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Research

Carry Investing on the Yield Curve

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Bond carry is the expected return on a bond when the yield curve does not change. The curve carry strategy within each country constructs buckets based on bond maturities on a monthly basis and buys the government bond buckets with high carry while selling those with low carry. Combining these curve carry strategies for 13 countries, we found a global curve carry factor with an information ratio of 1.0. Returns to a global curve carry factor cannot be explained by value or momentum, and the strategy subsumes the betting-against-beta factor.

CE Credits: 1

Factor strategies are popular in equity investing, both in academic publications and in practice. But are they useful in fixed-income investing? Houweling and van Zundert (2017) showed that size, low-risk, value, and momentum strategies can also be successfully applied to credits. For government bonds, Ilmanen and Sayood (2002) showed strong results for selecting countries based on carry. And in this article, we propose a global curve carry factor with an impressive information ratio (IR) of 1.0. This result makes factor investing for government bonds also interesting for practitioners.

The *carry* of a government bond is the return on the bond when the yield curve does not change. Carry is approximately the sum of the yield pick-up[1] (the difference between the bond yield and the risk-free rate) and the roll-down (the repricing of the bond as it rolls down the yield curve) as shown in Pedersen (2015) and Koijen, Moskowitz, Pedersen, and Vrugt (2018). The use of carry to predict government bond returns goes all the way back to Fama (1984a): He showed for US Treasuries that forward rates can predict the relative performance of bonds with different maturities. Given that, for example, the 1-year forward rate starting in 4 years is equivalent to the carry of a 5-year zero-coupon bond, Fama (1984a) laid the foundations for carry investing in government bonds. Koijen et al. (2018) provided results for three bond carry strategies: (1) country carry—buying the 10-year bonds of a country that has high carry and selling those of a country with low carry; (2) country carry applied to 10-year minus 2-year bonds instead of 10-year bonds; and (3) curve carry applied to US Treasuries. Within a country, *curve carry* buys the government bond maturity buckets with high carry and sells the maturity buckets with low carry.

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Our key finding is that curve carry performed positively for all 13 countries in the J.P. Morgan Global Government Bond Index (JPM GBI). Hence, curve carry works not only for US Treasuries but also for the government bonds of 12 additional countries. We also found that the correlations between curve carry strategies in different countries are low. As a result, the strategies can provide large diversification benefits, leading to an IR of 1.0 for a global curve carry factor that invested equally across the 13 (country) curve carry strategies. This global curve carry factor cannot be explained by country carry, cross-sectional momentum, time-series momentum, value, or betting-against-beta (BAB) strategies applied to government bonds.[2]

BAB is also a curve strategy—always buying the short maturities and selling the long maturities. Pilotte and Sterbenz (2006), Duffee (2010), and Frazzini and Pedersen (2014) showed for US Treasuries that short-maturity bonds have higher risk-adjusted returns (i.e., higher Sharpe ratios) than long-maturity bonds.[3] Durham (2016) confirmed this pattern for international bond markets, although the results for international markets were generally weaker than those for the US market. We show that BAB has a strong link with curve carry. We found that short-maturity bonds have higher Sharpe ratios because, on average, their risk-adjusted carry is higher, implying that yield curves are steeper at the short end than at the long end. This effect is strongest for US Treasuries, which explains the stronger results for BAB in Frazzini and Pedersen (2014) than for international markets in Durham (2016). But short maturities do not always have the highest risk-adjusted carry. So, curve carry can be seen as a smarter version of BAB: On average, the curve carry strategy also has a preference for shorter maturities, but when the carry of the shortest maturities is not attractive, curve carry will take its long positions further up the curve.

For practitioners, we see two reasons to invest in the carry factor for government bonds. First, the results for the global curve carry and country carry factors are strong. Second, these returns have low correlations with other bond factors. We believe this is the case because the majority of bond factors focus on predicting yield changes over time (e.g., time-series momentum in Moskowitz et al. 2012) or in the cross-section (e.g., value and cross-sectional momentum in Asness, Moskowitz, and Pedersen 2013). These bond factors are predominantly backward looking—measured by past yield changes—and in order for investors to benefit from their performance, yields must move in the predicted direction. Carry, in contrast, is a forward-looking measure, driven by current yield levels, and its performance does not depend on yields moving in the predicted direction. In fact, when yields do not move at all, the carry factors will earn exactly the *ex ante* carry.

Data

We collected bond maturity buckets for 13 countries from Datastream and J.P. Morgan (JPM). The countries are the constituents of the JPM GBI: Australia, Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Spain, Sweden, the United Kingdom, and the United States. The six maturity buckets we considered are the 1-year to 3-year maturities, 3-year to 5-year maturities, 5-year to 7-year maturities, 7-year to 10-year maturities, 10-year to 15-year maturities, and 15-plus-year maturities from bond index provider JPM. The first four Datastream buckets are the same as the first four JPM buckets, but the Datastream long-maturity bucket is limited to maturities greater than 10 years. The advantage of Datastream is a longer history. Therefore, we used Datastream when JPM had no data. Both data sources provided returns, durations, maturities, and yields for each maturity bucket, which are all crucial for the analysis. **Table 1** shows the data availability for all 78 country and maturity buckets.

For the cash rates, we used three-month t-bill rates. Whenever the history of t-bill rates was not long enough, we added three-month Eurocurrency Rates. We used these rates to compute not only excess carry but also excess returns for the bonds. Ilmanen (1995) indicated that these excess returns are a good proxy for currency-hedged returns. Note that in the later section "Building a Long-Only Government Bond Factor Portfolio without Leverage," we show how to build a long-only cash bond portfolio that outperforms JPM's investable hedged bond series.

Methodology

Koijen et al. (2018) illustrated the relationships between carry, forward rates, and yield pick-up plus roll-down. We needed to approximate the roll-down because we used the JPM maturity-bucket data. Remember that roll-down is the expected capital appreciation of the bond when the yield curve does not change. Take a bond that is to mature in

Table 1. Available Government Bond Maturity Buckets

	Maturity-Bucket Start Dates					
Country	1Y–3Y	3Y–5Y	5Y–7Y	7Y–10Y	10Y–15Y (10+Y)	15+Y
Australia	Aug 86	Aug 86	Mar 87	Mar 87	Mar 87	Nov 11
Belgium	Jan 85	Jan 85	Jan 85	Jun 86	May 91	Jun 99
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
France	Oct 86	Sep 86	Sep 86	Sep 86	Sep 86	Jun 99
Germany	Jan 85	Jan 85	Jan 85	Jan 85	May 86	Jun 99
Italy	Jan 88	Jan 88	Jul 90	Apr 91	Dec 93	Jun 99
Japan	Jan 85	Jan 85	Jan 85	Jan 85	Mar 87	Jun 99
Netherlands	Jan 85	Jan 85	Jan 85	Jan 85	Jul 91	Jun 99
Spain	Jan 89	Sep 89	Apr 93	Dec 90	Jan 94	Jun 99
Sweden	Apr 90	Apr 90	Apr 90	Apr 90	Apr 90	Mar 04
United Kingdom	Jan 85	Jan 85	Jan 85	Jan 85	Jan 85	Jun 99
United States	Jan 85	Jan 85	Jan 85	Jan 85	Jan 85	Jun 99

Notes: Total returns, yields, and durations for six maturity buckets are from Datastream and JPM. Datastream data are limited to five maturity buckets (only 10+Y instead of 10Y–15Y and 15+Y) but sometimes provided a longer history. We used Datastream when JPM data were not available.

10 years: Currently, its cash flows are discounted at the 10-year yield. In 1 year from now, however, the remaining cash flows will be discounted at the then-prevailing 9-year yield. This 9-year yield 1 year from now will be equal to the current 9-year yield, if the yield curve does not change. On an upward-sloping curve, the 9-year yield will be below the 10-year yield. Hence, in that case, the bond price will be higher in 1 year than it is today—reflecting the return resulting from rolling down the curve. Our research is based not on individual bonds but on maturity buckets filled with multiple bonds: for example, the bucket containing all bonds with maturities between 7 years and 10 years (bucket $M = 4$ in the notation that follows) and the bucket containing bonds with maturities between 5 years and 7 years (bucket $M - 1 = 3$ in the notation that follows). So, to compute the roll-down of the 7Y–10Y maturity bucket, we had the current yield of that bucket, but we also needed the yield it would roll to. Hence, for the roll-down of maturity bucket $[M]$ with time to maturity $T[M]$, we needed the yield of that maturity bucket, $y_t^{T[M]}$, and the yield this bucket would roll to in one year from now if the yield curve did not change, $y_t^{T[M]-1}$. For the latter, we interpolated between $y_t^{T[M]}$ and $y_t^{T[M-1]}$ (i.e., the yield for maturity bucket $[M - 1]$),

$$y_t^{T[M]-1} = y_t^{T[M]} - \frac{y_t^{T[M]} - y_t^{T[M-1]}}{T_{t,[M]} - T_{t,[M-1]}}. \qquad (1)$$

Then, the annualized excess carry for maturity bucket $[M]$, $C_t^{[M]}$, is approximately equal to

$$C_t^{[M]} \approx \left(y_t^{T[M]} - r_t^f\right) - D_t^{\text{mod},[M]}\left(y_t^{T[M]-1} - y_t^{T[M]}\right), \qquad (2)$$

where r_t^f is the t-bill rate and $D_t^{\text{mod},[M]}$ is the modified duration for maturity bucket $[M]$. The first (1Y–3Y) maturity bucket has no shorter-maturity bucket to roll to, and we used the t-bill rate as the $[M - 1]$ maturity-bucket yield. Going forward in this article, we will call excess carry simply "carry." Hence, intuitively, the bond carry consists of two effects shown in Equation 2: (1) the bond's yield pick-up, $y_t^{T[M]} - r_t^f$, and (2) the roll-down.

For a carry portfolio that selects bonds with different maturities on the curve, adjusting the position sizing to account for the differences in risk is important. Bonds with longer durations have more risk than bonds with shorter durations. To put these bonds on a common scale, we used excess bond returns per unit of duration and carry per unit of duration. Any long–short portfolio will be duration neutral by having, in total, one year of duration long and one year of duration short.

Table 2 provides some insight into the importance of carry for US bond returns. First of all, thanks to a substantial positive contribution from yield changes, bond returns per unit of duration clearly have been positive. From January 1985 to October 2018, the yields of the first five maturity buckets declined by more than 8%, or about 0.25% per year. This result also illustrates that if yields had not changed over this 34-year period, the bond return would have been entirely dependent on carry. In the long run, the entire excess bond return is carry; hence, carry can be viewed as the expected bond risk premium.[4]

Second, for the United States, Table 2 shows more carry per unit of duration, on average, in the low-maturity buckets. This result indicates that the curve tends to be steeper at the short end than at the long end. Because of this tendency, short-term bonds earn a higher yield in excess of the funding rate and a higher roll-down per unit of duration.

We followed Koijen et al. (2018) to determine the exact weights for rebalancing the curve carry strategy at the end of each month. Instead of fixed long and short positions, we applied a ranking-based weighting scheme based on the carry divided by the duration. Specifically, the weight on each bond maturity bucket $[M]$ at time t is given by

$$w_t^{[M]} = z_t \left[\text{rank}\left(\frac{C_t^{[M]}}{D_t^{\text{mod},[M]}} \right) - \frac{N_t + 1}{2} \right], \tag{3}$$

where N_t is the number of available bond maturities at time t and the scalar z_t ensures that the sums of the long and short positions equal, respectively, 1 and –1. The term rank determines the cross-sectional ranking. With these portfolio weights, the return of the curve carry strategy is the weighted sum of the (duration-adjusted) excess bond maturity-bucket returns.

The Global Curve Carry Factor

We started by testing the curve carry strategy for the 13 countries. **Table 3** reports the annualized mean, standard deviation, and IR of this strategy for each country. The final row also shows the performance of a portfolio that invested 1/13th in each of the 13 individual country curve carry strategies. As mentioned in the methodology description, the curve carry strategy is long and short one year of duration. Of course, it is scalable, so the main statistic useful for evaluating the results is the IR.

In the final row of Table 3, we see that the global curve carry factor combining the curve strategies of the 13 countries had an annualized IR of 0.98. Hence, carry is a strong predictor of expected return differences between bonds of different maturities, which is consistent with Fama's (1984a) findings for US Treasuries. The breakdown of the mean return into the part resulting from carry and the part resulting from yield changes is also interesting. For the global curve carry factor, the carry earned 0.25% per year and the average spot return was –0.01% per year. Hence, although the curve carry strategy was continuously positioning itself in the maturity buckets where most interest rate rises were priced in, it hardly lost anything on yield changes. As a result, the total performance is nearly equal to the carry earned.

The average of the curve carry strategies over all 13 countries had a volatility of 0.24% per year in this

Table 2. US Bond Return Decomposition into Carry and Yield (Curve) Changes, January 1985–October 2018

	Maturity Bucket					
Measure	1Y–3Y	3Y–5Y	5Y–7Y	7Y–10Y	10Y–15Y (10+Y)	15+Y
Excess return	0.82%	0.76%	0.70%	0.61%	0.56%	0.40%
Carry	0.61	0.51	0.45	0.36	0.30	0.26
Yield change	0.22	0.24	0.26	0.25	0.26	0.15

Notes: For each month in which a maturity bucket was available, excess bond returns per unit of duration were split into carry and excess return resulting from yield (curve) changes. Carry and yield changes add up exactly to excess return; any deviations are the result of rounding. Note that Table 1 shows that the 15+Y maturity bucket for the United States started at a later date.

Table 3. Returns of the Curve Carry Strategy, January 1985–October 2018

Country	Mean	Carry	Yield Changes	Standard Deviation	IR
Australia	0.14%	0.26%	−0.12%	0.53%	0.27
Belgium	0.32	0.25	0.07	0.42	0.76
Canada	0.24	0.26	−0.02	0.60	0.40
Denmark	0.15	0.22	−0.07	0.49	0.31
France	0.20	0.26	−0.06	0.48	0.42
Germany	0.25	0.27	−0.02	0.46	0.55
Italy	0.38	0.24	0.13	0.67	0.56
Japan	0.37	0.21	0.16	0.35	1.04
Netherlands	0.22	0.21	0.01	0.45	0.48
Spain	0.34	0.31	0.03	0.79	0.44
Sweden	0.02	0.30	−0.27	0.51	0.05
United Kingdom	0.21	0.27	−0.06	0.59	0.35
United States	0.15	0.34	−0.19	0.47	0.31
All countries	0.24%	0.25%	−0.01%	0.24%	0.98

Notes: The curve carry strategy takes, at the end of each month, long positions in bond maturity buckets with high carry per unit of duration and short positions in bond maturity buckets with low carry per unit of duration. The curve carry strategy per country in total, based on the weights in Equation 3, is long one-year duration and short one-year duration. Excess returns are returns in excess of local t-bill rates. The final row, labeled “All countries,” shows the results from investing 1/13th in each of the individual country curve carry strategies (what we call the “global curve carry factor” in the text). For the mean annualized excess return (column labeled “Mean”), we show in the next two columns the decomposition into the part that can be ascribed to carry (return when the yield curve does not change) and the part that can be ascribed to yield changes.

time period, which is much lower than the average volatility per country. Therefore, strong diversification benefits could be achieved by simultaneously taking curve carry positions in 13 countries. In fact, the average pairwise correlation between curve carry strategy returns is only 18%.[5] Hence, no strong common factor is linking the returns of the curve carry factor in international bond markets, and on average, the international results are much stronger than those for the United States, which makes data mining as an explanation for the US curve carry factor unlikely.

BAB and Curve Carry

Frazzini and Pedersen (2014) investigated whether the BAB strategy would also work on the US Treasuries curve. Their starting point was the observation that short-maturity Treasuries have higher Sharpe ratios than long-maturity Treasuries. Subsequently, they used empirical betas to construct a long–short beta-neutral strategy that bought the short maturities and sold the long maturities.

We first investigated whether the observation is also true for global maturity buckets that short-maturity bonds have had higher Sharpe ratios than long-maturity bonds. In this analysis, we started our sample in 2000 so that almost all the maturity buckets for all countries would be available. Otherwise, differences between maturity buckets could have been driven by differences in the sample periods.

The results in **Table 4** confirm for our 13-country global universe the US findings of Frazzini and Pedersen (2014) and the international findings of Durham (2016). Table 4 shows a monotonic decline in Sharpe ratios from 1.03 for the 1Y–3Y maturity bucket to 0.72 for the 15+Y maturity bucket. This decline is not caused by differences in the volatility of the excess return per unit of duration. We do see a slightly lower volatility for the 1Y–3Y maturity bucket than for the middle maturities, but we also see a lower volatility for the longest maturities. The Sharpe ratio pattern is caused mainly by the low-maturity buckets having higher excess return per unit of duration.

Table 4. Global BAB Pattern, January 2000–October 2018

Measure	1Y–3Y	3Y–5Y	5Y–7Y	7Y–10Y	10Y–15Y	15+Y
Excess return	0.59%	0.60%	0.57%	0.53%	0.48%	0.40%
Carry	0.36%	0.37%	0.35%	0.30%	0.26%	0.20%
Yield change	0.22%	0.23%	0.23%	0.22%	0.23%	0.20%
Standard deviation	0.57%	0.60%	0.60%	0.60%	0.58%	0.55%
Sharpe ratio	1.03	1.00	0.95	0.88	0.82	0.72

Notes: Each month for each bucket, the equally weighted average over the 13 countries was used to compute excess return per unit of duration. All statistics are annualized. For the excess return, the breakdown into the part that is the result of carry and the part that is the result of yield changes is shown. We started the sample period in January 2000 to make sure that most maturity buckets were available.

Table 4 also splits the excess returns into the returns resulting from carry earned and the returns resulting from yield changes. And here, we see a new result not reported before in the literature: The BAB pattern across the maturity buckets is driven by the carry differences between the buckets. For example, the 1Y–3Y maturity bucket, on average, earned 36 basis points (bps) in carry per unit of duration, whereas the 15+Y maturity bucket earned only 20 bps, on average.

This result raises the question of how closely curve carry and BAB are related. We first computed BAB per country.[6] The results are presented in **Table 5**. The global BAB factor has an IR of 0.29. This result is positive, but note that it is lower than that for the US BAB factor (IR of 0.47). This result echoes the conclusion of Durham (2016) that BAB is not working as well in other countries as in the United States.

Table 5. Returns of the BAB Strategy, January 1985–October 2018

Country	Mean	Carry	Yield Changes	Standard Deviation	IR
Australia	0.03%	0.00%	0.03%	0.63%	0.05
Belgium	0.13	0.12	0.01	0.51	0.26
Canada	0.16	0.22	−0.06	0.64	0.25
Denmark	0.00	0.01	−0.01	0.55	0.00
France	0.08	0.06	0.02	0.54	0.15
Germany	0.13	0.12	0.00	0.56	0.23
Italy	0.17	0.15	0.02	0.73	0.24
Japan	−0.03	−0.01	−0.02	0.42	−0.07
Netherlands	0.13	0.12	0.01	0.50	0.26
Spain	0.26	0.16	0.10	0.85	0.31
Sweden	0.12	0.08	0.04	0.54	0.22
United Kingdom	0.05	0.02	0.03	0.65	0.08
United States	0.25	0.28	−0.03	0.53	0.47
All countries	0.10%	0.10%	0.00%	0.36%	0.29

Notes: Excess returns are returns in excess of local t-bill rates. For the mean annualized excess return (column labeled "Mean"), we show in the next two columns the decomposition into the part that can be ascribed to carry (return when the yield curve does not change) and the part that can be ascribed to yield changes. These statistics are reported for the BAB strategy that was long the short-maturity buckets and short the long-maturity buckets. Per country in total, the BAB strategy was long one year of duration and short one year of duration.

The results in Table 5 also confirm that returns to the global BAB factor are driven mainly by carry earned. All of the 10 bps average return per year came from carry. But of course, comparing this result with that of the global curve carry factor in Table 3, we see that the global BAB factor earned less carry than the global curve carry factor. On average, the curve carry strategy bought the short-maturity buckets and sold the long-maturity buckets because, on average, short-dated bonds had the more attractive carry. But when carry opportunities were better further up the curve, the strategy could also buy longer-maturity buckets and sell the shorter-maturity buckets. In contrast, BAB always bought the short-maturity buckets and always sold the long-maturity buckets. For example, BAB was long the 3Y–5Y maturity bucket 100% of the time, whereas the curve carry strategy was long that bucket 62% of the time.

Table 6 provides the results of four regressions for the returns to the global curve carry factor $\left(R_t^{Global\ Curve\ Carry}\right)$ and the global BAB factor $\left(R_t^{Global\ BAB}\right)$:

$$R_t^{Global\ Curve\ Carry} = \alpha + \beta \times R_t^{Market} + \varepsilon_t \tag{4}$$

$$R_t^{Global\ Curve\ Carry} = \alpha + \beta_1 \times R_t^{Market} + \beta_2 \times R_t^{Global\ BAB} + \varepsilon_t \tag{5}$$

$$R_t^{Global\ BAB} = \alpha + \beta \times R_t^{Market} + \varepsilon_t \tag{6}$$

$$R_t^{Global\ BAB} = \alpha + \beta_1 \times R_t^{Market} + \beta_2 \times R_t^{Global\ Curve\ Carry} + \varepsilon_t, \tag{7}$$

where R_t^{Market} is the equally weighted average return per unit duration of all the maturity buckets.

Given the pattern revealed in Table 4, it is no surprise that the returns of the factors are significantly related. Indeed, we found a significant correlation of 32% between the returns to the global curve carry factor and the global BAB factor. The global curve carry factor subsumes the global BAB factor, however, when we consider the resulting alphas. After correction for the market and global BAB exposures, the alpha for the global curve carry factor is a highly significant 20 bps per year. In contrast, the BAB factor alpha after correction for the market and the global curve carry is an insignificant –3 bps per year.[7]

Exposures to Other Factors

Koijen et al. (2018) regressed the carry strategy returns per asset group on the market value (equally weighted average return of all assets in the group), specific to the asset group and cross-sectional 12-month momentum returns from Asness et al. (2013), and on the 12-month time-series momentum returns from Moskowitz et al. (2012). In this section, we report our results for the same analysis applied to the global curve carry factor; we used the fixed-income value factor and momentum factor results of the aforementioned papers. We added two factors—namely, the global BAB factor discussed earlier and the country carry factor from Koijen et al. (2018). The results are presented in **Table 7**.

First, we regressed the performance of each factor on the market. The value factor loaded negatively on the market, whereas time-series momentum loaded positively on the market. This time-series momentum loading is not surprising because time-series momentum entails no long–short restriction and yields were declining throughout the sample period. The alphas

Table 6. Risk-Adjusted Returns for the Global Curve Carry Strategy vis-à-vis the Global BAB Strategy, January 1985–October 2018

	Global Curve Carry		Global BAB	
α (per year)	0.21%**	0.20%**	0.07%	–0.03%
Market	0.04	0.03	0.07	0.05
Global BAB	—	0.21**	—	—
Global curve carry	—	—	—	0.46**

Notes: Market = the equal-weighted average of all individual maturity buckets and all countries. Curve carry was long the high-carry maturity buckets and short the low-carry maturity buckets. BAB was long the short-maturity buckets and short the long-maturity buckets. Per country in total, both strategies were long one year of duration and short one year of duration. The results are for the portfolio that invested an equal weight in each of the 13 individual country strategies. The regression coefficients are for Equations 4–7.

**Significant at the 1% level (per Newey–West standard errors).

Table 7. Curve Carry Exposures as Related to Other Factors, 1985–2017

	Value	MOM	TSMOM	Global BAB	Country Carry	Global Curve Carry	
α (per year)	0.15%	–0.02%	0.16%	0.07%	0.37%**	0.22%**	0.19%**
Market	–0.14**	0.10	0.42**	0.07**	0.03	0.04	–0.00
Value							–0.01
MOM							0.02
TSMOM							0.06*
Global BAB							0.23**
Country carry							0.02
R^2	4.8%	2.6%	24.8%	1.7%	0.1%	1.6%	13.8%
IR	0.35	–0.04	0.33	0.19	0.56	0.90	0.82

Notes: Market = the equal-weighted average of all individual maturity buckets and all countries. MOM = momentum. TSMOM = time-series momentum. We are grateful to Lasse Heje Pedersen for making the data of his published papers available through his website (www.lhpedersen.com/data), including updates until 2017. The global curve carry and global BAB strategies are as described earlier in the text. Reported are the intercepts, or alphas (per year), from these regressions and the betas on the various factors. The reported IR is the (annualized) alpha divided by the (annualized) residual volatility from the regression.

*Significant at the 5% level (per Newey–West standard errors).

**Significant at the 1% level (per Newey–West standard errors).

of the country carry and the global curve carry factors are statistically significant.

Second, we regressed the global curve carry factor returns on all other factor returns, with results shown in the final column of Table 7. Although the alpha was reduced from 0.22% (when correcting only for market exposure) to 0.19%, it remains significant at the 1% level with an IR still of 0.82. Therefore, global curve carry can be considered a new factor not captured by existing factors in the literature. Global curve carry returns do load significantly on global BAB returns—because, on average, the BAB strategy prefers short maturities—and they also load significantly at the 5% level on time-series momentum. This latter result could be because Moskowitz et al. (2012) applied 12-month momentum to 13 futures, including multiple maturities for Australia, Germany, and the United States. With a 12-month window, carry will play an important role in the past 12-month return, so some bias toward the same maturities preferred by curve carry can be expected.

Possible Risk Explanations

If other bond factors cannot explain the global curve carry factor, the next logical question is, then, what are the risks of this new factor? We began by examining the various risks with which Koijen et al. (2018) had some success in explaining their global carry factor. First, downside bond beta (Henriksson and Merton 1981) and downside equity beta (Lettau, Maggiori, and Weber 2014) were found to be insignificant; hence, downside risk is not an explanation. The skewness was also only a small positive 0.09. Second, the global curve carry factor did not load significantly on changes in the Chicago Board Options Exchange Volatility Index or the level of the TED spread (the difference between LIBOR and US T-bills), showing that neither changes in volatility nor an illiquidity proxy could explain the global curve carry factor returns. Third, contrary to the findings in Koijen et al. (2018) for their global carry factor, we did not find the global curve carry factor returns to be poor in global recessionary periods.

Studying the drawdowns of the global curve carry factor, we found that the worst periods were May 1997–March 2002 (cumulative loss of –0.90%) and March 2004–December 2006 (loss of –0.52%). These periods appear to have coincided with multiple central banks raising their policy rates. Intuitively, rate hikes by central banks are a risk for curve carry because, on average, curve carry is long the short maturities and short the long maturities. And such rate increases will generally lead to a flattening of the curve, meaning that short maturities underperform long maturities. To formalize this idea, we first classified a central bank as hiking rates in month t if the central bank raised the target interest rate in month t

or in month $t + 1$. (The reason to include the $t + 1$ period is that most central banks have a six-week meeting cycle.) Hence, if a central bank raised interest rates in consecutive meetings, the result was a period of concatenated months classified as "hiking." Second, we defined a global hiking month as a month in which at least five out of eight central banks were hiking.[8] We identified a total of 18 global hiking months. Notably, of these 18 months, 7 coincided with the largest drawdown and 8 coincided with the second-largest drawdown.

We then ran the following regression:

$$R_t^{Global\ Curve\ Carry} = \alpha + \beta \times D_t \left[\geq 5 \text{ central banks hiking}\right] + \varepsilon_t, \quad (8)$$

where D_t is a dummy variable that took on the value of 1 if at least five central banks were hiking in month t or $t + 1$ and the value of 0 otherwise. The results are shown in **Table 8**.

The dummy in Table 8 is highly significant. On average, the annualized performance was 0.27% when we did not have global central bank hiking (up from 0.24% in all months). And the annualized performance when we observed global central bank hiking was (0.27% – 0.77% =) –0.50%.

Given the small number of times different central banks simultaneously hiked rates, Table 8 provides some explanation for the low correlation between the curve carry strategies of the individual countries. Therefore, it also provides some explanation for the strong results for the global curve carry factor—because it largely diversifies away the individual country risk of a target rate increase by a central bank.

Building a Long-Only Government Bond Factor Portfolio without Leverage

In all the preceding analyses, we considered long–short duration-neutral portfolios. This procedure assumed that taking short positions and using leverage were possible. Also, we ignored transaction costs and assumed that small markets, such as Sweden, were as investable as the US market. In this section, we address these concerns by building a long-only government bond portfolio with the JPM GBI as the benchmark. This portfolio could select from (a maximum of) 13 countries × 6 maturity buckets. First, we used Equation 2 to compute, at the end of each month, the carry for each maturity bucket in each country, $C_{c,m}$. Given the strong results for country carry and our global curve carry factor, we then ran the following optimization on a monthly basis:

$$\text{Max} \sum_{c=1}^{C} \sum_{m=1}^{M} w_{c,m} C_{c,m}, \quad (9)$$

$$\text{subject to} \sum_{c=1}^{C} \sum_{m=1}^{M} w_{c,m} = 1, w_{c,m} \geq 0, \quad (9a)$$

$$\text{subject to} \sum_{c=1}^{C} \sum_{m=1}^{M} w_{c,m} \times D_{c,m} = D_{JPM\ GBI}, \quad (9b)$$

Table 8. Curve Carry Largest Drawdowns and Exposure to Global Hiking, January 1985–October 2018

A. Drawdowns	Cumulative loss
May 1997–March 2002	–0.90%
March 2004–December 2006	–0.52%
B. Global hiking exposure	Coefficient
α (per year)	0.27%**
At least 5 central banks hiking (per year)	–0.77%**

Notes: A central bank was hiking in month t if an increase occurred in the target rate in month t or in month $t + 1$. In total, we followed eight central banks. A rate hike by at least five central banks happened 18 times in the sample period. Of these 18 months, 7 months fell in the May 1997–March 2002 drawdown and 8 months fell in the March 2004–December 2006 drawdown.

**Significant at the 1% level (per Newey–West standard errors).

$$\text{subject to}\left|\sum_{m=1}^{M} w_{c,m} \times D_{c,m} - D_{JPM\ GBI,c}\right| \leq 1. \quad (9c)$$

We maximized the duration-weighted carry (Equation 9) subject to a number of constraints: We wanted to be fully invested and did not allow nonnegative weights (9a); the portfolio duration had to match that of the JPM GBI (9b); and for each country, the maximum difference with the JPM GBI duration is one year (9c). The result will be the weights, $w_{c,m}$, to invest in each maturity bucket for the coming month.

We built two additional portfolios. Portfolio 2 used the same optimization, but the last constraint was set tighter to permit the duration per country to deviate from the JPM GBI country duration by 0.25 year of duration at most (instead of 1 year). Portfolio 3 addressed the issue of smaller markets by imposing an additional constraint that limited the position in a maturity bucket to five times its weight in the JPM GBI. This restriction is very tight; for example, the smallest maturity-bucket market cap in our sample was historically USD190 million for the Australia 10+Y bucket in December 1990. That market cap translated to a market value weight of 0.008%, so under this restriction, the maximum portfolio weight was 0.04%. A USD1 billion portfolio size would translate to buying a maximum of USD400,000 of Australian 10+Y treasuries. Given a total index market cap of USD2.6 trillion, the result was about 0.2% of the market cap of the bucket. Therefore, we added the restriction that the weight of a maturity bucket could not be more than five times the weight that bucket had in the JPM GBI index:

$$\text{subject to } w_{c,m} \leq 5 \times w_{JPM\,GBI,c,m}.$$

To calculate returns net of transaction costs, we assumed a 1 bp bid–ask spread on the yield for the large bond markets—Germany, Japan, the United Kingdom, and the United States—and 2 bps for the other nine countries. We used the JPM GBI US dollar currency-hedged indexes. They are available from May 1993 for 35 of the 72 maturity buckets and from June 1999 for all the other maturity buckets. Prior to this currency-hedged return series becoming available, we used local-currency returns minus the difference between the local cash interest rate and the US cash interest rate. This proxy is a good one for currency hedging until about 2007. After that date, using the currency-hedged indexes based on market-priced forward rates is important because of the distortions seen in the market from covered interest rate parity (see Du, Tepper, and Verdelhan 2018). Note that these JPM indexes are investable. Of course, in practice, when one is investing, for example, 3% in the US 5Y–7Y maturity bucket, one does not need to buy all 60 underlying bonds. A few bonds spread over the maturity bucket should suffice to get returns similar to the JPM bucket returns.

The results for these portfolios, given in **Table 9**, are promising—despite the relatively simple portfolio construction rules. For Portfolio 1, the "Net outperformance" of 1.37% per year after trading costs since 1985 produced an IR of 0.69. The Sharpe ratio is 1.04, 0.19 higher than that of the JPM GBI. Hence, this portfolio is a practical, implementable government bond portfolio with a healthy outperformance resulting from creating a carry advantage over the benchmark. With the "Carry earned" difference of 1.48% (3.18% minus 1.70%) per year and annual transaction costs of 0.35%, net carry is 1.13%. This amount is close to the net outperformance of 1.37%.

In **Figure 1**, we show the growth over time of USD1 invested in Portfolio 1. For reference, we added the growth of USD1 invested in the JPM GBI index and of USD1 invested in US cash. As the reader can see, the performance of Portfolio 1 accumulates steadily during the more than 33-year simulation and the outperformance is not concentrated in a single subperiod.

The results reported for Portfolio 2 in Table 9 show that the relative performance of the carry strategy can be scaled to a less aggressive risk budget without losing its strong IR. When the tracking error was reduced from 2% to 1%, the IR slightly increased from 0.69 to 0.76. Less outperformance is compensated by an even larger reduction in risk.

Finally, for trading in the small bond markets, Portfolio 3 shows a reduced gross return for the strategy; it also shows that the restrictions reduced transaction costs. The reason is that the portfolio invested less in markets for which we assumed higher costs and tracking error was reduced because positions were forced to remain closer to the JPM GBI than in Portfolio 1. The IR of 0.80 indicates that the strong risk-adjusted performance of the long-only carry strategy does not depend on taking large positions in small, illiquid markets.

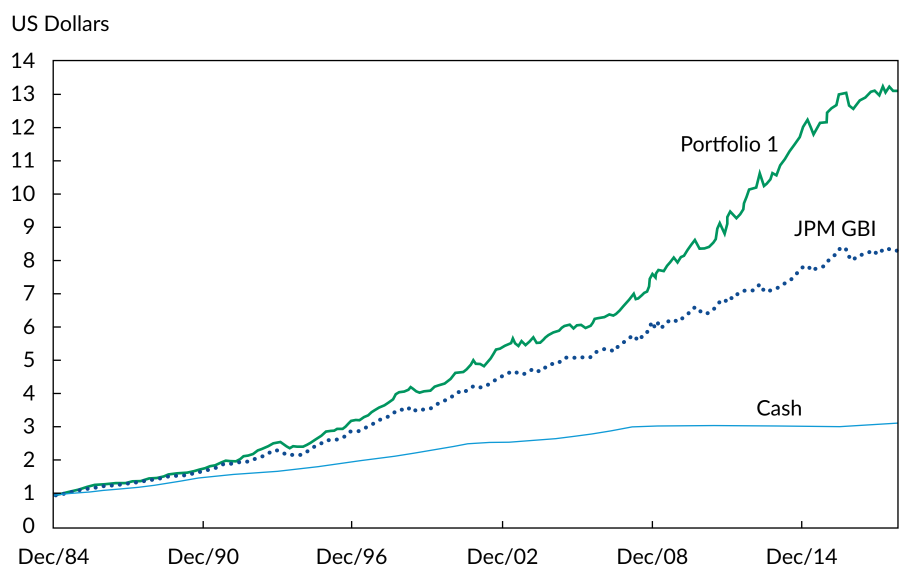
Table 9. Long-Only Cash Government Bond Portfolios Based on Carry, January 1985–October 2018

Measure	Portfolio 1	Portfolio 2	Portfolio 3	JPM GBI
Gross total return (USD hedged)	8.06%	7.34%	7.21%	6.34%
Cash return	3.42%	3.42%	3.42%	3.42%
Transaction costs	0.35%	0.25%	0.17%	—
Net excess return	4.29%	3.68%	3.63%	2.92%
Standard deviation	4.13%	3.73%	3.74%	3.43%
Sharpe ratio	1.04	0.99	0.97	0.85
Carry earned	3.18%	2.72%	2.55%	1.70%
Net outperformance	1.37%	0.76%	0.71%	
Tracking error	2.00%	1.00%	0.88%	
IR	0.69	0.76	0.80	
Alpha from regression on JPM GBI	1.21%**	0.62%**	0.54%**	
Duration	5.81	5.81	5.81	5.81

Notes: Only nonnegative positions were allowed, and portfolio weights added up to 100% (that is, we allowed no shorting and no leverage). Portfolio duration was set equal to the JPM GBI duration at the moment of rebalancing. For Portfolio 1, a limit of one year of duration per country was set as the maximum over- and underweight relative to the JPM GBI duration weights. For Portfolio 2, the maximum country deviation limit was set to 0.25 year of duration. For Portfolio 3, a (5 × market cap) proportional constraint was added to limit positions in small, illiquid markets. All returns and return components are annualized.

**Significant at the 1% level (per Newey–West standard errors).

Figure 1. Cumulative Net Total Return of USD1 Invested at Close of 31 December 1984



Note: The graph includes returns up to and including October 2018.

Conclusion

We have provided evidence for a strong global curve carry factor for government bonds. This finding on a global scale is new; so far, curve carry has been investigated only for US Treasuries. Curve carry buys bond maturities with a high carry and sells bond maturities with a low carry. Correlations between curve carry strategies in different countries are low, suggesting strong diversification benefits. Curve carry earns its returns from carry while giving up only a small fraction of that carry to adverse movements in yields. Hence, carry, equivalent to the forward rate, is good at identifying differences in future returns (risk premiums) between bonds with different maturities. Global curve carry is a new bond factor because its alpha cannot be explained by existing bond factors in the academic literature, including value, cross-sectional momentum, time-series momentum, and country carry.

Globally, short-maturity bonds provide, on average, higher risk-adjusted excess returns than long-maturity bonds. We showed that the reason is that short-maturity bonds have higher risk-adjusted excess carry, on average, than long-maturity bonds. Therefore, it is not surprising that the global curve carry factor is strongly related to global BAB, which always buys the short-maturity bonds and sells the long-maturity bonds. When short-maturity bonds are unattractive from a carry perspective, however, BAB will stubbornly stick with the short-maturity bonds whereas curve carry will look further up the curve.

From a broad perspective, we believe these results should encourage investors to seriously consider factor investing in government bonds. Constructing a government bond portfolio based on the global curve carry factor as a smart version of BAB, in combination with the strong country carry factor as a specific value measure, has strong academic backing. We showed that a simple portfolio constructed from long-only government bond positions based on carry outperformed the JPM GBI by 1.37% per year in our sample period, with a tracking error of 2%, after deducting transaction costs.

Editor's Note

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Notes

1. The yield pick-up is also known as the "term spread" and is the subject of many studies that see it as a value measure and a direct measure of the bond risk premium. See, for example, Fama (1984b), Fama and Bliss (1987), Fama (2006), and Campbell and Shiller (1991) for US bonds; Ilmanen (1995) for other developed bond markets; and Duyvesteyn and Martens (2014) for emerging market government bonds.

2. See Moskowitz, Ooi, and Pedersen (2012) for time-series momentum; Asness, Moskowitz, and Pedersen (2013) for value and cross-sectional momentum; Frazzini and Pedersen (2014) for BAB; and Koijen et al. (2018) for carry.

3. Pilotte and Sterbenz (2006) provided the limits-to-arbitrage argument as a reason for the existence or persistence of this pattern. It may not be possible for investors to leverage the pattern (at acceptable cost). Hence, investors desiring high excess returns may have to use the longer-maturity bonds and accept a lower expected return per unit of risk (i.e., a lower Sharpe ratio) to get a higher return on a fixed investment amount.

4. Many studies have been published on expected bond risk premiums. One strand of the literature has compared current bond yields with *expected* short rates over the life of a bond. For example, Adrian, Crump, and Moench (2013) based their estimates on bond yields only, whereas Kim and Wright (2005) included survey forecasts for short rates. Our yield pick-up is based on *current* short rates. For the yield pick-up, we found a correlation of 74% with the Adrian et al. (2013) estimates for the bond risk premium and a correlation of 41% with those from Kim and Wright (2005). For carry (including roll-down), the correlations dropped to, respectively, 62% and 25%. Hence, these authors' measures for bond risk premiums are related to carry but are also different from it.

5. Leaving out the strongest country, Japan (with a stand-alone IR of 1.04), still resulted in a portfolio IR of 0.87, down from 0.98 for "All countries." This result underscores the diversification benefits that are a key factor in the strong risk-adjusted performance of the portfolio.

6. Instead of beta-neutral portfolios, we examined duration-neutral BAB portfolios to make the comparison with the curve carry portfolios. Actually, duration-neutral BAB portfolios had better performance than beta-neutral BAB portfolios: The IR was 0.29 for the duration-neutral global BAB portfolio and 0.18 for the beta-neutral global BAB portfolio.

7. The conclusions from the Table 6 results remained the same when we replaced R^{Market} with the JPM GBI market-capitalization-weighted returns. This outcome is not surprising because R^{Market} and the JPM GBI returns have a correlation of 89%.

8. For this analysis, we used the Bundesbank before 1999 and, thereafter, the European Central Bank as the central bank representing all current euro countries. Apart from an obvious change over time, some central banks had already started to follow the Bundesbank before the euro introduction.

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