Carry Investing on the Yield Curve

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Abstract

We investigate two yield curve strategies: Curve carry selects bond maturities based on carry and betting-against-beta always selects the shortest maturities. We investigate these strategies for international bond markets. We find that the global curve carry factor has strong performance that cannot be explained by other factors. For betting-against-beta, however, this depends on the assumed funding rate. We also show that the betting-against-beta strategy has no added value for an investor that already invests in curve carry.

EFM Classification Codes: 340 - Fixed Income; 350 - Market Efficiency and Anomalies

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Introduction

The investor that keeps a coupon-bearing nominal government bond from issuance to maturity will be returned the initial outlay (given no default) and periodic coupons. Hence in the long-run a bond investor earns coupons with the only uncertainty the re-investment rate of these coupons. In the short-run, however, the bond returns will be mostly determined by yield (curve) changes. This dynamic part of the bond returns has received most attention in the academic literature.[1]

Recently, however, there has been more interest in the long-run component of the bond returns, the part that does not depend on changes in yields. Specifically Koijen et al. (2015) define bond carry as the return on a government bond when the yield curve does not change during the holding period. By approximation bond carry is then equal to the yield-pick up – the bond yield minus the risk-free rate – and the roll-down – the capital gain or loss on a bond due to revaluing the remaining cash flows at the yield belonging to the shorter maturity. Koijen et al. show that a long-short portfolio buying the U.S. treasury maturities with the highest carry per unit duration and selling those with the lowest carry has a Sharpe ratio of 0.68.

Frazzini and Pedersen (2014) study a different strategy on the U.S. yield curve. Their long-short strategy is long in the shorter maturities and short in the longer maturities such that the position is bond beta neutral. Like the curve carry strategy of Koijen, this betting-against-beta strategy yields strong results. How should we interpret these two strong anomalies for the U.S. yield curve? Are these premiums a compensation for pervasive risk factors? Are they inefficiencies in the way markets incorporate information in bond prices? Or are these premiums biased by survivorship or data snooping? We examine the two strategies in international bond markets to provide independent samples to study the return premiums and to test whether they are driven by a common global factor.

In this study we contribute in several ways. First, we show the importance of carry as performance driver of bond returns. Second, in addition to the existing evidence for U.S. treasuries, we find that selecting maturities based on carry also works for international bond markets. Applying curve carry simultaneously to all bond markets also provides diversification

[1] There is quite a large literature on forecasting government bond yields. We will discuss carry related measures including the use of forward rates in the main text. For time-series momentum applied to government bonds see for example Cutler, Poterba and Summers (1990) and Moskowitz, Ooi and Pedersen (2012). For macro-related predictors of government bond yields see for example Cooper and Priestley (2009), Ludvigson and Ng (2009) and Cieslak and Povala (2015).

benefits making it an even stronger anomaly. Third, we present mixed evidence for a low maturity effect in international bond markets, casting doubt on the robustness of this anomaly. We also show that successful betting-against-beta strategies mainly benefit from carry differences. The regression of the betting-against-beta returns on the bond market and the curve carry factor results in an insignificant alpha. The reverse regression of curve carry returns on betting-against-beta returns results in a highly significant alpha. Hence betting-against-beta has no independent value. Finally we show that other factors that make use of bond market information cannot explain curve carry. We also note that of these other bond factors only country carry (Koijen et al., 2015) and time-series momentum (Moskowitz, Ooi and Pedersen, 2012) are successful; whereas value measured by mean-reversion and cross-sectional momentum (Asness et al., 2013) are not successful in predicting government bond returns.

Decomposing the total bond return in two parts depending on whether the yield curve does not change (carry) and on changes in the yield curve is an interesting concept. In the long-run carry will drive bond returns, but in the short-run changes in the yield curve will dominate.[2] Carry, however, is not a new concept in the bond literature. First, it is interesting to note that for example the one-year carry for a 5-year zero-coupon bond is equal to the 1-year forward rate from year 4 to year 5. Fama (1984a) already shows that this forward rate is a predictor of U.S. bond returns.[3] Fama (1984b) also shows that forward rates can be used to predict opportunities on the (short-end of the) U.S. yield curve. Second, the carry combines the bond yield minus the risk-free rate with the roll-down. But the first part is better known as the term spread and has been the subject of many academic studies. The term spread is seen as a value measure and a direct measure of the bond risk premium. It is a strong predictor for individual bond markets[4], but also to choose between countries (Ilmanen and Sayood, 2002). For the latter Koijen et al.

[2] Litterman and Scheinkman (1991) show that changes in the yield level explain about 90% of the variation in monthly U.S. government bond returns. Driessen, Melenberg and Nijman (2003) find the same result for international bond markets.

[3] Cochrane and Piazzesi (CP) find that a combination of forward rates even has higher predictive ability for U.S. bond returns than using a single forward rate. Also note that they look at a 12-month horizon, making carry more important relative to yield changes than when considering a 1-month horizon. See also Dahlquist and Hasseltoft (2013) for international evidence on the CP forward factor; and Fama and Bliss (1987) for the importance of using longer horizons to illustrate the importance of forward rates.

[4] See for example Fama and Bliss (1987), Fama (2006) and Campbell and Shiller (1991) for U.S. bonds, Ilmanen (1995) for other developed bond markets, and Duyvesteyn and Martens (2014) for emerging government bonds.

(2015) also have strong results based on carry. We find that roll-down is important for choosing between maturities on the curve.

1. Data

We collect bond maturity buckets for 10 countries from Datastream and J.P. Morgan. The countries are Australia, Canada, Denmark, Germany, Japan, Norway, Sweden, Switzerland, the U.K. and the U.S. The six maturity buckets we consider are the 1-3Y, 3-5Y, 5-7Y, 7-10Y, 10-15Y and 15+Y from bond index provider J.P. Morgan. Datastream bond indices are limited to five maturity buckets. The first four are the same, but they only have a 10+Y bucket for the longer maturities. The advantage of Datastream is a longer history. Hence we use Datastream when J.P. Morgan has no data or if one of the longer maturity buckets is not yet available. And we use J.P. Morgan data as soon as all six maturities are available. Both data sources provide returns, durations, maturities and yields for each maturity bucket which are all crucial for the analysis. Table 1 shows the data availability for all 60 country and maturity buckets.

-Insert Table 1 about here-

For their carry strategy across U.S. Treasuries of different maturities Koijen et al. (2015) use constant maturity zero coupon yields for the 1Y, 2Y, 3Y, 5Y, 7Y and 10Y maturities which start in August 1971. We use maturity bucket data from Datastream and J.P. Morgan. These sources also cover international bond markets which makes it possible to test the curve carry strategy for 9 more countries. We will use the 7-10Y maturity bucket to investigate the added value of curve carry to choosing between countries based on carry.

For the cash rates we use 3-month Eurocurrency rates as they seem most relevant for bond investors. Only governments can borrow at the T-bill rate. Also implied interest rate differentials in currency forwards, which an international bond investor would use to hedge currency risk, are close to differences between Eurocurrency rates. An added benefit is that Eurocurrency rates have good coverage in terms of countries and historical data.

The choice for the cash rate is important in long-short duration-neutral portfolios. For example to buy 1 year of duration of a 2-year bond requires more cash than to buy 1 year of duration of a 10-year bond. A duration-neutral long 2-year bond short 10-year bond position therefore requires funding. The funding rate is based on the Eurocurrency rates. These rates, however, are generally higher than the risk-free rate, e.g. the T-bill rate for the U.S. Based on the T-bill rate a long 2-year bond short 10-year bond will have a higher return than the same position based on funding at the Eurocurrency rate. The carry measure (see Section 2) takes the funding rate into account, but the betting-against-beta (BAB) strategy does not. Hence the latter strategy will always have a lower return when using Eurocurrency rates. Frazzini and Pedersen (2014) also show this in their study for the U.S. curve. Because in our study we will show that BAB has no added value to curve carry we create the best possible circumstances for BAB by also conducting an analysis based on T-bills. Data coverage is poor for international T-bill rates. We therefore base the additional results on U.S. 1-month T-Bills. Specifically the proxy for the T-bill rates of say the U.K. is equal to the U.K Eurocurrency rate minus the U.S. Eurocurrency rate plus the U.S. T-bill rate. This avoids the poor data coverage for T-Bills in these 9 countries. For countries where T-Bills are available we find that on average the US-implied T-Bills rates are below the local T-Bills rates.[5] Hence in this analysis we underestimate the funding rate thereby giving an (unfair) advantage to the betting-against-beta strategy.

2. Methodology

Koijen et al. (2015) defines carry for any asset based on using (synthetic) futures contracts. For a fictive bond futures contract on a 10-year zero-coupon bond with one month to expiration (i.e. the obligation to buy a 9-year-and-11-months zero-coupon bond one month from now) they find

$$C_t = \frac{S_t}{F_t} - 1 = \frac{1/(1+y_t^{9Y11M})^{9+11/12}}{\left(1+r_t^f\right)^{1/12}/(1+y_t^{10Y})^{10}} - 1 \tag{1}$$

where C_t is the carry of the (synthetic) futures contract, S_t is the current price of a 9-year-and-11-month zero-coupon bond, F_t is the current futures price, y_t^{10Y} is the current annualized yield on a

[5] The countries for which we (besides U.S) have 1-month T-bills are Canada (from Dec 1993 onwards), Germany (Nov 2012), Japan (Feb 2006), Sweden (Apr 1989) and U.K. (Jul 2001). The average difference between 3-month Eurocurrency rates and 1-month U.S. T-bill rates is 0.49%. Comparing the local T-bill rates with the U.S. implied T-bill rates we find that local T-bill rates are on average higher, which means that the difference between Eurocurrency rates and T-bill rates is larger for the U.S. than for other countries. The average difference between the local T-bill rates and the U.S. implied T-bill rates is 0.22%, 0.07%, 0.42%, 0.45% and 0.18% for Canada, Germany, Japan, Sweden and U.K., respectively.

10-year zero-coupon bond, and r_t^f is the annualized short-term interest rate. This carry expression can be approximated based on the bond's modified duration, D_t^{mod}, with

$$C_t \approx \frac{1}{12}\left(y_t^{10Y} - r_t^f\right) - D_t^{mod}\left(y_t^{9Y11M} - y_t^{10Y}\right) \tag{2}$$

Hence, intuitively the bond carry consists of two effects: (i) the bond's yield spread to the risk-free rate, which is also called the slope of the term structure[6] (multiplied by 1/12 to adjust annualized rates to a monthly holding period); plus (ii) the "roll down", which captures the price increase due to the fact that the bond rolls down the yield curve (remember it is assumed that the entire term structure of interest rates stays constant). When the bond rolls down the yield curve, the yield changes from y_t^{10Y} to y_t^{9Y11M}, resulting in a price appreciation which is minus the yield change times the modified duration.

For a carry portfolio that selects bonds with different maturities on the curve it is important to adjust the position sizing to account for the differences in risk. Bonds with higher duration have more risk than bonds with lower duration. To put these bonds on a common scale we take positions of 1 year duration. Any long-short portfolio will be duration-neutral.

Equations (1) and (2) are based on an example for a 9-year-and-11-month bond. Our data consists of maturity buckets that contain one or more individual bonds. For these buckets we have the yield, duration, and maturity. Hence we need interpolation to determine the equivalence of equation (2). For example for the 5Y-7Y maturity we get the bucket's yield spread to the Eurocurrency rate (slope or yield pick-up) and we roll towards the yield of the 3Y-5Y maturity bucket to compute the roll down.[7]

-Insert Table 2 about here-

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[6] The slope of the term structure is also known in the literature as the yield pick-up, the term spread, or the term premium.

[7] This procedure provides a good proxy for carry but is not exact. Ideally every bond's cash flows would be used in combination with the zero yield curve to calculate an exact carry, but such data are not available. Note that all bond returns are a given, so a small error in the carry calculation will only affect negatively the selection power of any strategy based on carry. And it will make some error in the attribution of the strategy returns to carry and yield changes (but the total strategy returns are correct).

Table 2 provides some insight into the importance of carry for U.S. bond returns as well as the importance of using Eurocurrency rates versus T-bill rates. First of all it is clear that bond returns have been very positive thanks to a substantial positive contribution from yield changes. From 1985 to 2014 the yield of the first five maturity buckets has dropped by more than 9% or 0.3% per year. This also serves to illustrate that if yields would not have changed over this 30-year period the bond return would have been entirely dependent on carry. In the long-run the entire excess bond return is carry, and hence carry can be viewed as the bond risk premium.

Second, for the U.S. we see on average more carry per unit duration in the lower maturity buckets. This indicates that the curve tends to be steeper at the short-end than at the long-end of the curve. Because of this tendency short-term bonds earn a higher yield in excess of the funding rate and a higher roll-down per unit duration. Third, we see that the carry differences between the buckets are much larger for T-bill rates than for Eurocurrency rates, also leading to larger differences between the excess bond returns. Explanation is that the yield pick-up rises with the lower funding rate equally for all maturity buckets, and we calculate returns per unit duration. Hence the additional yield pick-up is divided by for example 2 duration years for the 1Y-3Y maturity bucket and 9 duration years for the 10-15Y maturity bucket. Finally, we observe a negative contribution from yield changes for T-bill rates in the 1Y-3Y maturity bucket. This is due to starting with carry, and attributing the remainder to yield (curve) changes. The roll-down part of carry is an issue for the shortest-maturity bucket, as there is no lower bond maturity bucket to roll to. Hence we roll to the funding rate. Obviously given the 9% decline in yield for the 1Y-3Y maturity bucket this understates the return due to yield changes. Our main results, however, will be based on Eurocurrency rates.

The carry trade is a trading strategy that goes long high-carry securities and shorts low-carry securities. We follow here Koijen et al. to determine the exact weights for the carry portfolio. Specifically, the weight on each bond *i* at time *t* is given by

$$w_t^i = z_t\left(rank\left(C_t^i/D_t^i\right) - \frac{N_t + 1}{2}\right) \tag{3}$$

where C_t^i is bond *i*'s carry, D_t^i is bond *i*'s duration, N_t is the number of available bonds at time *t*, and the scalar z_t ensures that the sum of the long and short positions equals 1 and –1, respectively.[8] With these portfolio weights, the return of the carry-trade portfolio is the weighted sum of the individual (duration-adjusted) bond returns.

3. Results for yield curve strategies

3.1 Selecting bond maturities based on carry

We start with testing the curve carry strategy for the ten countries using Eurocurrency rates as the funding rate. Table 3 reports the annualized mean, standard deviation and Sharpe ratio of the curve carry strategy for each country. The final row also shows the performance that invests 1/10th in each of the 10 individual country strategies. As mentioned in the methodology the carry strategy is long and short one year of duration. Of course this is scalable, so the main statistic to evaluate the results is the Sharpe ratio.

-Insert Table 3 about here-

In the final row of Table 3 we see that the curve carry portfolio combining the curve strategy of the 10 countries has a Sharpe ratio of 0.68 per annum. Hence carry is a strong predictor of expected return differences between bonds of different maturities. It is also interesting to see the breakdown of the mean return into the part that is due to carry and the part due to yield changes. For the curve carry strategy the carry is positive at 0.48% per annum, but the average spot return is –0.32% per annum. This reflects the fact that the curve carry strategy positions itself in maturity buckets where most yield increases are expected. The fact that the carry strategy does deliver a positive return means that not all of these expected yield increases do materialize fully. But on average the yield increases are relatively larger for maturity buckets with higher expected yield increases compared to maturity buckets with lower expected yield increases. The combination of the curve carry strategies over all countries has a volatility of 0.24% per annum, much lower than the volatilities per country. Hence strong diversification benefits are achieved by simultaneously taking curve carry positions in 10 countries. In fact, the average pair-wise correlation between curve carry strategy returns is only 18%. This makes curve carry a much stronger anomaly than based on the U.S. results only. There is no strong

[8] Of course other weighting schemes are possible. The resulting portfolios are highly correlated with other zero-cost portfolios that use different weights.

common factor that links the returns of the curve carry strategies in international bond markets, and on average the international results are much stronger than for the U.S. making data mining as an explanation for the U.S. curve carry strategy unlikely.

For the individual countries we observe strong results for most countries. The only negative performer is Norway, but for this country we only have three maturity buckets. Also U.S. results are weaker with a Sharpe ratio of 0.11. This is much lower than Koijen et al. (2015) find. Volatility is similar so the difference is in the returns. This difference is driven by the use of 3-month Eurocurrency rates instead of 1-month T-bill rates. T-bill rates are substantially lower making the shorter maturity buckets more attractive. Combined with U.S. on average having the most attractive carries in the short-maturity buckets (when using T-bill rates) this has a large impact: Based on T-bill rates the curve carry strategy for the U.S. has a Sharpe ratio of 0.52 (not shown in the Table) compared to the 0.11 based on Eurocurrency rates. For the global strategy the Sharpe ratio rises from 0.68 with Eurocurrency rates to 1.13 with T-bill rates. We come back to the funding rate in Section 3.2.

3.2 Betting-against-beta

Frazzini and Pedersen (2014) investigate whether betting-against-beta also works on the U.S. treasuries curve. The starting point is the observation that shorter maturity treasuries have higher Sharpe ratios than longer maturity treasuries. Subsequently empirical betas are used to construct a long-short strategy that is long the shorter maturities and short the longer maturities. Frazzini and Pedersen already note the importance of the funding rate we discussed before. They find their results for U.S. treasuries are no longer significant when using Eurocurrency rates. We therefore report results for both Eurocurrency and T-bill rates, even though we think the Eurocurrency results are more relevant. There is one difference in our approach compared to Frazzini and Pedersen. We use durations to create a duration-neutral portfolio whereas they use empirical betas to create a beta-neutral portfolio. Actually we find somewhat stronger results with durations than with empirical betas.[9] We therefore focus on the results based on durations. Table 4 reports the results for the 'betting-against-beta' strategy.

[9] The all countries Sharpe ratios in Table 4 would change to respectively 0.00 (from 0.08) and 0.55 (from 0.77) for Eurocurrency rates and U.S. implied T-bill rates, when using empirical betas instead of durations.

-Insert Table 4 about here -

The results based on Eurocurrency rates in the left panel of Table 4 are generally very poor. The high funding rate causes the 'betting-against-beta' strategy to have a near zero performance averaged over the ten countries. The results based on T-bill rates, however, are much better. The average return over the ten countries is equal to 0.24% with a Sharpe ratio of 0.77 (see the right panel in Table 4). Our results echo those of Frazzini and Pedersen who look at U.S. treasuries only. For most international bond markets the betting-against-beta strategy works for the low funding rate based on T-bills. But the strategy does not work when using the higher Eurocurrency rates as funding rate.

3.3 Risk-adjusted performance

In this section we analyze the risk-adjusted performance of curve carry and betting-against-beta. We do so both by adjusting the performance for the portfolio that is long in all maturity buckets of all countries using equal weights and by adjusting for the performance of one strategy by the other strategy.[10] We run the following regressions:

$$R_{t,p}^{CURVE\ CARRY} = \alpha + \beta \cdot R_t^{MKT} + \varepsilon_t \quad (4)$$

$$R_{t,p}^{CURVE\ CARRY} = \alpha + \beta_1 \cdot R_t^{MKT} + \beta_2 \cdot R_{t,p}^{BAB} + \varepsilon_t \quad (5)$$

$$R_{t,p}^{BAB} = \alpha + \beta \cdot R_t^{MKT} + \varepsilon_t \quad (6)$$

$$R_{t,p}^{BAB} = \alpha + \beta_1 \cdot R_t^{MKT} + \beta_2 \cdot R_{t,p}^{CURVE\ CARRY} + \varepsilon_t \quad (7)$$

where $R_{t,p}^{CURVE\ CARRY}$ ($R_{t,p}^{BAB}$) is the return in month *t* for the portfolio (*p*) that invests 1/10 in each of the 10 individual country curve carry (betting-against-beta) strategies, and R_t^{MKT} is the return of the equally weighted sum of the returns of the individual maturity buckets of all countries.

-Insert Table 5 about here-

[10] For example Fama and French (2015) use this approach to show the value-growth factor (HML) becomes redundant in their 5-factor model, which adds Investments and Profitability to their original 3-factor model.

The results are presented in Table 5. Panel A shows the results for Eurocurrency rates. Panel B shows the results based on U.S. T-bills imposing the observed differences between Eurodollar rates and T-bill rates on the international Eurocurrency rates. In Panel A we see for the regression in equation (4) that curve carry has a significant risk-adjusted performance of 0.15% with a t-statistic of 2.7. Panel A also confirms the BAB risk-adjusted returns are insignificant when using Eurocurrency rates as the funding rate; the intercept is only an insignificant -0.02%.

Panel B is more interesting for a comparison between curve carry and BAB. Both strategies have significant risk-adjusted returns correcting for the small market exposure. Due to the lower funding rate curve carry now has an even more significant risk-adjusted performance of 0.24% with a t-statistic of 4.4. Also BAB has a significant risk-adjusted performance of 0.18% with a t-statistic of 2.6 based on equation (6).

The result of equation (5) shows that curve carry also has a significant risk-adjusted performance of 0.15% (t-statistic 3.5) when including betting-against-beta as an explanatory variable, despite loading significantly on betting-against-beta with a coefficient of 0.56 and a t-statistic of 8.5. The explanation for this high statistic is that with the lower funding rate both curve carry and BAB have a preference for lower maturity buckets. Indeed we find a high correlation of 70 percent between the curve carry returns and the BAB returns.

The results for equation (7) in the final row of Table 5 show that betting-against-beta no longer has a significant positive risk-adjusted performance after adjusting for both the market and the curve carry returns. The intercept is -0.03%. Hence betting-against-beta has no added value beyond curve carry, not even when using the advantageous T-bill rates as the funding rate.

An investor considering these two strategies should opt for curve carry and ignore the low maturity effect. Even more so when this investor faces Eurocurrency rates as the funding rate rather than T-bill rates. Curve carry reacts to the funding rate because it directly takes the funding rate into account in the carry measure that decides on the relative attractiveness of the maturity buckets. BAB, however, does not as it always prefers lower maturity buckets over larger maturity buckets.

4. Additional analyses curve carry

4.1 Carry vis-à-vis yield pick-up

Carry is the sum of the yield pick-up and the roll-down. The yield pick-up, however, has always been the popular valuation measure. So does it matter to include roll-down? Table 6 shows the results from selecting for each country the maturity buckets based on carry (including roll-down) and based on yield pick-up only. We first regress the strategy returns of each on the passive long-only portfolio returns. The results in columns 2 and 3 of this regression show that both have a significant alpha after correcting for market exposure. Based on the information ratio and the t-statistic of the alpha carry is slightly better than only using yield pick-up.

In the final two columns of Table 6 we put carry and yield pick-up directly into competition by regressing each on the market and the other. As expected both are highly correlated with each other (96%). But the alpha of carry is still significant at the 10% significance level, and the alpha of yield pick-up is no long statistically significant. Hence also here the result is that carry improves over the yield pick-up.

-Insert Table 6 about here-

4.2 Curve carry trade exposures to other factors

Koijen et al. (2015) regress the carry strategy returns on the market (equally weighted passive long of all assets), value and momentum from Asness et al. (2013) and time-series momentum from Pedersen et al. (2012). In this section we do the same for the global curve carry strategy using the fixed income value and momentum results of the aforementioned papers. We also add two additional factors: The BAB factor for U.S. Treasuries from Frazzini and Pedersen (2014) and the country carry factor from Koijen et al. (2015). The results are presented in Table 7.

First we compare the performance of each factor regressed on the market. Not surprisingly the long-short strategies do not significantly load on the market proxy which is long-only. Interestingly the value and (cross-sectional) momentum factors of Asness et al. (2013) have an insignificant alpha for government bonds. In contrast time-series momentum (TSMOM) applied to government bonds, betting-against-beta (BAB) on the U.S. treasury curve[11], and

[11] Frazzini and Pedersen (2014) also apply BAB to selecting countries. We omitted this here in the analysis because the return series only start in July 1989. Over the period July 1989 – March 2012 the IR is -0.04 and the correlation with curve carry is -0.02. Hence this will not affect our conclusions.

country carry all have significant positive alphas and information ratios (IR's) ranging from 0.44 to 0.77. Whereas we put a different perspective on BAB in this study, the results for TSMOM and country carry confirm that these are also good factors to invest in government bonds besides curve carry.

-Insert Table 7 about here-

Second, the final column shows the results of the regression of curve carry on all other factors. Whereas this reduces alpha the t-statistic is still a significant 2.5 and the IR still 0.54. In fact the only significant loading is on country carry, although the correlation between the monthly strategy returns of curve carry and country carry is only 17%.

4.3 U.S. curve carry in a period of rising yields

Our sample period from 1985-2014 is a period of 30 years with mostly declining yields. Curve carry is a long-short duration-neutral strategy and we already correct for any remaining market exposure to show curve carry does not depend on the long-term movement in interest rates. Nevertheless as a robustness test we show for the U.S. curve carry also works in the 30 years from 1952-1981. During this period yields most of the time increased peaking in 1981. We make use of the CRSP database and constant maturities: 2Y, 5Y, 7Y, 10Y, 20Y and 30Y. The results are shown in Table 8.

-Insert Table 8 about here-

The key result is the annualized alpha of 0.26%, with a t-statistic of 2.1. Hence curve carry shows excellent results for the U.S. in a period of strong rising yields. Combined with the main 10-country results from 1985 to 2014 this shows that the curve carry premium is significant in both bull and bear bond markets.

5. Conclusion

We investigate global yield curve opportunities by testing two strategies which were found to be successful for U.S. treasuries, on 9 other developed government bond markets. We find strong results for the strategy that selects bond maturities based on carry, effectively selecting the bonds with the highest expected bond risk premium per unit duration. The returns for the different countries have a low correlation resulting in a global curve carry factor that has a significant positive risk-adjusted performance.

In contrast we find mixed results for the so-called betting-against-beta (BAB) strategy that always prefers selecting lower maturity bonds over longer maturity bonds. The results of BAB are sensitive to the funding rate and fail to deliver returns in international markets when we assume that investors can borrow against the Eurocurrency rate instead of the risk-free T-bill rate. The positive results when using T-bill rates are subsumed by those of curve carry. Whenever the lower maturity buckets have the higher carries per unit duration both curve carry and BAB will select the same bonds. But when higher maturity buckets have the higher carries per unit duration curve carry will buy these higher maturity buckets outperforming the BAB strategy that sticks with the lower maturity buckets.

We also compare curve carry with other bond factor strategies reported in the literature. The alpha of curve carry remains highly significant when correcting for the market and these other bond factor strategies. When combining the evidence from the literature with our own analyses we conclude that in terms of long-short bond beta neutral factor strategies both curve carry and country carry are strong factors, but low volatility (BAB), cross-sectional momentum and value are not. This is different from long-short strategies for stocks and corporate bonds where such strategies are successful. We find that carry is an important part of bond returns, and the importance rises with the investment horizon. And strategies that make use of carry to select maturities and countries are successful.

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Table 1: Availability government bond maturity buckets

	Maturity buckets					
	1Y-3Y	3Y-5Y	5Y-7Y	7Y-10Y	10-15Y (10+)	15+Y
Australia	Jan-85	Mar-87	Mar-87	Mar-87	Mar-87	Nov-11
Canada	Jan-85	Jan-85	Jan-85	Jan-85	Jan-85	Jun-99
Denmark	Jun-85	Jun-85	Jun-85	Jun-85	Feb-92	Jun-99
Germany	Jan-85	Jan-85	Jan-85	Jan-85	May-86	Jun-99
Japan	Jan-85	Jan-85	Jan-85	Jan-85	Mar-87	Jun-99
Norway	-	Jan-89	Jan-89	Dec-92	-	-
Sweden	Dec-85	Jan-85	Feb-85	Feb-87	Jul-89	Oct-04
Switzerland	Jan-85	Jan-85	Jan-85	Jan-85	Jan-85	-
U.K.	Jan-85	Jan-85	Jan-85	Jan-85	Jan-85	Jun-99
U.S.	Jan-85	Jan-85	Jan-85	Jan-85	Jan-85	Aug-00

Note: We obtain total returns, yields and durations for six maturity buckets from Datastream and J.P. Morgan. Datastream data are limited to five maturity buckets (only 10+ instead of 10-15Y and 15+) but have a longer history. We use Datastream when J.P. Morgan has no data or if one of the longer maturity buckets is not yet available. And we use J.P. Morgan data as soon as all six maturities are available.

Table 2: U.S. bond return decomposition into carry and yield (curve) changes

	Maturity buckets					
	1Y-3Y	3Y-5Y	5Y-7Y	7Y-10Y	10-15Y (10+)	15+
Panel A: Eurocurrency rates						
Excess return	0.61%	0.69%	0.67%	0.60%	0.57%	0.52%
Carry	0.27%	0.44%	0.38%	0.32%	0.26%	0.20%
Yield changes	0.34%	0.25%	0.29%	0.28%	0.32%	0.31%
Panel B: T-bill rates						
Excess return	1.05%	0.90%	0.82%	0.72%	0.65%	0.56%
Carry	1.19%	0.65%	0.53%	0.44%	0.33%	0.24%
Yield changes	-0.14%	0.25%	0.29%	0.28%	0.32%	0.31%

Note: For each month a maturity bucket is available excess bond returns per unit duration are split in carry and excess returns due to yield (curve) changes. The table shows for each maturity bucket the annualized average excess bond return, carry and returns due to yield changes. Note that Table 1 shows that the 15+ maturity bucket for the U.S. starts at a later date.

Table 3: The returns of the curve carry strategy

	Mean	Carry	Yield changes	Stdev	Sharpe ratio
Australia	0.28%	0.45%	-0.17%	0.55%	0.52
Canada	0.14%	0.57%	-0.44%	0.59%	0.23
Denmark	0.11%	0.49%	-0.38%	0.47%	0.23
Germany	0.10%	0.41%	-0.32%	0.46%	0.21
Japan	0.32%	0.28%	0.04%	0.34%	0.95
Norway	-0.04%	0.34%	-0.38%	0.36%	-0.11
Sweden	0.09%	0.74%	-0.65%	0.44%	0.21
Switzerland	0.29%	0.42%	-0.12%	0.40%	0.73
U.K.	0.20%	0.56%	-0.36%	0.54%	0.37
U.S.	0.05%	0.45%	-0.40%	0.47%	0.11
All countries	0.16%	0.48%	-0.32%	0.24%	0.68

Note: This table reports for each country the mean annualized excess return, the annualized standard deviation of return and the annualized Sharpe ratio. Excess returns are returns in excess of Eurocurrency rates. For the mean annualized excess return (column 'Mean') we also show the decomposition into the part that can be ascribed to carry (return when the yield curve does not change) and the remainder which we call yield changes. These statistics are reported for the long/short curve carry strategy that is long high carry maturity buckets and short low carry maturity buckets. Carry is computed per unit duration and per country in total we are long 1 year duration and short 1 year duration in the curve carry strategy. The sample period is 1985-2014.

Table 4: The returns of the maturity strategy (BAB) per country

	Eurocurrency rates			U.S. implied T-bill rates		
	Mean	Stdev	Sharpe ratio	Mean	Stdev	Sharpe ratio
Australia	0.00%	0.65%	0.01	0.21%	0.65%	0.33
Canada	0.15%	0.63%	0.23	0.37%	0.63%	0.59
Denmark	-0.03%	0.52%	-0.06	0.18%	0.52%	0.36
Germany	0.07%	0.55%	0.12	0.30%	0.55%	0.54
Japan	-0.04%	0.42%	-0.11	0.17%	0.42%	0.41
Norway	0.00%	0.38%	-0.01	0.07%	0.38%	0.18
Sweden	0.08%	0.51%	0.15	0.29%	0.52%	0.56
Switzerland	-0.01%	0.44%	-0.02	0.22%	0.44%	0.50
U.K.	-0.05%	0.66%	-0.08	0.17%	0.66%	0.26
U.S.	0.11%	0.54%	0.21	0.34%	0.54%	0.64
All countries	0.03%	0.30%	0.08	0.24%	0.31%	0.77

Note: This table reports for each country the mean annualized excess return, the annualized standard deviation of return and the annualized Sharpe ratio. Excess returns are returns in excess of Eurocurrency rates (left panel) or in excess of U.S. implied T-bill rates (right panel) which are equal to the Eurocurrency rate minus the difference between the U.S. Eurocurrency rate and the U.S. T-bill rate to gain an estimate of the local T-bill rate. These statistics are reported for the long/short betting-against-beta (BAB) strategy that is long short maturity buckets and short long maturity buckets. Per country in total we are long 1 year duration and short 1 year duration in the maturity strategy. The sample period is 1985-2014.

Table 5: Risk-adjusted returns and carry vis-à-vis betting against beta

Dependent variable	Intercept	Market	Curve carry portfolio	BAB portfolio
Panel A: Eurocurrency rates				
Curve carry returns	0.15% (2.7)	0.03 (1.0)	-	-
Curve carry returns	0.15% (2.7)	0.04 (1.5)	-	-0.13 (-1.1)
BAB returns	-0.02% (-0.2)	0.08 (2.4)	-	-
BAB returns	0.01% (0.2)	0.09 (2.7)	-0.20 (-1.1)	-
Panel B:U.S. implied T-bill rates				
Curve carry returns	0.24% (4.4)	0.05 (2.0)	-	-
Curve carry returns	0.15% (3.5)	0.00 (-0.0)	-	0.56 (8.5)
BAB returns	0.18% (2.6)	0.09 (2.8)	-	-
BAB returns	-0.03% (-0.7)	0.05 (1.7)	0.85 (12.2)	-

Note: The curve carry strategy is long high carry maturity buckets and short low carry maturity buckets. The 'betting-against-beta' (BAB) strategy is long short maturity buckets and short long maturity buckets. In Panel A the Eurocurrency rates are used as funding rates, in Panel B the U.S. implied T-bill rates where the local Eurocurrency rates are combined with the difference between U.S. Eurocurrency and T-bill rates to gain an estimate of the local T-bill rate. Per country in total we are long 1 year duration and short 1 year duration for both curve carry and BAB. The results in this table are for the portfolio that invests 10% in each of the 10 individual country strategies. The table reports the coefficients for the regressions in equations (4) to (7). T-statistics based on Newey-West standard errors are shown between parentheses. The sample period is 1985-2014.

Table 6: Curve carry vis-à-vis yield pick-up

	Carry	**Yield pick-up**	**Carry**	**Yield pick-up**
α	0.15%	0.14%	0.03%	-0.01%
	(2.7)	(2.3)	(1.7)	(-0.7)
Market	0.03	0.03	0.00	0.00
	(1.0)	(1.0)	(0.2)	(0.3)
Carry	-	-	-	1.03
				(41.4)
Yield pick-up	-	-	0.87	-
			(35.9)	
R^2	0.7%	0.7%	89%	89%
IR	0.62	0.56	0.34	-0.16

Note: This table reports regression results for each factor portfolio's returns on the market returns (equal-weighted average of all individual maturity buckets and all countries). Column 2 shows the results for curve carry and column 3 shows the results for the yield pick-up where we select maturities only on yield pick-up instead of carry which also includes the roll-down. In the final columns we also show the regression on the market and the other factor: yield pick-up for carry and carry for yield pick-up. The table reports the annualized alphas (in percent) from these regressions and the betas on the various factors. The last two rows report the R^2 from the regression and the information ratio, IR, which is the alpha divided by the residual volatility from the regression. The results are based on Eurocurrency rates. The sample period is January 1985 – December 2014.

Table 7: Curve carry exposures to other factors

	Value	MOM	TSMOM	BAB	Country carry	Curve carry	Curve carry
α	1.15%	0.32%	0.21%	0.21%	0.30%	0.15%	0.13%
	(1.2)	(0.3)	(3.6)	(3.9)	(2.3)	(3.2)	(2.5)
Market	-0.10	-0.45	0.04	-0.01	0.07	0.01	0.01
	(-0.2)	(-1.1)	(1.5)	(-0.3)	(1.3)	(0.6)	(0.0)
Value							-0.00
							(-1.1)
Momentum							0.00
							(0.6)
TSMOM							0.01
							(0.1)
BAB							0.05
							(1.1)
Country carry							0.06
							(2.9)
R^2	0.0%	0.4%	0.7%	0.0%	0.5%	0.1%	3.9%
IR	0.23	0.07	0.71	0.77	0.44	0.63	0.54

Note: The table reports regression results for each factor portfolio's returns on the passive long portfolio returns (equal-weighted average of all individual maturity buckets and all countries). For curve carry in the final column we also show the regression on all other factor returns: Value and momentum (MOM) for fixed income from Asness, Moskowitz and Pedersen (2013), time-series momentum (TSMOM) for fixed-income from Moskowitz, Ooi and Pedersen (2012), Betting-Against-Beta (BAB) for U.S. treasuries from Frazzini and Pedersen (2014), and country carry from Koijen et al. (2015). We are grateful to Pedersen for making the data of his published papers available through his website (http://www.lhpedersen.com/data). Since Koijen et al. (2015) is still a working paper we made the country carry factor ourselves based our set of 10 countries and using the 7-10Y maturity bucket. The table reports the intercepts or alphas (in percent) from these regressions and the betas on the various factors. The last two rows report the R^2 from the regression and the information ratio, IR, which is the alpha divided by the residual volatility from the regression. The sample period is January 1985 – March 2012 (limited by the end-date of the BAB factor).

Table 8: U.S. curve carry 1952-1981

Dependent variable	Intercept	Market
U.S. Curve carry returns	0.26%	0.07
	(2.1)	(2.0)

Note: The table reports regression results for U.S. curve carry on the passive long portfolio returns (equal-weighted average of all individual maturities) for the period 1952-1981.