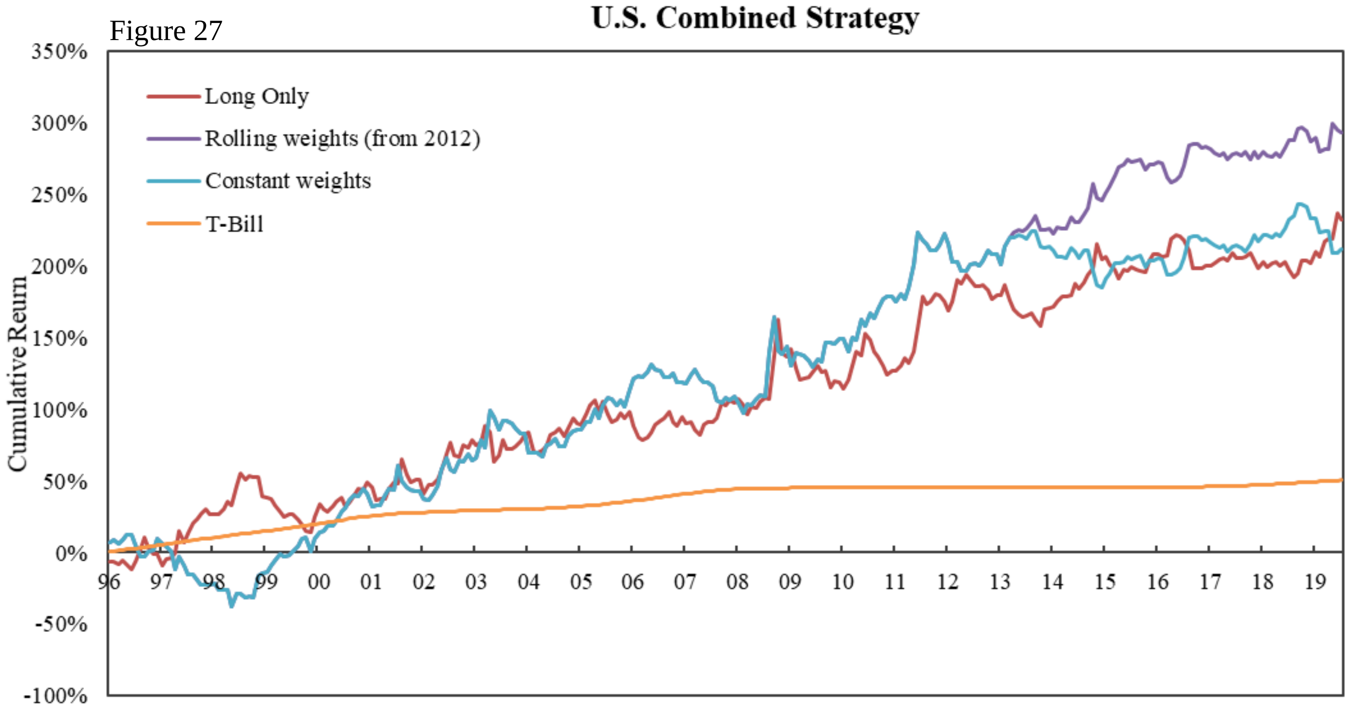
Signals Strategy with constant weights (25%) up to 2012, then monthly rolling.

	PMI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long only
Return	71,7%	-6,9%	176,9%	161,2%	**293,0%**	232,6%
Annual Return	3,0%	-0,3%	7,5%	6,8%	**12,4%**	9,9%
Risk (std)	6,6%	7,3%	6,6%	6,5%	**6,5%**	6,6%
Ret. To Risk	0,46	-0,04	1,13	1,05	**1,92**	1,49
% True	46,7%	54,9%	57,8%	53,5%	**56,2%**	54,1%

The percentage of success refers to how often an indicator generated a successful signal with respect to the long-term interest rate forecast. The rolling approach is advantageous to boost performance while keeping almost constant the volatility.

The strategies are compared to a long-only approach, which goes long each month and to hold up-to-maturity a 3-month U.S. T-Bill.

Figure 27



What happen including FCI

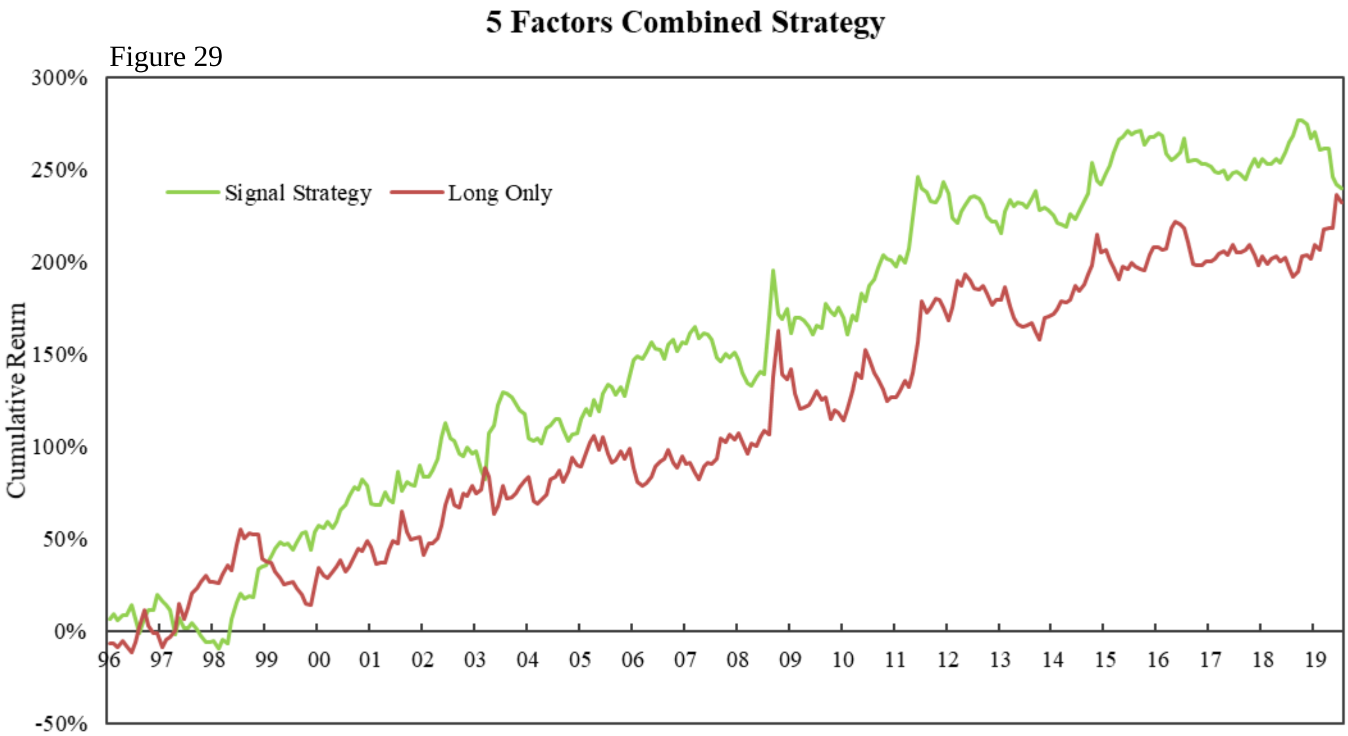
Regardless the FCI is one of the best indicators, its introduction does not seem to produce extra performance into the U.S. contest. This is due to that the FCI is a variable already in synchrony with the model and does not add extra value. On the opposite, an underperforming variable (such as the PMI) is not always a synonym of lower performance, in the sense that is better to have signals that counterbalance with each other (when 3 are head, 1 is tail) rather than always using “same side” indicators. Therefore, taking away weights of “negative” variables does not necessarily lead to an increase in performance.

Figure 28

20% first 2 years, then monthly rolling

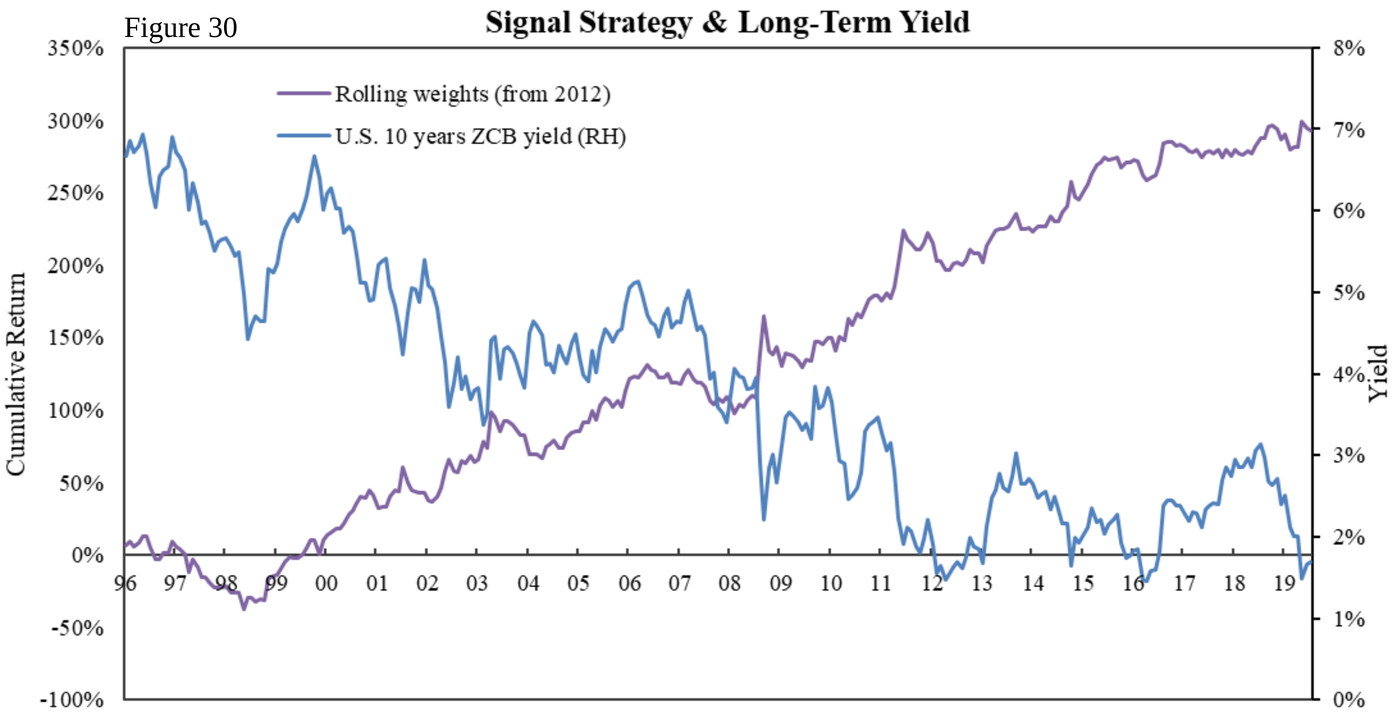
	FCI	PMI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long only
Return	**307,7%**	71,7%	-6,9%	176,9%	161,2%	**240,3%**	232,6%
Annual Return	**13,0%**	3,0%	-0,3%	7,5%	6,8%	**10,2%**	9,9%
Risk (std)	**6,7%**	6,6%	7,3%	6,6%	6,5%	**6,6%**	6,6%
Ret. To Risk	**1,94**	0,46	-0,04	1,13	1,05	**1,55**	1,49
% True	**55,7%**	48,4%	49,2%	57,1%	54,3%	**55,0%**	54,1%

Figure 29



The last figure for the United States shows how the rolling signal strategy performed with respect to long-term interest rates fluctuations. The trend is good looking for the entire sample but the beginning years, and the model generated quite good signals in contests of both high and low interest rate volatility.

Figure 30



Germany

The strategy seems to be performing for the U.S.; what about Germany? The table below shows the results of the same strategy applied to the German contest.

Figure 31

25% up to 2012, then monthly rolling						
	PMI IFO	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long Only
Return	261,3%	48,6%	68,2%	60,9%	**147,3%**	215,5%
Annual Return	12,5%	2,3%	3,3%	2,9%	**7,0%**	10,3%
Std	5,5%	5,9%	5,6%	5,6%	**5,3%**	5,7%
Return to Risk	2,26	0,39	0,59	0,52	**1,33**	1,82
% True	60,7%	53,9%	52,6%	50,0%	**54,8%**	54,6%

The constant weight approach gives very similar results, and for this reason, is not reported. It is worth highlighting the considerable contribution from the German PMI: more than 60% of right predictions with a return to risk greater than 2 points.

The underperformance with respect to the Long-Only strategy does not mean that the model is wrong or has to be rejected. Indeed, the combined method is correct almost 55% of the time and experienced slightly less volatility in returns. More important, the sample period is highly characterized by a bear trend in bond yields, which boosted substantially the performance of the long-only strategy.

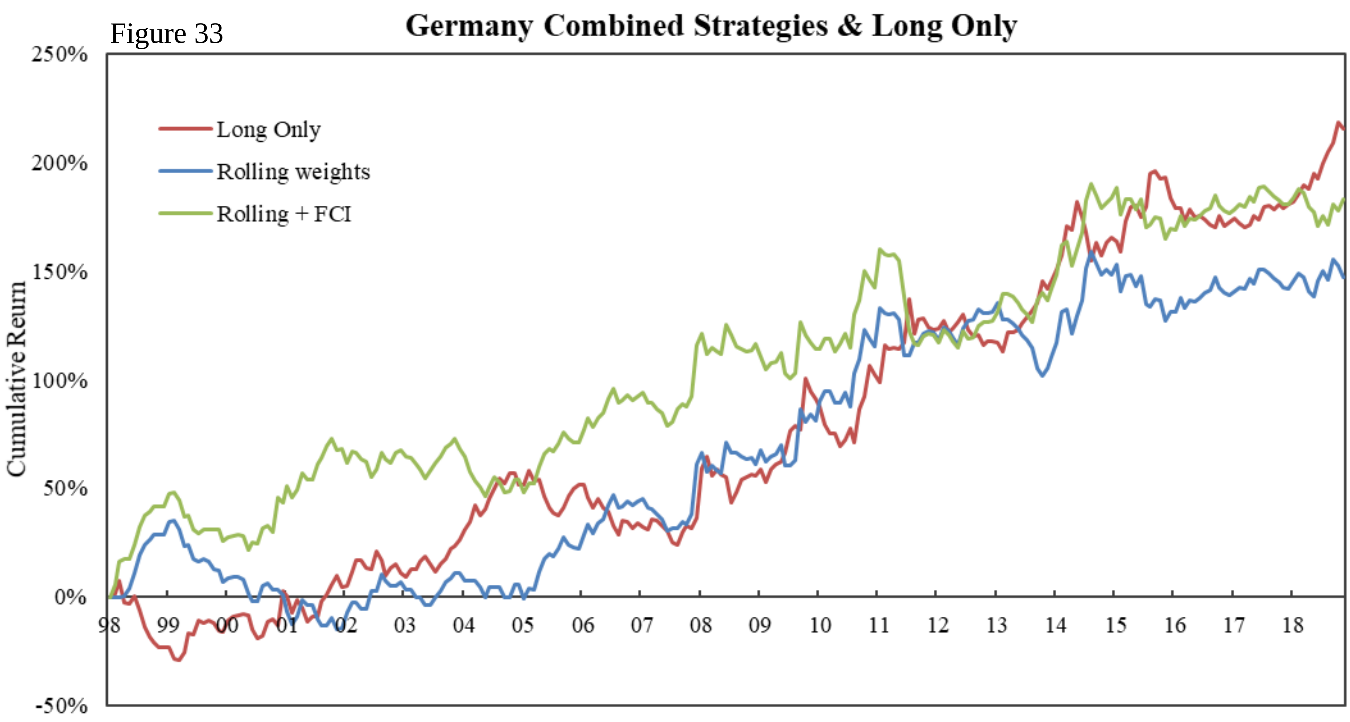
The FCI is also added in this case to understand the magnitude of its contribution. Apparently, it does not seem to give any help to the model because of its true outcome percentage around 50%, but, when combined with other signals, the overall return increases. The idea is the same as U.S.: in this case, the FCI, being a “weak” indicator for Germany, can make the model more equilibrated (it gives good predictions when other variables fail and vice versa).

Figure 32

20% first 2 years, then monthly rolling							
	FCI	PMI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long Only
Return	**129,5%**	261,3%	48,6%	68,2%	60,9%	**182,9%**	215,5%
Annual Return	**6,2%**	12,5%	2,3%	3,3%	2,9%	**8,7%**	10,3%
Std	**5,5%**	5,5%	5,9%	5,6%	5,6%	**5,6%**	5,7%
Return to Risk	**1,13**	2,26	0,39	0,59	0,52	**1,56**	1,82
% True	**50,8%**	59,0%	54,5%	51,8%	51,0%	**54,3%**	54,6%

The figure below shows the performance of both strategies compared to the long-only approach:

Figure 33



Overall, Germany is well-performing, and the introduction of the FCI component significantly contribute to better results.

JAPAN

With Japan the focus now moves to the Asian market. From now on, the FCI will completely substitute the PMI (also for U.K.) because of a lack of information. Indeed, the PMI for both Japan and U.K. is only available from 2017, which is too close to the time-series stopping time. Even if the FCI is available starting from 1996, the analysis for Japan begins in 1999, with a total of 241 observations. The methodology is the same as before, and the results follow in the figure.

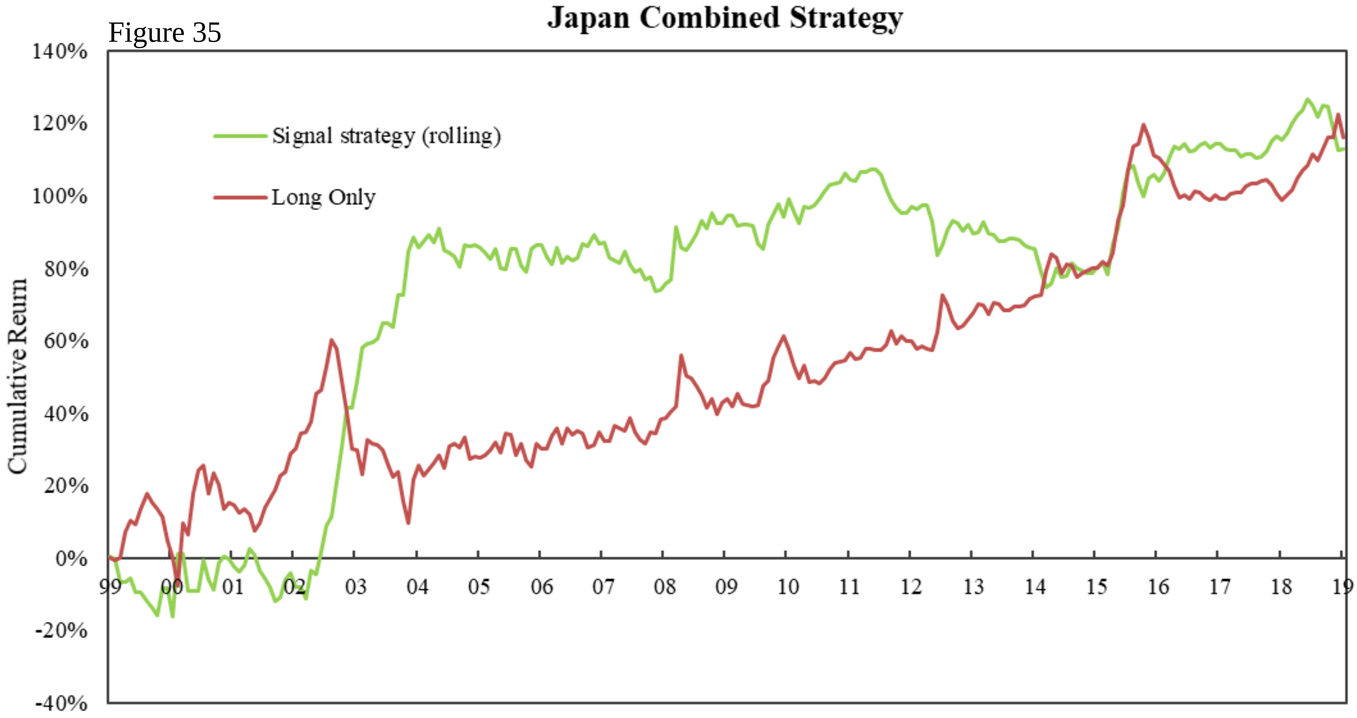
Figure 34

25% up to 2012, then monthly rolling

	FCI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long Only
Return	80,0%	4,0%	80,9%	-35,5%	**113,0%**	116,1%
Annul Return	4,0%	0,2%	4,0%	-1,8%	**5,6%**	5,8%
Risk	3,9%	3,7%	3,9%	3,8%	**3,8%**	3,9%
Ret. To Risk	1,03	0,05	1,04	-0,47	**1,49**	1,50
% True	54,1%	38,5%	57,6%	44,5%	**56,8%**	55,6%

Japan is the first country to experience a negative performance in on of its indicators, the Carry to risk. However, even if carry alone is not useful, the combined strategy generated a valid signal, almost 57% of the time.

Figure 35



UK

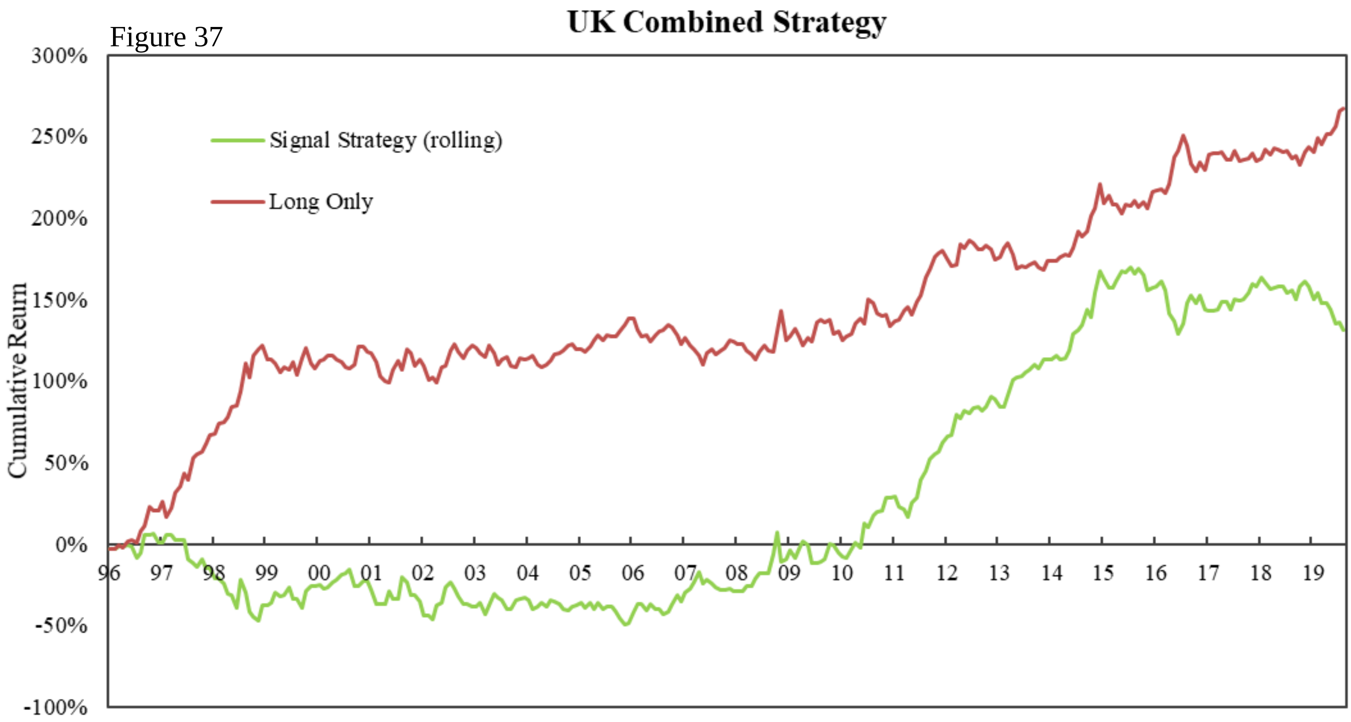
The last country is the United Kingdom, which was the worst-performing country in terms of return compared to the long-only strategy. It achieved only half of the "target" performance; furthermore, it persistently experienced negative returns during the first half of the observation period. The positive return is from the ability of the model to give successful signals in "bad times" (e.g., great recession).

Figure 36

25% up to 2012, then monthly rolling						
	FCI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long Only
Return	232,1%	39,9%	122,6%	79,2%	**131,5%**	267,1%
Annul Return	11,6%	2,0%	6,1%	3,9%	**6,5%**	13,3%
Risk	5,3%	5,8%	5,4%	5,3%	**5,2%**	5,3%
Ret. To Risk	2,16	0,34	1,14	0,74	**1,27**	2,49
% True	58,4%	49,4%	54,9%	47,5%	**54,9%**	58,0%

Also in this case it is worthy of note the superior performance of the FCI component in terms of both return and risk.

Figure 37



The Global Portfolio

The last analysis is made with respect to the aggregated portfolio. This section will look at two main strategies:

- Static Portfolio
- Dynamic Portfolio

For the static portfolio, the assumption is that the investor is willing to risk an equal amount of money in each country. He/she is then assembling a monthly trading portfolio that follows the previous trading rules. Each country strategy follows the “constant plus rolling weights“ approach (i.e., each signal's weight is constant up to 2012, and then the weights are monthly rolled by looking to their previous results). U.S. and Germany do not incorporate the FCI component to follow best the model proposed by Mac Gorain.

The dynamic portfolio follows the same approach of the static but, instead of assigning the same weights to each country (would be 25% for US, DE, JP, UK), it changes its composition over time. The dynamic portfolio follows the same “ratio” of rolling the signals over time. Hence the investor will monthly rebalance the portfolio allocation by looking to the past countries’ performances. For example, if U.S. best performed in the last two years, then the investor will overweight U.S. in the next trading (40%, then 30% to the second-ranked, 20% to the third, 10% to the worst performer). Thus, the capital invested is the same as the static portfolio, but it is allocated more efficiently.

The results are very satisfactory in both the strategies, and the dynamic portfolio vastly outperformed both the static and long-only portfolios.

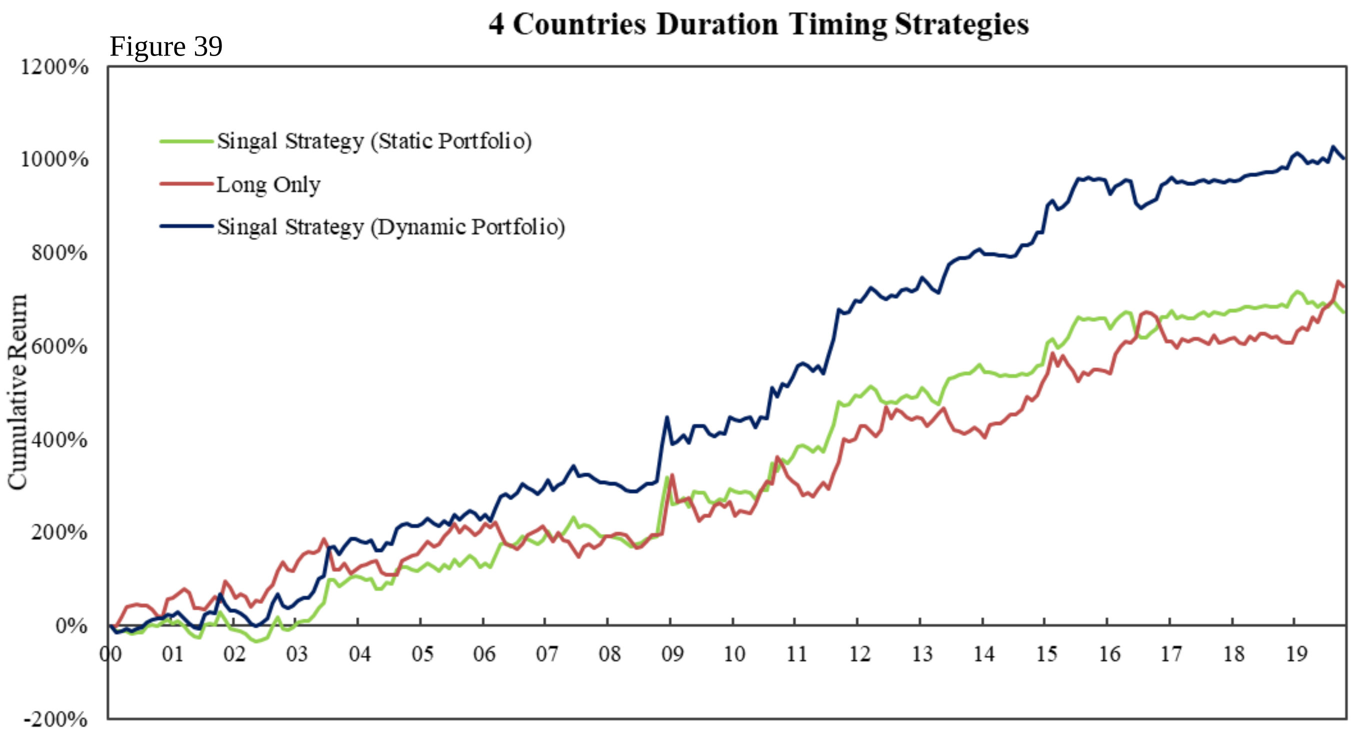
Figure 38

G-4 Statistics (Rolling Strategy)			
	Signal Strategy (Static Portfolio)	Signal Strategy (Dynamic Portfolio)	Long-Only
Return	672,1%	1001,3%	727,2%
Annual Return	33,9%	50,5%	36,7%
Risk (std)	14,9%	16,8%	17,8%
Ret. To Risk	2,27	3,00	2,05
% True	55,9%	58,0%	55,0%

Again, in a standard scenario, where long-term interest rates move in a random-walk fashion, the long-only strategy should not lead to superior performance. It is merely betting each month that interest rates will fall, without looking to any indicator.

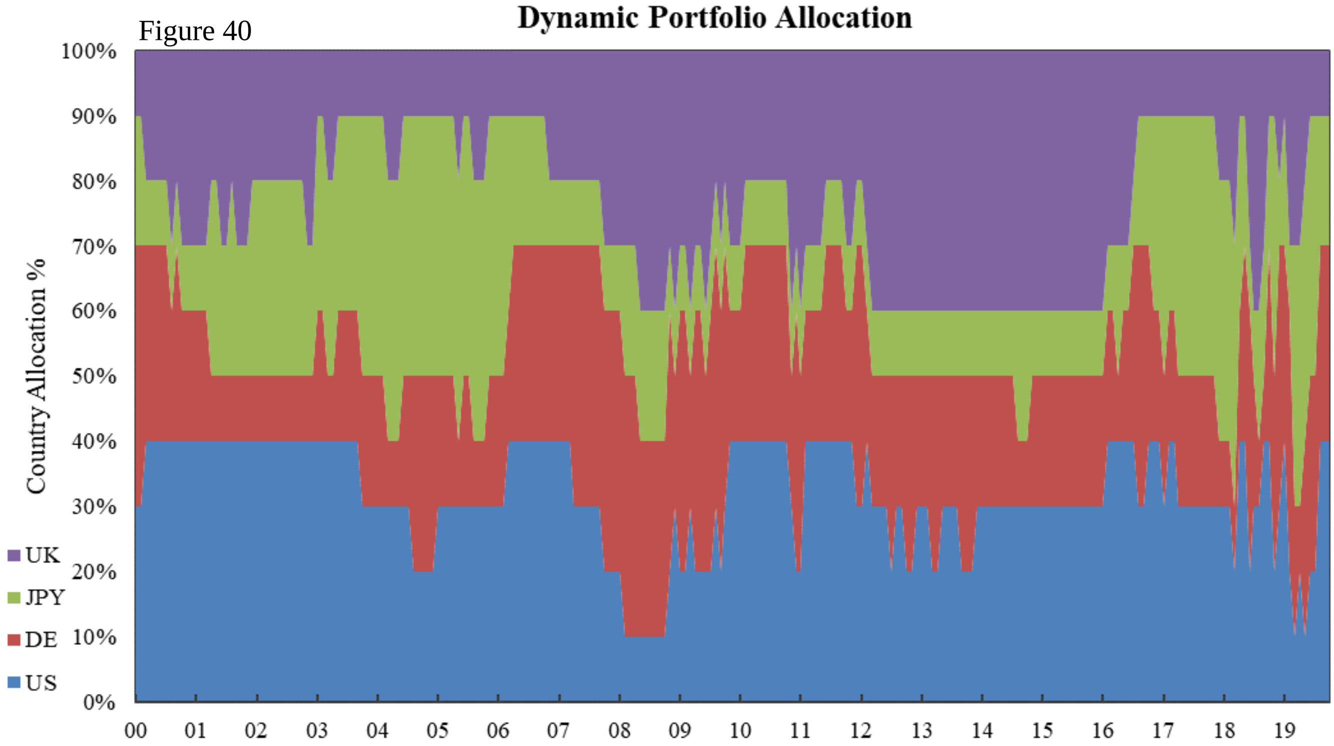
The "% true" above indicates how often the aggregated portfolio experienced positive returns, and the superior dynamic statistic (58%) is from the better allocation.

Figure 39



Finally, the next figure shows how the dynamic portfolio evolved over time. U.S. is often overweighted (81% of times its weight is 40% or 30% of the portfolio) while other countries have, on average, the same grade of exposure.

Figure 40



Dynamic Portfolio Allocation
Country Allocation %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
UK
JPY
DE
US
00
01
02
03
04
05
06
07
08
09
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18
19

CONCLUSIONS

This work was born with the idea of studying in-depth fixed income portfolio strategies. The vast literature (and professional experiences) suggested how important it is to properly manage portfolio duration in order to achieve the high required level of performance. The first section described the main theories behind bond risk premium and interest rates expectations. The second part focus on what tools could the portfolio manager rely on to engage in a profitable strategy.

An existent set of indicators (Carry, bond momentum, PMI, stock momentum) is studied to understand whether these variables are still useful and statistically significant. It comprehends economic and financial indicators. An extra variable was introduced (the FCI), and the findings behind it are impressive. Overall all the variables are beneficial to make genuine predictions about interest rates fluctuations.

Then, by merging the signals of the indicators, it was possible to generate a single powerful trading signal for each country. The strategy diverged from the literature due to the introduction of the rolling-weights. This intuition translates in boosting the performance and decreasing the risk.

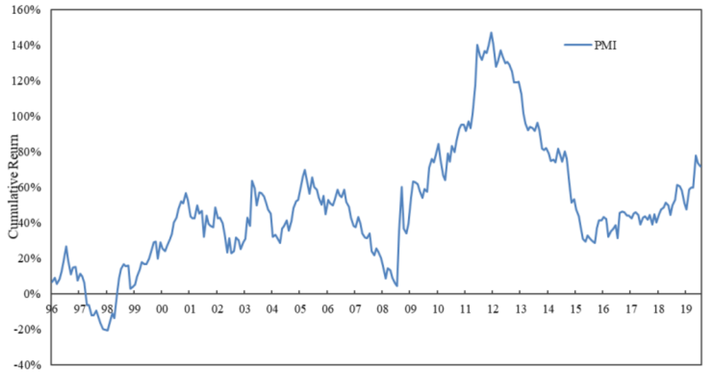
Overall, the results from this analysis are positive in terms of truthfulness of the prediction and performance over time. The best-performing country is U.S. followed by Germany, Japan, and U.K.. The last step was the development of a global portfolio, both static and dynamic.

In conclusion, it is possible to forecast interest rate fluctuation with a sufficient confidence level. The results from the model should help the portfolio manager to adjust the duration but do not represent a strict trading rule. Indeed, the signals should not overcome the discretionary of the portfolio manager but instead be an auxiliary tool in case of uncertainty.

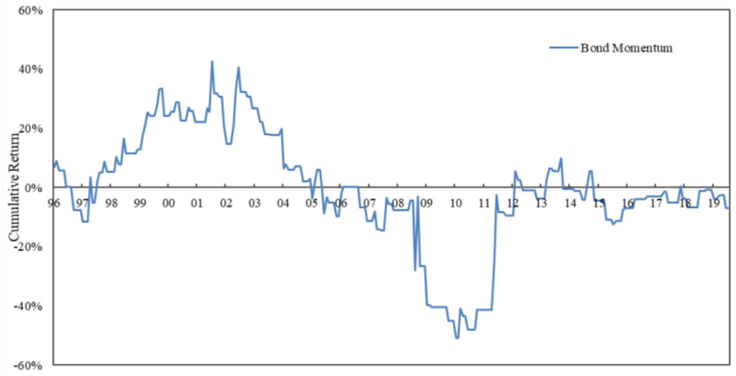
ANNEX

U.S. Signals Performance

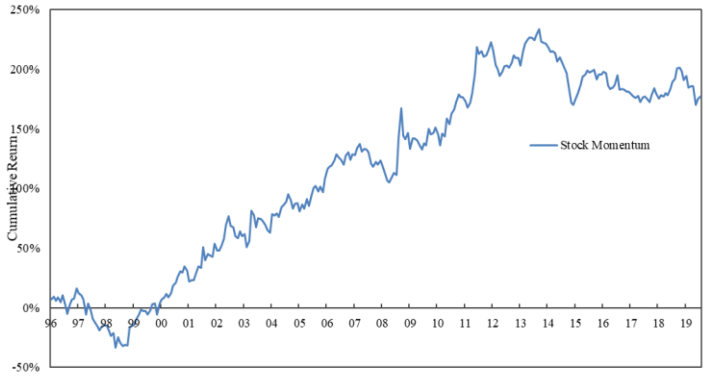
PMI



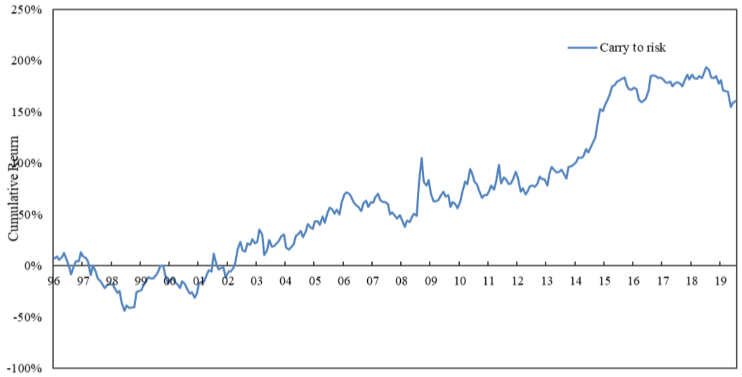
Bond Momentum



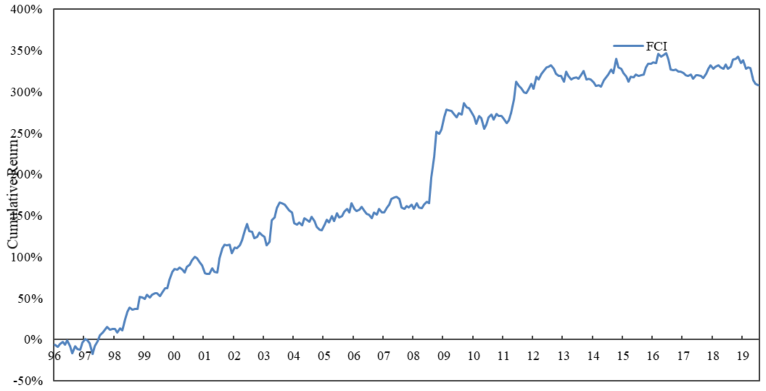
Stock Momentum



Carry to risk

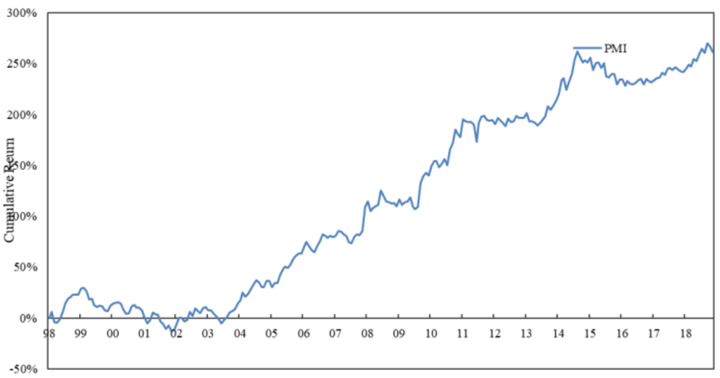


FCI

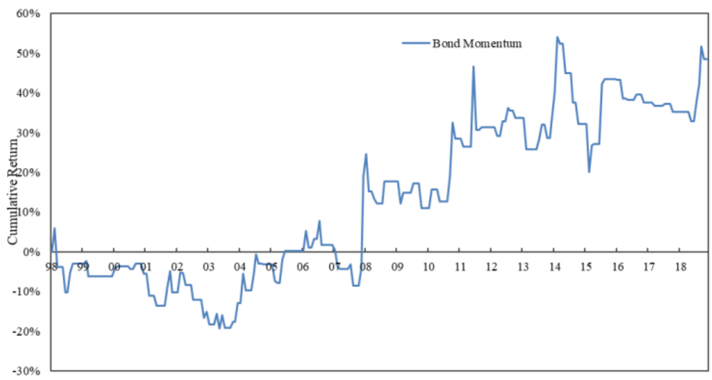


Germany Signals Performance

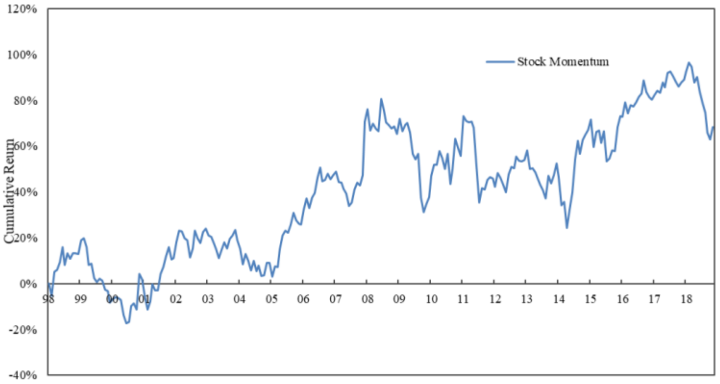
PMI



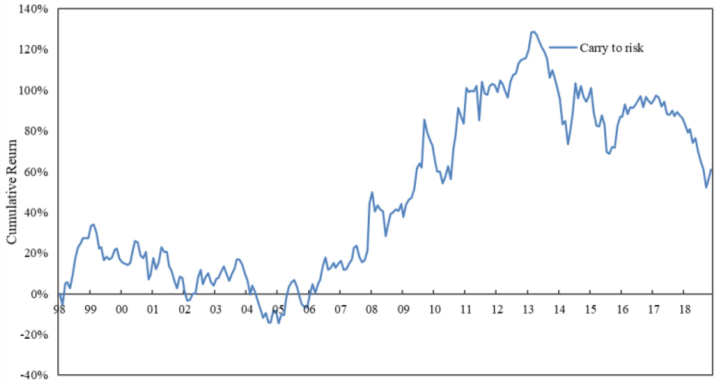
Bond Momentum



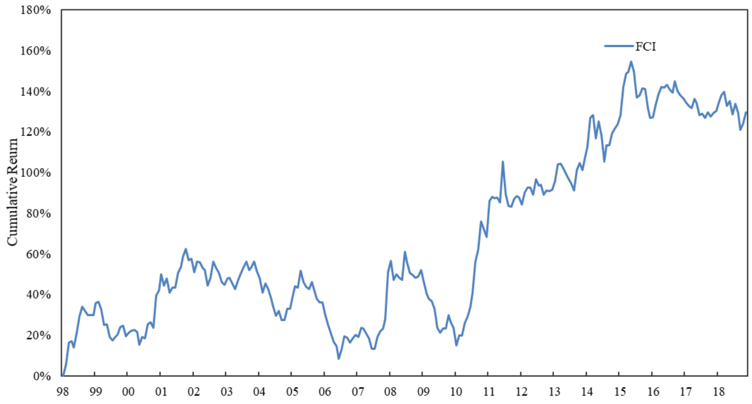
Stock Momentum



Carry to risk

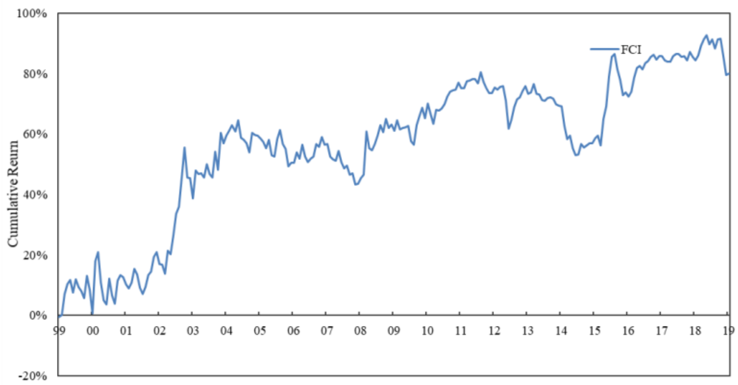


FCI

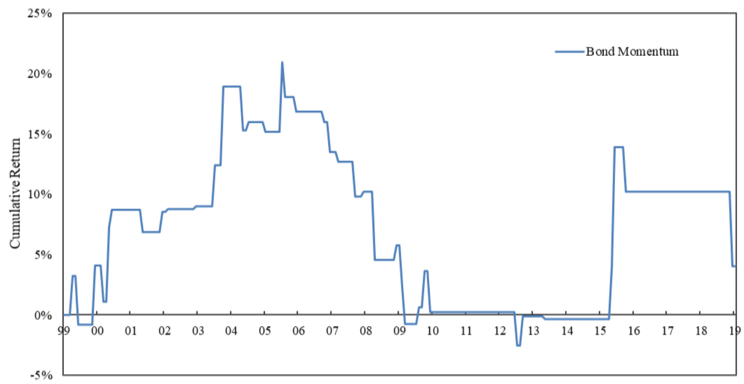


Japan Signals Return

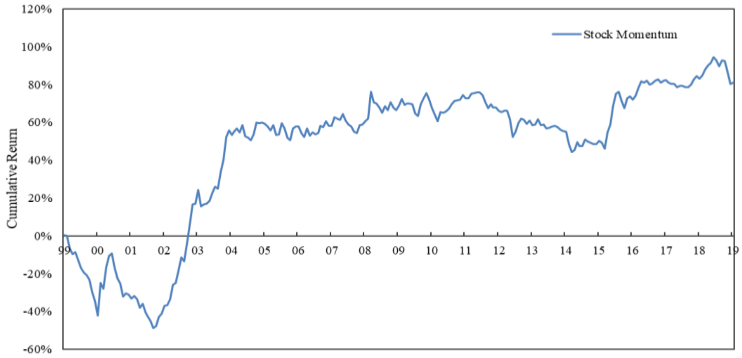
FCI



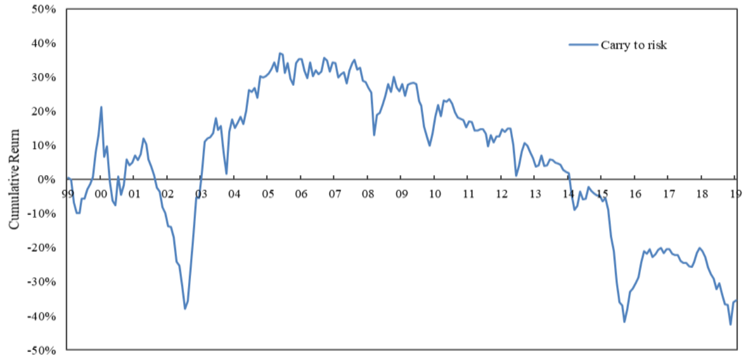
Bond Momentum



Stock Momentum

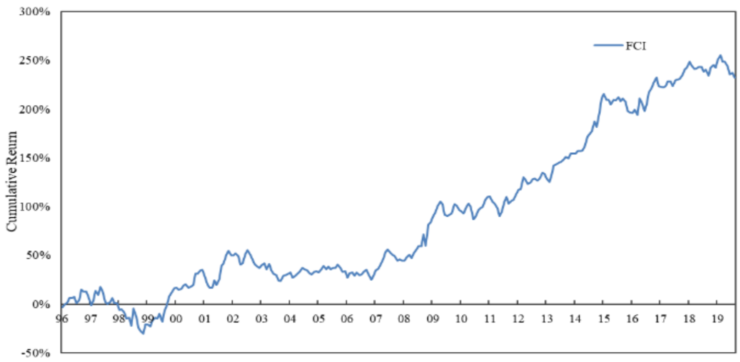


Carry to risk

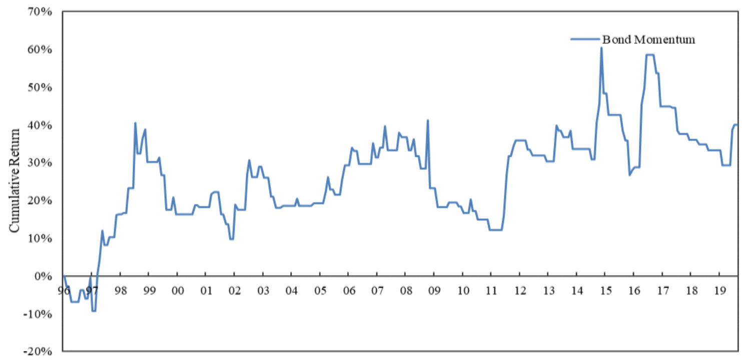


U.K. Signals Performance

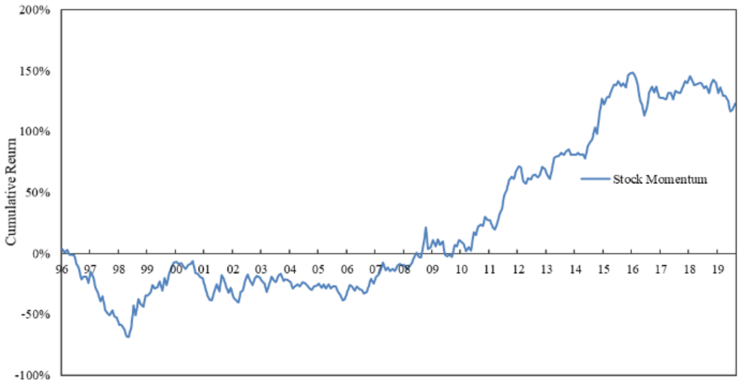
FCI



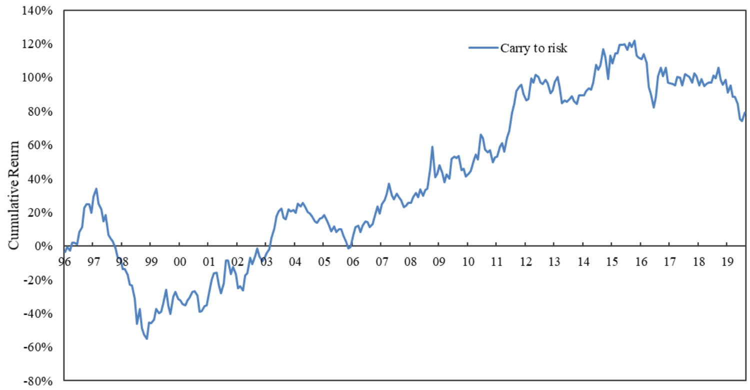
Bond Momentum



Stock Momentum



Carry to risk



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Global Fixed Income Duration Timing Strategies

ABSTRACT

This work aims to furnish a systematic set of rules to manage portfolio duration efficiently. The idea is to develop a model able to generate reasonable predictions about changes in long term bond yields.

This abstract describes the strategies that a portfolio manager could implement to trade duration on a monthly basis. Key points are: variables identification and their relationships with the forecast that is object of this paper; model description; empirical application.

A large focus will be on an innovative variable, which is gaining a lot of attention from both investors and policymakers: the Financial Conditions Index. It results in being extremely powerful with concern to the prediction of changes in future interest rates.

The analysis will develop across the so-called G-4 countries (U.S., Germany, U.K. and Japan) to prove that the thesis is robust globally speaking. The observation period, on average, is from the end of the ’90s to the end of 2019. A focus will be on 2012, which corresponds to the stopping year of another empirical research from which this dissertation took inspiration. Indeed, one of the reasons behind this work was to study the so-called signal strategy and extend and implement it with unique ideas.

The entire work is out-of-the-sample, meaning that the analysis and the strategies are truthful to what it could have happened if the investor followed these rules (i.e., working only with available data at the decision time, without looking to the future).

The strategy will be tested on each country (hence creating four different portfolios.), and the results are quite interesting compared to their respective benchmark. Finally, the work closes with the composition of a global government bond portfolio, which is developed both static and dynamic.

The Signal Strategy

The abstract goes directly through the duration timing strategy applied to each G-4 country. The analysis first reflects what Mac Gorain did his paper, then is extended both in terms of the sample period and personal intuitions. The focus is going to be on U.S., Germany, Japan and U.K.. Each country will have its duration timing strategy for a given set of variables and then will be presented the aggregated portfolio.

Given a set of indicators (Global and local PMIs, IBES revisions ratio, carry, bond momentum, and stock momentum), is it possible to generate a single trading signal. The methodology behind is the same as before: for example, the bond momentum variable tells us to go long if the current bond price is below its 1, 6, 12-month average. The same concept is for the other variables (hence to go long or short). Therefore, each month the investor has, for example, 4 signals (e.g. long(1), long(1), short(-1), neutral(0)) linked to the 4 variables (e.g. PMI, carry, bond, stock). At this point, he/she assigns to each signal the same weight (e.g., 25%) and gets the final unique signal $\left(1 * \frac{1}{4} + 1 * \frac{1}{4} - 1 * \frac{1}{4} + 0 * \frac{1}{4} = \frac{1}{4} > 0 \ \rightarrow \text{Long}\right)$. The model aims to predict changes in sign of the ten-year ZCB yield and not the precise value. Obviously, more potent is the aggregate signal (an integer 1 is better than a $\frac{1}{4}$) more probabilities there are that the forecast will correspond to the real value.

Mac Gorain proposed to use both equal and discretionary weights, but always constant in time. In this paper will be presented two main strategies:

- Mac Gorain approach: equal and constant weights (25% for the entire sample)
- Equal weights up to 2012 (Mac Gorain stopping year) and monthly rolling after that.

Concerning the second strategy, the idea is to study the behavior of the signals for a given window (keeping them constant) and then to monthly roll the weights according to the past (2 years) predictive power (in terms of numbers of correct predictions). This approach results in being not only more performing but also more truthful (in fact, an investor would never assigns the same weight to a signal that is not giving useful hints and would tend to overweight more reliable indicators).

For each country, the portfolio will be cash-based, and the trading will be done through 30 years ZCB, to enhance potential returns from interest rate fluctuations (but also increasing the volatility). Furthermore, the strategy is self-financing, meaning that when the signal tells to go long, the investor will finance himself at the country 1-month LIBOR rate and then buys the bond. On the opposite, when short, he/she will borrow the security and sells it on the market, and the cash from the transaction will be invested at the 1-month country LIBOR rate.

The performance will be compared to both a "long-only" trading strategy, which goes always long each month (basically is a bet that interest rates will always decline in the future) and to an always-bond portfolio, i.e., holding up to maturity a 3-month country T-Bill.

The set of signals is the following:

1) Stock Price Momentum: 6-month momentum.
2) Carry to risk: Term Premium percentage change scaled by both its past 10-year volatility and its positioning along the antecedent 10-years.
3) Bonds price momentum: 12-month momentum.

4) Manufacturing purchasing manager indices: 3-month change in the local PMI.
5) Extra: FCI 3-month changes

1) Stock Price Momentum

Stock Price Momentum works under the assumption that if stock returns decline too much and follow a momentum behavior (i.e. the negative trend is going to persist in a near future), then the investors starts to switch over safer assets, such as long-term government bond, raising the demand and lowering the yields. The coefficient from the regression confirms what stated, and the relationship is statistically significant.

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	-0.0043968	0.0049649	-0.88557	0.37661
x1	0.00014682	6.7838e-05	2.1643	0.03128

Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0802
R-squared: 0.0164, Adjusted R-Squared: 0.0129
F-statistic vs. constant model: 4.68, p-value = 0.0313

Therefore, the trading rule is to go long if the current stock price fall below its 6-month average and short otherwise.

2) Carry-to-Risk

The same approach is developed with respect to the carry-to-risk. As stated earlier, this variable does not simply express the slope of the yield curve but instead scale it by its volatility of 10-years bond returns. Furthermore, it considers its ranking over the past 10-years values.

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	-0.00093545	0.0047658	-0.19628	0.84453
x1	0.0079868	0.0034818	2.2938	0.022538

Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0801
R-squared: 0.0184, Adjusted R-Squared: 0.0149
F-statistic vs. constant model: 5.26, p-value = 0.0225

The variable is statistically significant, proving how the yield curve slope is one of the most determinant indicators for predicting changes in yields.

3) Bond Momentum

Bond momentum seems not to be particularly performing both in terms of explanatory power and single signal trading approach. The regression is made with the 12-month bond momentum instead of the 1 & 12-month combination (which goes long/short only if 1-month and 12-month momentums are equal in signs, stay neutral otherwise) to overcome the large component of neutral signals. Even if the bond momentum is not statistically significant with changes in long-term yield, it still gives good equilibrium to the model, moving inversely with the other predictors.

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	-0.0016827	0.0048247	-0.34876	0.72753
x1	0.0030737	0.0048247	0.63708	0.52459

```
Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0808
R-squared: 0.00144,  Adjusted R-Squared: -0.00211
F-statistic vs. constant model: 0.406, p-value = 0.525
```

4) PMI

The ISM Manufacturing PMI for United States is a reliable indicator of country business conditions. The monthly change shows whether the general business condition is expanding or contracting, and it furnishes a quick look of the investor's current perception about the economic wealth.

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	0.071509	0.054376	1.3151	0.18955
x1	-0.0013834	0.0010279	-1.3459	0.17943

```
Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0806
R-squared: 0.0064,  Adjusted R-Squared: 0.00287
F-statistic vs. constant model: 1.81, p-value = 0.179
```

The coefficient seems not to be in line with what one should expect, in fact, an increase in PMI should correspond with an overall increase of economic wealth and less risk-averse investors. However, the window is full of unusual monetary policies which could drive interest rates out of this assumption. Furthermore, it is not always true that business conditions are the key determinants of investors' behavior. This model does not consider changes in Global PMIs and IBES revision ratios (2 key variables of economic condition in the Mac Gorain model). In any case, going long duration when the local PMI decreases and short otherwise seems to be in line with the original assumption, and more is a profitable strategy.

5) FCI

The FCI variable is also introduced to overcome the previous lack of information. As stated before, FCI is able to summarize the overall financial conditions and is getting more and more attention both from investors and policymakers. The FCI measure varies around 100, and a value above of it means that financial conditions are tightening. The FCI 3-month change is one of the best indicators both in terms of trading performance and statistical significance.

```
Estimated Coefficients:
                   Estimate        SE         tStat       pValue
                   _________    ________    ________    __________

    (Intercept)    -0.0015061   0.004671    -0.32244       0.74736
    x1              -0.079273   0.019511     -4.0631    6.2898e-05


Number of observations: 283, Error degrees of freedom: 281
Root Mean Squared Error: 0.0786
R-squared: 0.0555,  Adjusted R-Squared: 0.0521
F-statistic vs. constant model: 16.5, p-value = 6.29e-05
```

The coefficient is negative, meaning that an increase in the weakness of financial conditions drives down long-term interest rates.

Combining the signals

U.S.

The next step is to combine the previous trading signals into a single one indicator. Therefore, each month the investor will look to the variables and the weighted average of these will generate the duration trading signal. The aggregated performance of keeping constant the weights is worse than the previous proposed rolling strategy, as it is possible to check in the next figures. Overall, the variables are reliable indicators having a percentage of truthfulness over 50%, and the model, overall, generated a quite satisfactory percentage of correct interest rate predictions.

Figure 1

Signal Strategy with constant weights over time: always 25% for each signal						
	PMI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long only
Return	71,7%	-6,9%	176,9%	161,2%	**211,5%**	232,6%
Annual Return	3,0%	-0,3%	7,5%	6,8%	**9,0%**	9,9%
Risk (std)	6,6%	7,3%	6,6%	6,5%	**6,4%**	6,6%
Ret. To Risk	0,46	-0,04	1,13	1,05	**1,40**	1,49
% True	47,6%	55,2%	56,6%	53,8%	**56,2%**	54,1%

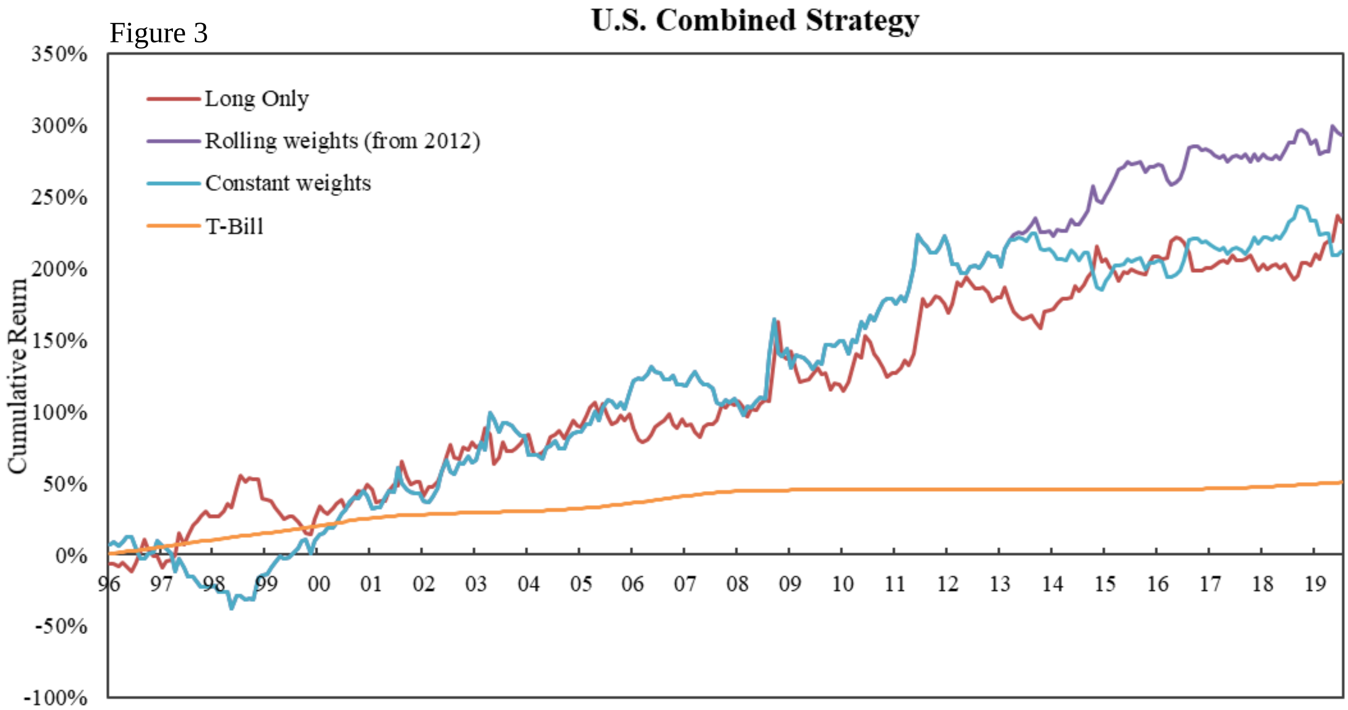
Figure 2

Signals Strategy with constant weights (25%) up to 2012, then monthly rolling.						
	PMI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long only
Return	71,7%	-6,9%	176,9%	161,2%	**293,0%**	232,6%
Annual Return	3,0%	-0,3%	7,5%	6,8%	**12,4%**	9,9%
Risk (std)	6,6%	7,3%	6,6%	6,5%	**6,5%**	6,6%
Ret. To Risk	0,46	-0,04	1,13	1,05	**1,92**	1,49
% True	46,7%	54,9%	57,8%	53,5%	**56,2%**	54,1%

The percentage of success refers to how often an indicator generated a successful signal with respect to the long-term interest rate forecast. The rolling approach is advantageous to boost performance while keeping almost constant the volatility.

The strategies are compared to a long-only approach, which goes long each month and to hold up-to-maturity a 3-month U.S. T-Bill.

Figure 3



What happen including FCI

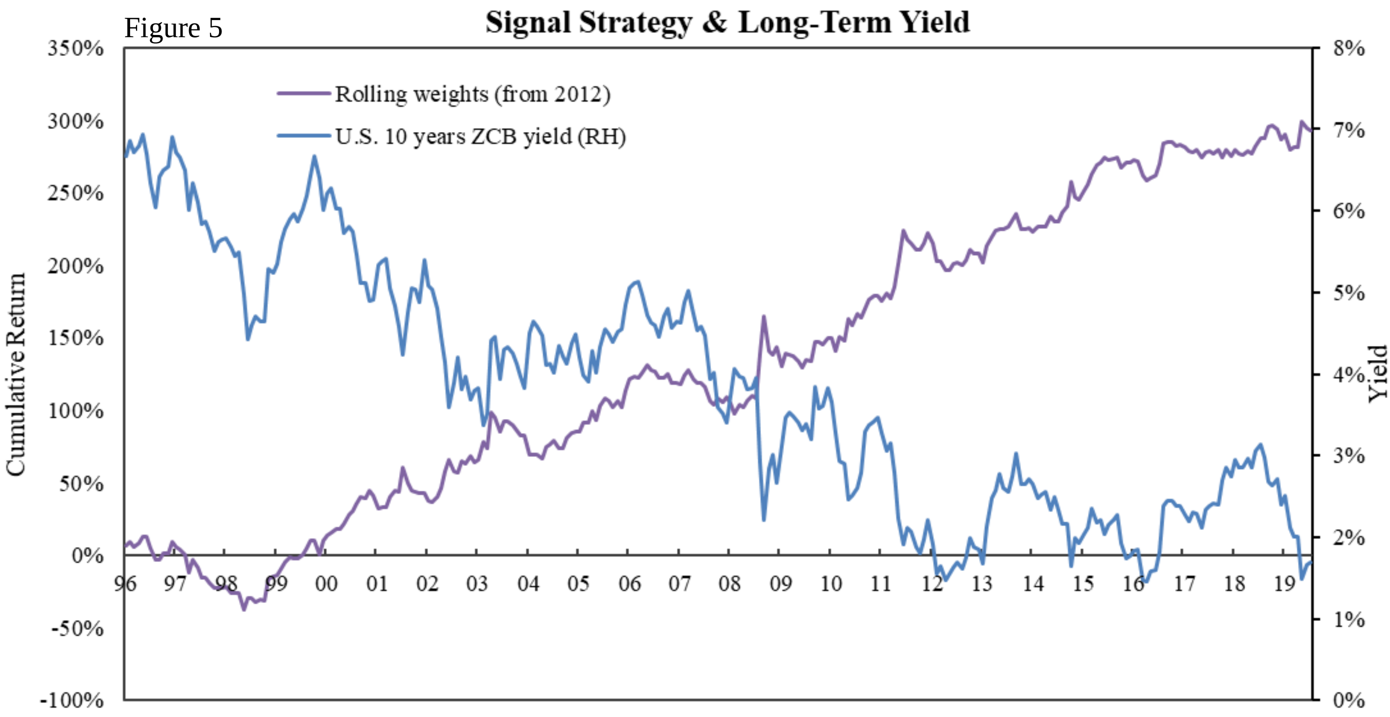
Regardless the FCI is one of the best indicators, its introduction does not seem to produce extra performance into the U.S. contest. This is due to that the FCI is a variable already in synchrony with the model and does not add extra value. On the opposite, an underperforming variable (such as the PMI) is not always a synonym of lower performance, in the sense that is better to have signals that counterbalance with each other (when 3 are head, 1 is tail) rather than always using “same side” indicators. Therefore, taking away weights of “negative” variables does not necessarily lead to an increase in performance.

Figure 4

20% first 2 years, then monthly rolling	**FCI**	PMI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long only
Return	**307,7%**	71,7%	-6,9%	176,9%	161,2%	**240,3%**	232,6%
Annual Return	**13,0%**	3,0%	-0,3%	7,5%	6,8%	**10,2%**	9,9%
Risk (std)	**6,7%**	6,6%	7,3%	6,6%	6,5%	**6,6%**	6,6%
Ret. To Risk	**1,94**	0,46	-0,04	1,13	1,05	**1,55**	1,49
% True	**55,7%**	48,4%	49,2%	57,1%	54,3%	**55,0%**	54,1%

The last figure for the United States shows how the rolling signal strategy performed with respect to long-term interest rates fluctuations. The trend is good looking for the entire sample but the beginning years, and the model generated quite good signals in contests of both high and low interest rate volatility.

Figure 5



Germany

The strategy seems to be performing for the U.S.; what about Germany? The table below shows the results of the same strategy applied to the German contest.

Figure 6

25% up to 2012, then monthly rolling	PMI IFO	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long Only
Return	261,3%	48,6%	68,2%	60,9%	**147,3%**	215,5%
Annual Return	12,5%	2,3%	3,3%	2,9%	**7,0%**	10,3%
Std	5,5%	5,9%	5,6%	5,6%	**5,3%**	5,7%
Return to Risk	2,26	0,39	0,59	0,52	**1,33**	1,82
% True	60,7%	53,9%	52,6%	50,0%	**54,8%**	54,6%

The constant weight approach gives very similar results, and for this reason, is not reported. It is worth highlighting the considerable contribution from the German PMI: more than 60% of right predictions with a return to risk greater than 2 points.

The underperformance with respect to the Long-Only strategy does not mean that the model is wrong or has to be rejected. Indeed, the combined method is correct almost 55% of the time and experienced slightly less volatility in returns. More important, the sample period is highly characterized by a bear trend in bond yields, which boosted substantially the performance of the long-only strategy.

The FCI is also added in this case to understand the magnitude of its contribution. Apparently, it does not seem to give any help to the model because of its true outcome percentage around 50%, but, when combined with other signals, the overall return increases. The idea is the same as U.S.: in this case, the FCI, being a "weak" indicator for Germany, can make the model more equilibrated (it gives good predictions when other variables fail and vice versa).

Figure 7

20% first 2 years, then monthly rolling

	FCI	PMI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long Only
Return	**129,5%**	261,3%	48,6%	68,2%	60,9%	**182,9%**	215,5%
Annual Return	**6,2%**	12,5%	2,3%	3,3%	2,9%	**8,7%**	10,3%
Std	**5,5%**	5,5%	5,9%	5,6%	5,6%	**5,6%**	5,7%
Return to Risk	**1,13**	2,26	0,39	0,59	0,52	**1,56**	1,82
% True	**50,8%**	59,0%	54,5%	51,8%	51,0%	**54,3%**	54,6%

The figure below shows the performance of both strategies compared to the long-only approach:

Figure 8

Overall, Germany is well-performing, and the introduction of the FCI component significantly contribute to better results.

JAPAN

With Japan the focus now moves to the Asian market. From now on, the FCI will completely substitute the PMI (also for U.K.) because of a lack of information. Indeed, the PMI for both Japan and U.K. is only available from 2017, which is too close to the time-series stopping time. Even if the FCI is available starting from 1996, the analysis for Japan begins in 1999, with a total of 241 observations. The methodology is the same as before, and the results follow in the figure.

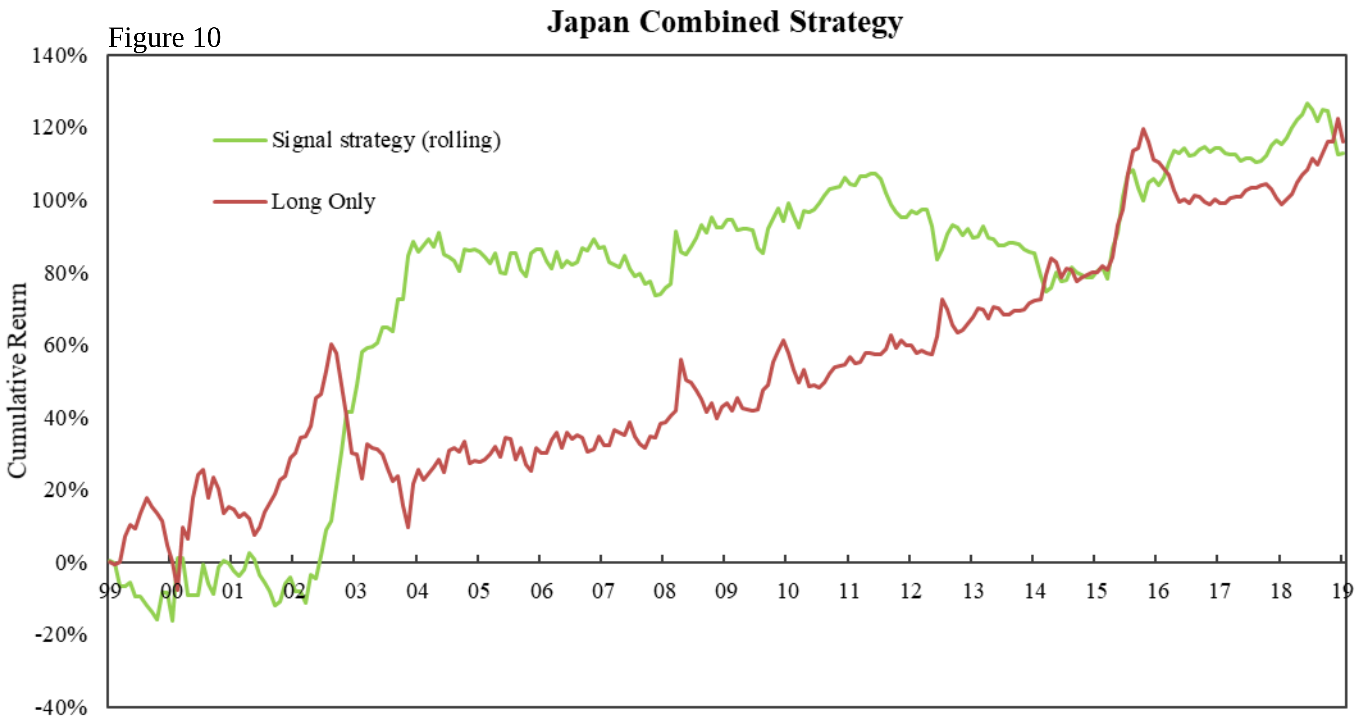
Figure 9

25% up to 2012, then monthly rolling

	FCI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long Only
Return	80,0%	4,0%	80,9%	-35,5%	**113,0%**	116,1%
Annul Return	4,0%	0,2%	4,0%	-1,8%	**5,6%**	5,8%
Risk	3,9%	3,7%	3,9%	3,8%	**3,8%**	3,9%
Ret. To Risk	1,03	0,05	1,04	-0,47	**1,49**	1,50
% True	54,1%	38,5%	57,6%	44,5%	**56,8%**	55,6%

Japan is the first country to experience a negative performance in on of its indicators, the Carry to risk. However, even if carry alone is not useful, the combined strategy generated a valid signal, almost 57% of the time.

Figure 10



UK

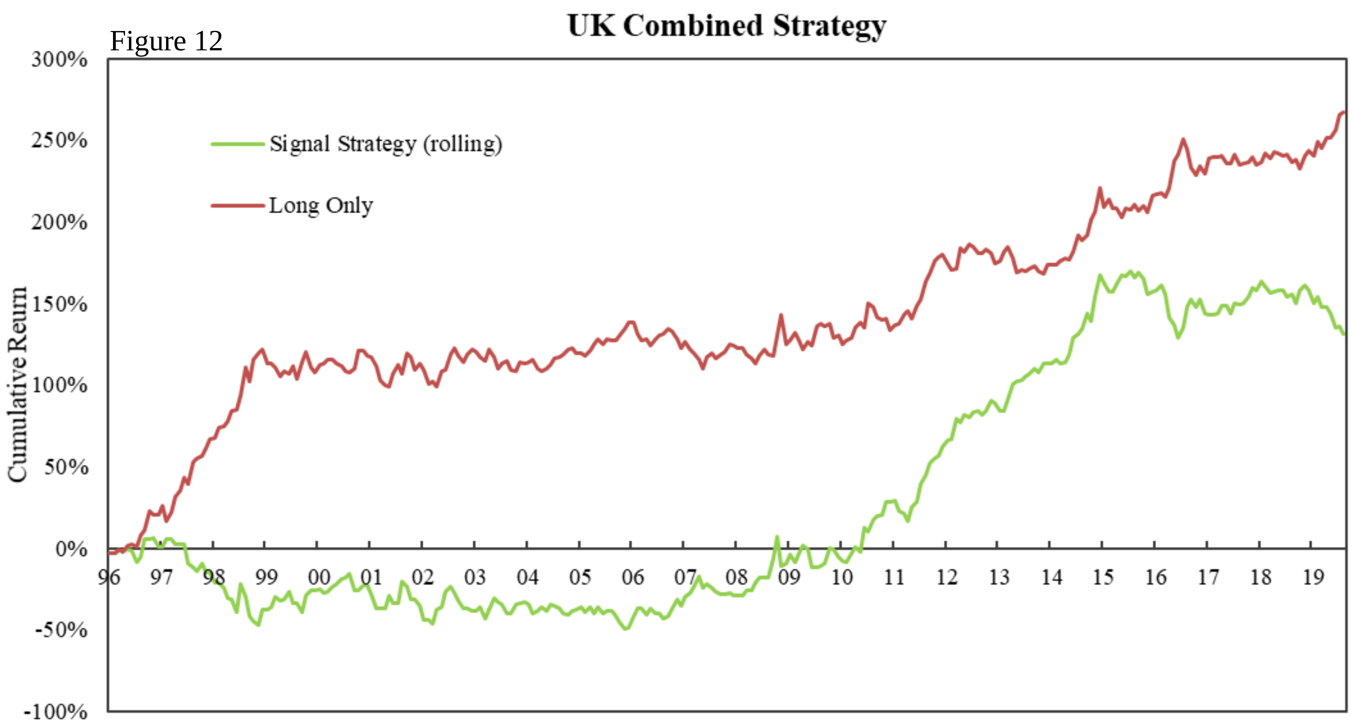
The last country is the United Kingdom, which was the worst-performing country in terms of return compared to the long-only strategy. It achieved only half of the “target” performance; furthermore, it persistently experienced negative returns during the first half of the observation period. The positive return is from the ability of the model to give successful signals in “bad times” (e.g., great recession).

Figure 11

25% up to 2012, then monthly rolling						
	FCI	Bond Momentum	Stock Momentum	Carry to risk	**Combined**	Long Only
Return	232,1%	39,9%	122,6%	79,2%	**131,5%**	267,1%
Annul Return	11,6%	2,0%	6,1%	3,9%	**6,5%**	13,3%
Risk	5,3%	5,8%	5,4%	5,3%	**5,2%**	5,3%
Ret. To Risk	2,16	0,34	1,14	0,74	**1,27**	2,49
% True	58,4%	49,4%	54,9%	47,5%	**54,9%**	58,0%

Also in this case it is worthy of note the superior performance of the FCI component in terms of both return and risk.

Figure 12



The Global Portfolio

The last analysis is made with respect to the aggregated portfolio. This section will look at two main strategies:

- Static Portfolio
- Dynamic Portfolio

For the static portfolio, the assumption is that the investor is willing to risk an equal amount of money in each country. He/she is then assembling a monthly trading portfolio that follows the previous trading rules. Each country strategy follows the "constant plus rolling weights" approach (i.e., each signal's weight is constant up to 2012, and then the weights are monthly rolled by looking to their previous results). U.S. and Germany do not incorporate the FCI component to follow best the model proposed by Mac Gorain.

The dynamic portfolio follows the same approach of the static but, instead of assigning the same weights to each country (would be 25% for US, DE, JP, UK), it changes its composition over time. The dynamic portfolio follows the same "ratio" of rolling the signals over time. Hence the investor will monthly rebalance the portfolio allocation by looking to the past countries' performances. For example, if U.S. best performed in the last two years, then the investor will overweight U.S. in the next trading (40%, then 30% to the second-ranked, 20% to the third, 10% to the worst performer). Thus, the capital invested is the same as the static portfolio, but it is allocated more efficiently.

The results are very satisfactory in both the strategies, and the dynamic portfolio vastly outperformed both the static and long-only portfolios.

Figure 13

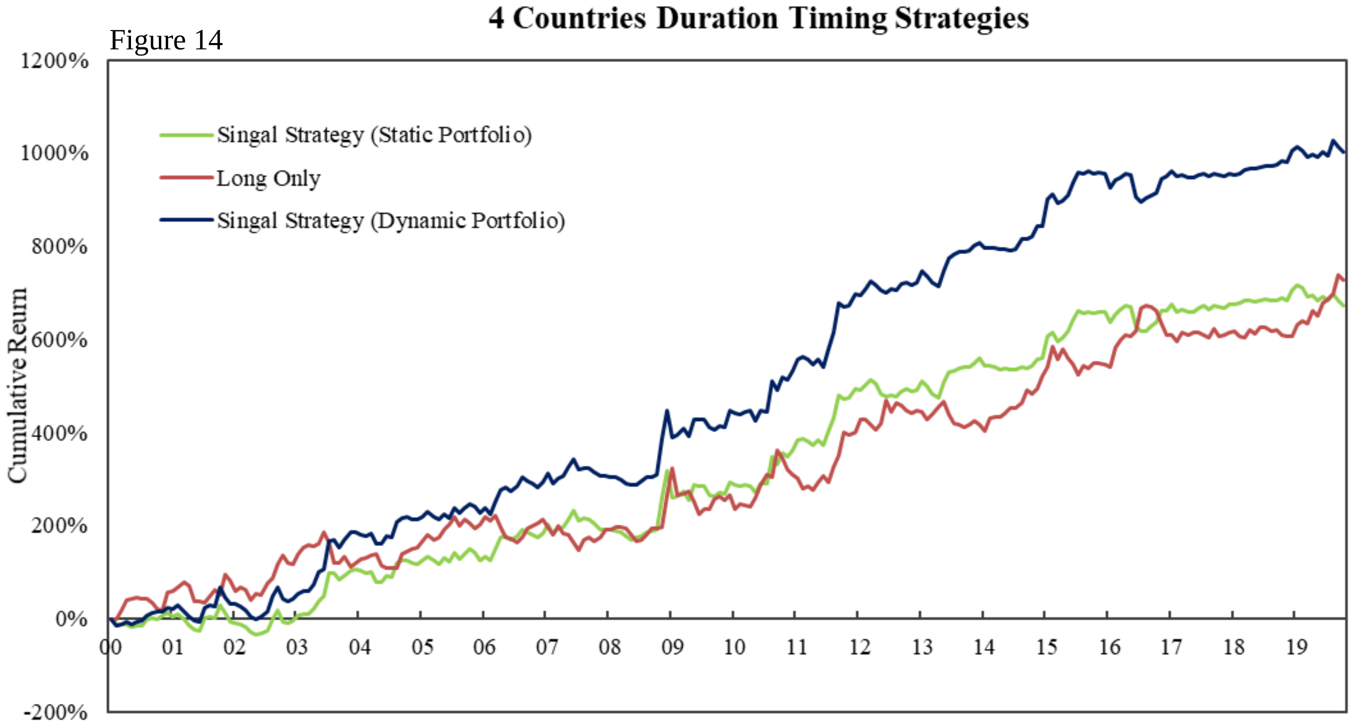
G-4 Statistics (Rolling Strategy)

	Signal Strategy (Static Portfolio)	Signal Strategy (Dynamic Portfolio)	Long-Only
Return	672,1%	1001,3%	727,2%
Annual Return	33,9%	50,5%	36,7%
Risk (std)	14,9%	16,8%	17,8%
Ret. To Risk	2,27	3,00	2,05
% True	55,9%	58,0%	55,0%

Again, in a standard scenario, where long-term interest rates move in a random-walk fashion, the long-only strategy should not lead to superior performance. It is merely betting each month that interest rates will fall, without looking to any indicator.

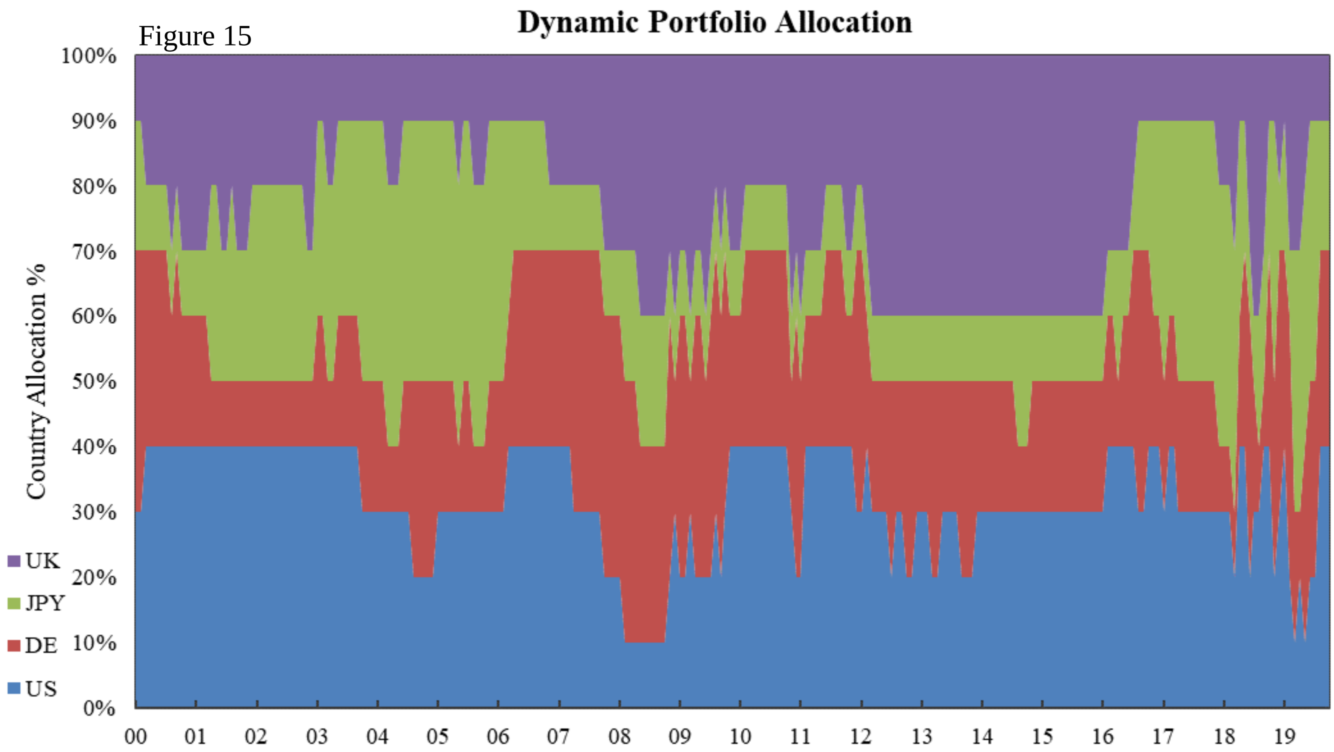
The "% true" above indicates how often the aggregated portfolio experienced positive returns, and the superior dynamic statistic (58%) is from the better allocation.

Figure 14



Finally, the next figure shows how the dynamic portfolio evolved over time. U.S. is often overweighted (81% of times its weight is 40% or 30% of the portfolio) while other countries have, on average, the same grade of exposure.

Figure 15



CONCLUSIONS

This work was born with the idea of studying in-depth fixed income portfolio strategies. The vast literature (and professional experiences) suggested how important it is to properly manage portfolio duration in order to achieve the high required level of performance. This abstract focus on what tools could the portfolio manager rely on to engage in a profitable strategy.

An existent set of indicators (Carry, bond momentum, PMI, stock momentum) is studied to understand whether these variables are still useful and statistically significant. It comprehends economic and financial indicators. An extra variable was introduced (the FCI), and the findings behind it are impressive. Overall, all the variables are beneficial to make genuine predictions about interest rates fluctuations.

Then, by merging the signals of the indicators, it was possible to generate a single powerful trading signal for each country. The strategy diverged from the literature due to the introduction of the rolling-weights. This intuition translates in boosting the performance and decreasing the risk.

Overall, the results from this analysis are positive in terms of truthfulness of the prediction and performance over time. The best-performing country is U.S. followed by Germany, Japan, and U.K.. The last step was the development of a global portfolio, both static and dynamic.

In conclusion, it is possible to forecast interest rate fluctuation with a sufficient confidence level. The results from the model should help the portfolio manager to adjust the duration but do not represent a strict trading rule. Indeed, the signals should not overcome the discretionary of the portfolio manager but instead be an auxiliary tool in case of uncertainty.

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