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Systematic Strategies

Deconstructing currency carry

Is there a single benchmark?

January 23 2019

Bloomberg

Currency Carry

Investigating currency markets

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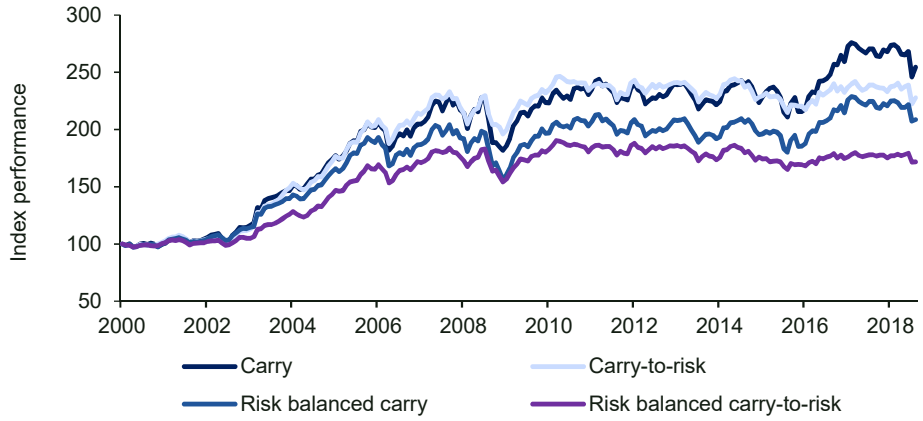
The carry trade is one of the most popular systematic investment strategies in the currency markets. The concept of investing in high yielding currencies while funding that investment in low yielding currencies has been discussed in numerous academic publications and practitioner forums. Despite this, there is a surprising amount of variation in the execution of the strategy. In the absence of a market-agreed benchmark, how can managers assess the performance of their strategy? Should there be a single benchmark for currency carry or should there be multiple benchmarks which correspond to different implementations?

We discuss some common approaches to both signal development and portfolio construction. In the process, we assess the feasibility of a single carry benchmark. In this publication, we:

- Outline the five dimensions that define a carry strategy
- Examine the performance of tradable carry strategies that correspond to the choices made along those dimensions
- Specify measures to gauge whether different implementations of carry strategies can be assessed against a common benchmark

Figure 1: Carry implementations



Source: Bloomberg

Not surprisingly, we find that carry and risk are related. The various choices made by practitioners in trading higher exposure to carry for commensurately higher portfolio risk results in strategies that can have substantial differences in average returns and volatilities. However, all these strategies' returns profiles are similar and highly correlated, indicating the existence of a single, common currency carry risk factor.

Introduction

There is a vast library of literature on the currency carry trade; from academic articles discussing the drivers of returns to practitioners outlining optimal trading strategies. What is largely absent is any discussion of whether a single benchmark—against which investors can measure performance—for this style exists. We have written extensively about the characteristics and historical performance of the carry trade in previous publications. Here, we take a different approach: breaking-down the carry strategy into five dimensions, we assess the potential benefits of a universal currency carry benchmark.

Carry strategies seek to maximize portfolio yield, while also controlling, or aiming to minimize, portfolio volatility. Many implementations adopt a rules-based (heuristic) approach despite the vast theoretical body of work on mean-variance optimization. In this publication we describe a simple optimization implementation. We also draw attention to some potential shortcomings of the optimization approach that may explain why simpler, heuristic-based strategies tend to be favored by practitioners.

There are five independent dimensions to consider when constructing a carry strategy.

1. **Investment universe**: considerations include liquidity and administrative/ operational ability
2. **Ranking methodology**: signals used to determine long and short currencies
3. **Portfolio construction**: number of currencies selected along with weights assigned to each currency
4. **Rebalancing frequency**: daily, weekly or monthly
5. **Tactical exposure**: timing of exposure to the carry premium

Each of these is an active decision and has an impact on the returns profile. By looking at a set of five strategies summarized in Figure 2, we examine the effects of the various choices along these dimensions. When comparing these strategies, it is also important to note that all else equal, a more parsimonious implementation is preferred.

Figure 2: Carry strategy implementations

Strategy	Ranking signal	Currency exposure	Pair weight
Concentrated carry	Carry	Currency can appear in multiple pairs	Equal notional
Carry	Carry	Currency can only appear in one pair	Equal notional
Carry-to-risk	$\frac{Carry}{Volatility}$	Currency can only appear in one pair	Equal notional
Risk balanced carry	Carry	Currency can only appear in one pair	Inverse volatility
Risk balanced carry-to-risk	$\frac{Carry}{Volatility}$	Currency can only appear in one pair	Inverse volatility

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

To understand the trade-offs that influence these strategies' risk and return characteristics, we examine three relationships fundamental to the currency carry trade. They map the available carry of a currency pair and the first three moments of the pair's return distribution. This information could help assess whether the decisions made along the five dimensions constitute variations of a single strategy with different risk tolerances, or whether they result in fundamentally different strategies.

The drivers of positive long run expected returns have been discussed at length in some of our past publications (please refer to the bibliography). In brief, the economic argument explains the long-run positive expected return as compensation for exposure to inflation in regions which experience high productivity growth (*see Economic Growth and Real Exchange Rate: An Overview of the Balassa-Samuelson Hypothesis in Asia, Ito T., Isard P. and Symansky S., Jan 1999*). The risk-sharing discussion centers around the typical returns profile for a currency carry investor. Extended periods of small accruals are punctuated by sudden, large losses, leading to a returns distribution that is left-skewed. Thus, the positive long-run expected return is seen as compensation for the relatively unattractive prospect of bearing the risk of suffering these sudden large losses (*see Carry Trades and Currency Crashes, Brunnermeier M., Nagel S., Pedersen L., Apr 2009*).

Data, implementation and costs

Our data spans the period from January 1999 to September 2018. Prior to 2007, we use Bloomberg BGN data; after that we use Bloomberg BFIX data when possible. To construct and calculate the returns for our strategies, we developed the Bloomberg FX Forward Indices. These represent the U.S. dollar excess return of maintaining a long 1-month forward position in the currencies listed in Figure 3. The indices can be found on the Terminal via IN <GO> under the Strategy tab.

Figure 3: Currency universe

G10	Emerging Markets	
	Deliverable	Non-deliverable
AUD	CZK	BRL
CAD	HUF	IDR
CHF	ILS	INR
EUR	MXN	KRW
GBP	PLN	PHP
JPY	RUB	TWD
NOK	SGD	
NZD	TRY	
SEK	ZAR	

Since the Bloomberg FX Forward Indices have different base dates depending on data availability, the size of our investment universe varies (increases) with time. Appendix A provides additional detail for each of the 24 Bloomberg FX Forward Indices.

Implied yields are calculated for each foreign currency and are derived from three components: (1) spot FX rates, (2) 1-month forward FX rates and (3) the 1-month US LIBOR rate.

All returns in our carry models are expressed net of transaction costs with an assumed 1bp Bid/Ask spread for G10 currencies and 2bp Bid/Ask spread for EM currencies.

Characteristics of the carry trade

The carry trade can be characterized by three relationships of currency returns, which we illustrate using data comprising of U.S. dollar currency pairs spanning August 2006–September 2018[1]:

1. The trade-off between the implied carry available and spot FX volatility
2. The relationship between the implied carry available versus the skewness of currency return
3. The subsequent currency return as a function of implied carry

Decomposing the universe into G10 (blue) and EM (gray) provides some pointers about whether a combined universe is reasonable.

Figure 4:
Volatility versus carry

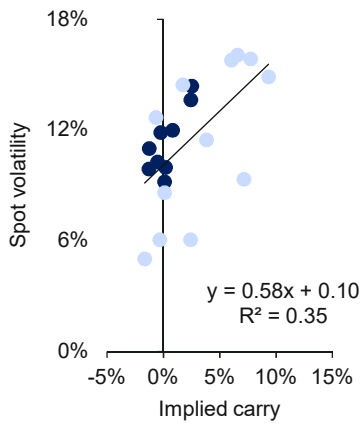


Figure 5:
Skewness versus carry

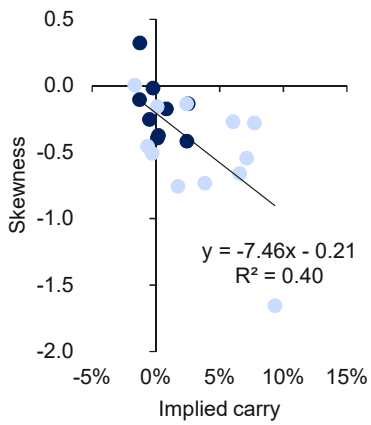
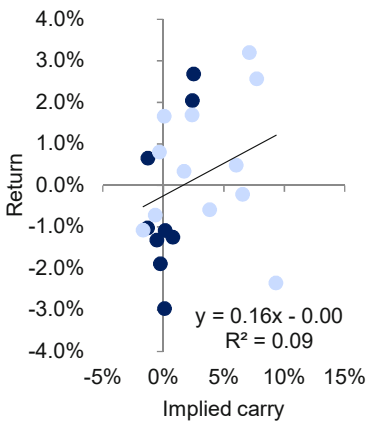


Figure 6:
Return versus carry



Source: Bloomberg

Figure 4 suggests a broad, positive relationship between implied carry (the interest rate differential between two currencies) and the volatility of returns of a currency pair for both the EM and G10 universes. Note that as a group, the EM currencies have a wider range of implied carry. Figure 5 indicates G10 and EM currencies display a negative relationship between the amount of carry available and the skewness of returns of a currency pair. Lastly, the positive (albeit weaker than the other two) relationship between the realized excess returns and ex-ante implied carry (Figure 6) highlights the compensation for the additional risks that investors in higher yielding currencies may face.

[1] HUF, INR, and KRW are excluded due to the lack of available data for the full period.

Optimized carry

Constructing a carry strategy through an optimization process is an appealing concept; the objective function is clearly stated and the approach is well documented. We use a fairly straightforward mean-variance optimization technique to illustrate the construction of a carry strategy ('Optimized carry'). The goal is to determine a basket of currencies that maximizes the ratio of carry to forecasted portfolio volatility.

The investment universe consists of 25 currencies: 24 U.S. dollar currency pairs and the U.S. dollar itself. For this purpose, we assume that the expected return of each currency is its available carry (the currency's implied 1M yield versus the U.S. dollar 1M yield)[2]. We use trailing historical returns to determine currency volatilities and correlations in order to estimate portfolio volatility. The carry signal is calculated and the portfolio is rebalanced monthly.

Figure 7: Performance summary for Optimized carry

	Optimized carry
Full sample (Feb 2000 - Sep 2018)	
Annualized implied carry	4.4%
Annualized return	1.9%
Annualized volatility	3.8%
Sharpe ratio	0.50
Max drawdown	-13.0%
Skew	-0.99
Max monthly gain	3.0%
Max monthly loss	-5.8%

Source: Bloomberg

Figure 8: Optimized carry strategy

Source: Bloomberg

2 As a result, the U.S. dollar is assumed to have a carry of zero.

The Sharpe ratio over the full sample is modest (0.5). While the skewness (highly negative) and drawdown/volatility ratio (in excess of 3) conform to a typical carry-like profile, the size of the annualized return is atypically small.

Since optimized strategies are more complex—both from an explanatory and implementation standpoint—adopting this approach depends on the corresponding improvement in performance versus the simpler heuristic approaches. When using an optimizer, the stability of the covariance matrix along with the potential for overfitting through parameter selection and constraints must be accounted for.

Thus, we now turn to the rules-based implementations that are commonly used by investors and discuss five common types of carry strategies.

Dimensions of the carry trade

A currency carry strategy is constructed by making decisions along five dimensions: investment universe, ranking methodology, portfolio construction, rebalancing frequency and tactical timing. We detail our approach for four of the five dimensions, leaving aside the tactical exposure dimension for later publications since it is often considered an active manager's decision.

Investment universe

The 24 currencies selected for inclusion (Figure 3) are chosen for their liquidity and to provide geographical diversification. To ensure maximum tradability, all currencies selected in the carry portfolio are traded through the U.S. dollar.

For the bulk of our analysis, we use a global currency approach. However, as seen from the previous section, there are differences in characteristics between emerging and developed market currencies. We examine the implications of these differences on strategy returns. In particular, we address the question that has been often asked: if the investment universe is restricted to only include EM currencies (funding and investment), is there an improvement in downside risk characteristics?[3]

Ranking signal

A) Maximizing carry

Currency can appear in multiple pairs

The first approach is arguably the simplest carry signal. It ranks all currency pairs (in our case: 300 pairs, i.e. 25 choose 2) by the carry available in each pair. Carry is calculated as the implied interest rate differential between the investment leg and funding leg of a currency pair. This "concentrated carry" strategy selects the N highest yielding currency pairs.

Currency can appear in only one pair

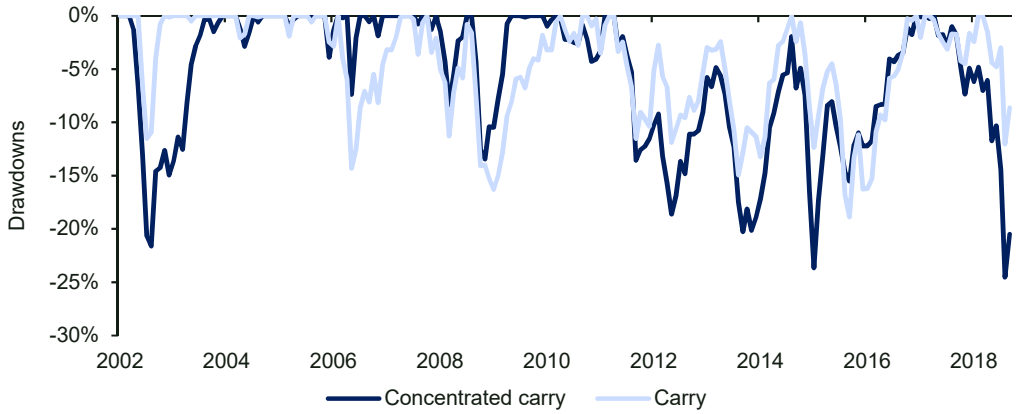
A variant on this approach is to rank individual currencies (not pairs) based on their local short-term rates—implied by the forward and spot FX rates and US Libor—and select the N highest and lowest ranked currencies for the investment and funding legs of the portfolio respectively. This is attractive from the viewpoint of simplicity and diversification. There is little opportunity to over-engineer the signal and the enforced restriction on currencies appearing only once in the portfolio controls idiosyncratic risk.

By construction, the concentrated carry portfolio described first will have higher carry

[3] This relates to the potential of reducing macroeconomic crash risk by using an EM-only investment universe.

than the diversified portfolio described next. However, the trade-off is that it also has currency concentration in the portfolio. Furthermore, as evidenced in Figures 4-6, this portfolio is likely to be more volatile and to out/underperform during bullish/bearish carry environments and have deeper drawdowns, even after accounting for the difference in volatility (Figure 9).

Figure 9: Drawdowns of 5-pair carry portfolios with 10% target volatility



Source: Bloomberg

B) Adjusting for risk

Does accounting for pair-wise risk benefit risk-adjusted performance? Typically, attribution of currency returns involves decomposing excess returns into carry and spot components. The carry returns display low volatility, given short-term yields are a function of relatively slow-moving central banks' policies. By contrast, the volatility of the spot component can be quite large since it is driven by macroeconomic movements and financial markets.

Account for risk in the carry measure

An intuitive adjustment we make to the carry maximizing approach is to calculate the carry/spot FX volatility ratio for all possible pairs (all 300 pairs). However, we then select the top N pairs such that any single currency appears only once in the portfolio. Naturally, this defines risk as the standard deviation of spot returns. Alternatively, downside risk can be used to account for the asymmetric utility functions of investors with loss aversion. For this publication, we restrict our results to the volatility measure as the two are very similar for our sample period.

In contrast to the carry maximizing approach, since the selection criterion is carry/volatility, there may not be a monotonic decline in the available carry as successive pairs are selected.

Portfolio construction

A) Equal weights

Portfolios tend to comprise of 3-5 currency pairs depending on the size of the investible universe. The exposure to each currency is dependent on the number of currencies selected and any need to control idiosyncratic risk.

Equal notional weight

The most common approach to weighting currency pairs is by equal notional exposures; i.e. if there are N pairs selected in the portfolio, each pair is assigned 1/N of the U.S. dollar amount. The advantage of this approach is its simplicity, whereas the disadvantage is

potentially being overly influenced by pairs with high volatility.

B) Risk weights

Inverse volatility weight

The influence on the portfolio of pairs with high volatility can be remedied by using a common approach to balance risk exposures within a portfolio. Each currency pair is assigned a weight inversely proportional to its volatility. As with the risk-adjusted carry signal, the volatility-adjusted portfolio construction technique potentially reduces exposure to pairs with higher available carry.

Rebalancing frequency

Depending on the ranking methodology and weighting scheme, the constituents of the carry portfolio are selected as a function of interest rate differentials and forecasted spot rate volatility. The first is slow-moving, in line with central bank policy, while the latter tends to change gradually if trailing historical returns are used to calculate forecasted volatility. This suggests a weekly or monthly signal generation and portfolio rebalancing can be employed without sacrificing performance or creating large differences in constituent selection across various implementations. The exception is if a timing mechanism such as an implied volatility filter is used to gain tactical exposure (see *Refining and timing the crash risk premium, 2010*). In this case, the carry signals are re-evaluated daily to ensure a more rapid reaction to bearish markets. In our analysis, we maintain a monthly rebalance in the absence of a timing mechanism.

It should be noted that the signal calculation and portfolio rebalancing frequencies should correspond to the holding periods and tenors of the currency instruments. Ideally, a holding period that matches the tenor of the investment helps reduce trading costs. That is, if the strategy invests in 1-month currency forwards, the signal can be calculated and the portfolio can be rebalanced at the same time that new forward contracts are put on to replace the expiring contracts. For the remainder of this paper, this is how we construct our strategies.

Constructing carry strategies

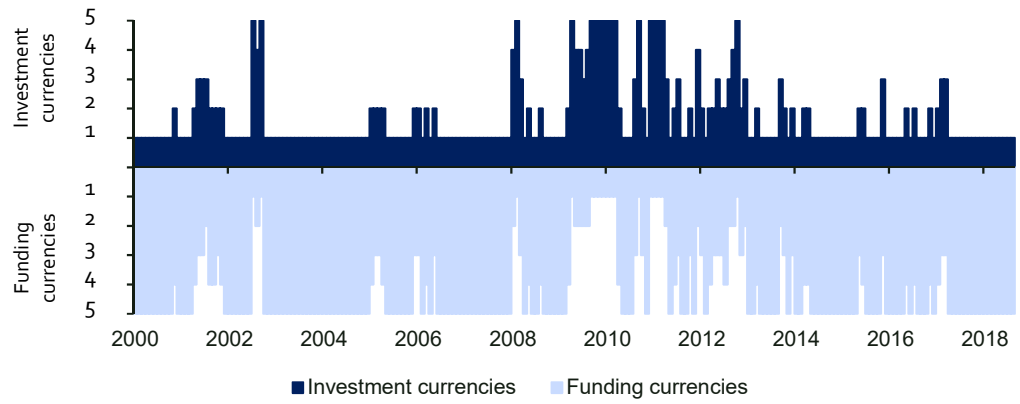
Using four dimensions of the carry trade, we construct five benchmarks (summarized in Figure 2). For completeness, we display results for portfolios consisting of between 1-5 currency pairs. In practice, for liquidity and diversification purposes, most carry strategies tend to consist of 3-5 pairs.

Maximizing carry

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

The concentrated carry strategy ('Concentrated carry') consists of ranking all the possible currency combinations (25 currencies choose 2) and picking the pairs with the highest available carry. Given the distribution of interest rates is typically right-skewed, we expect concentration in the investment currency. In a 5-pair portfolio, we see there are usually 1 or 2 investment currencies that are paired with 4 or 5 funding currencies each month (Figure 10).

Figure 10: Number of currencies used in the 5-pair Concentrated carry portfolio



Source: Bloomberg

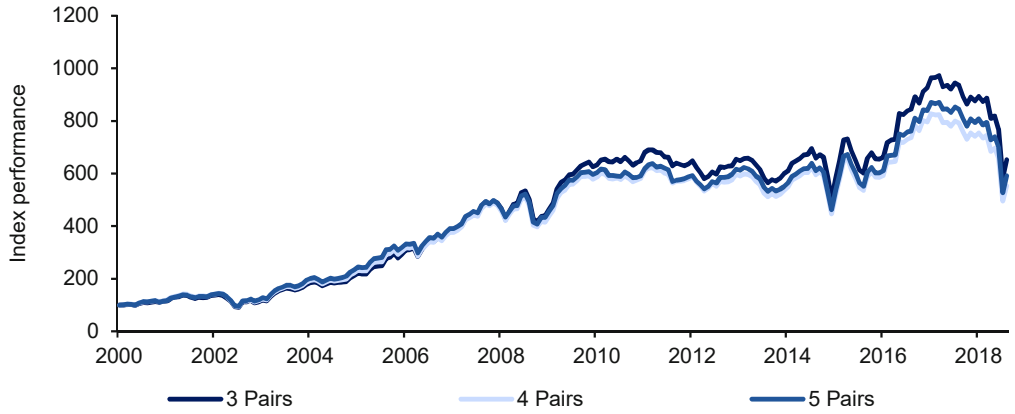
The available carry in the portfolio declines only slightly from 16.9% to 15.7% and the performance statistics in Figure 11 and Figure 12 confirm that after the addition of a second pair, the 2-5 pair portfolios are fairly robust to the choice of the number of constituents. The incremental addition of pairs has little impact on portfolio return and risk profiles.

Figure 11: Performance summary for Concentrated carry strategies

	Number of pairs				
	1	2	3	4	5
Full sample (Feb 2000-Sep 2018)					
Annualized implied carry	16.9%	16.4%	16.1%	15.9%	15.7%
Annualized return	14.1%	11.6%	10.6%	9.6%	10.0%
Annualized volatility	19.9%	18.5%	18.2%	18.2%	18.0%
Sharpe ratio	0.71	0.63	0.58	0.53	0.56
Maximum drawdown	-45.3%	-42.1%	-39.9%	-40.2%	-39.6%
Skew	-0.63	-0.32	-0.40	-0.44	-0.42
Maximum monthly gain	23.0%	22.8%	21.9%	22.5%	22.7%
Maximum monthly loss	-27.1%	-24.0%	-24.0%	-24.6%	-24.8%

Source: Bloomberg

Figure 12: Concentrated carry strategies



Source: Bloomberg

Due to the extreme downside risk characteristics of the Concentrated carry portfolio, investors will often forgo some carry in order to diversify the currencies in the portfolio by limiting the exposure of a single currency to one side of a single pair (2 x N currencies will appear in an N-pair portfolio). We present results in Figure 13 and Figure 14 using a simple equal notional weighting.

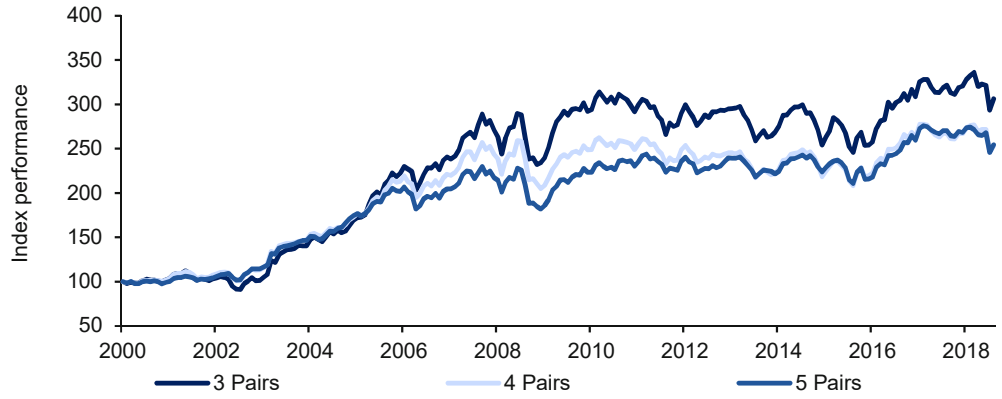
Figure 13: Performance summary for carry strategies

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

	Number of pairs				
	1	2	3	4	5
Full sample (Feb 2000 - Sep 2018)					
Annualized implied carry	16.9%	13.9%	11.9%	10.5%	9.4%
Annualized return	14.1%	8.5%	6.2%	5.1%	5.2%
Annualized volatility	19.9%	13.4%	11.6%	10.1%	9.2%
Sharpe ratio	0.71	0.64	0.54	0.51	0.56
Maximum drawdown	-45.3%	-23.6%	-21.7%	-20.9%	-20.9%
Skew	-0.63	-0.30	-0.09	-0.25	-0.40
Maximum monthly gain	23.0%	16.4%	14.2%	12.0%	11.2%
Maximum monthly loss	-27.1%	-14.9%	-9.4%	-10.0%	-10.0%

Source: Bloomberg

Figure 14: Carry strategies



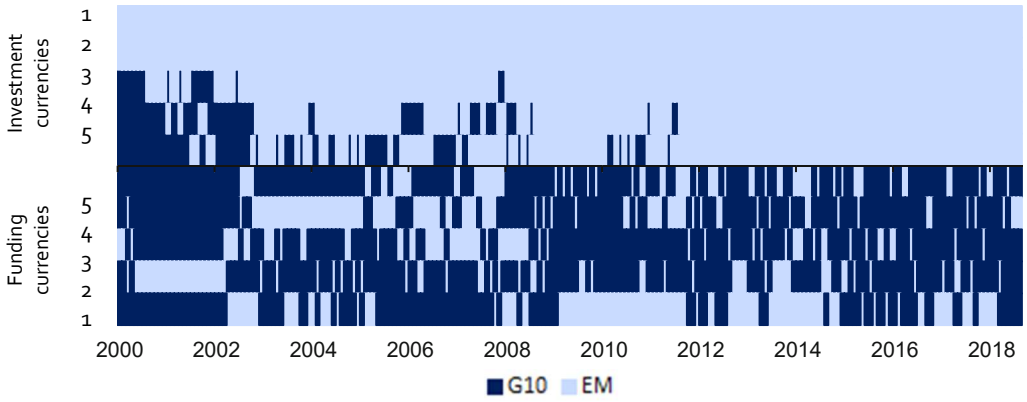
Source: Bloomberg

In contrast to the Concentrated carry portfolio, we see a significant decline in available carry as pairs are added to the diversified carry portfolio ('Carry'). While the decline in carry is accompanied by a corresponding decline in strategy returns, the diversified carry strategies are not meaningfully different in risk-adjusted return terms across this sample period. Furthermore, as we showed in Figure 9, when adjusted to account for the differences in volatility, the drawdowns of a Concentrated carry strategy were more severe than those of the Carry strategy.

Restricting the investment universe

Given the generally higher interest rates in emerging markets, is there a natural EM versus G10 division in funding/investment legs? Does this affect performance? Figure 15 highlights which group each currency within the 5-pair Carry portfolio comes from (investment currencies on top and funding on the bottom).

Figure 15: Exposure currency universe



Source: Bloomberg

Strategy
Concentrated carry
Carry: G10-only
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

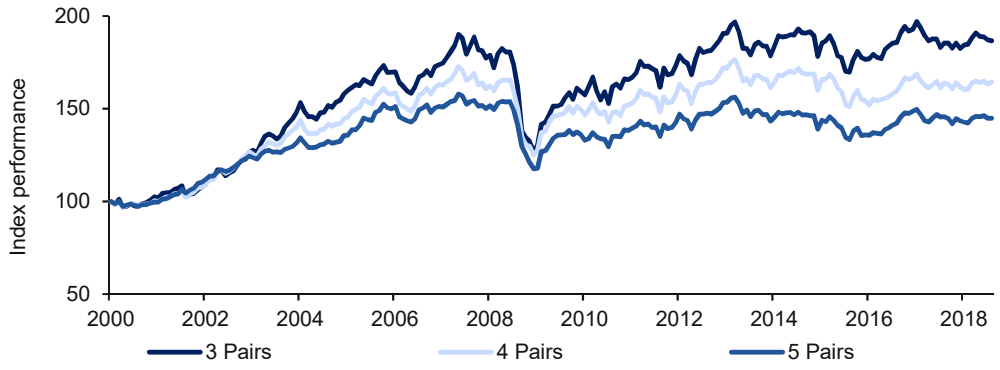
Due to their superior liquidity and long data histories some implementations of carry strategies are constructed solely from G10 currencies. To examine the effect of universe selection on performance we constructed G10-only and an EM-only Carry strategies.

Figure 16: Performance summary for G10-only Carry strategies

	Number of pairs				
	1	2	3	4	5
Full sample (Feb 2000 - Sep 2018)					
Annualized implied carry	5.2%	4.3%	3.6%	3.0%	2.5%
Annualized return	6.0%	3.9%	3.4%	2.7%	2.0%
Annualized volatility	12.7%	10.5%	8.7%	7.3%	6.2%
Sharpe ratio	0.48	0.37	0.39	0.37	0.32
Maximum drawdown	-42.4%	-36.7%	-33.0%	-27.6%	-25.6%
Skew	-0.76	-0.89	-1.07	-0.72	-0.46
Maximum monthly gain	15.1%	10.9%	8.8%	7.5%	7.6%
Maximum monthly loss	-20.2%	-15.9%	-14.6%	-10.1%	-8.2%

Source: Bloomberg

Figure 17: G10-only Carry strategies



Source: Bloomberg

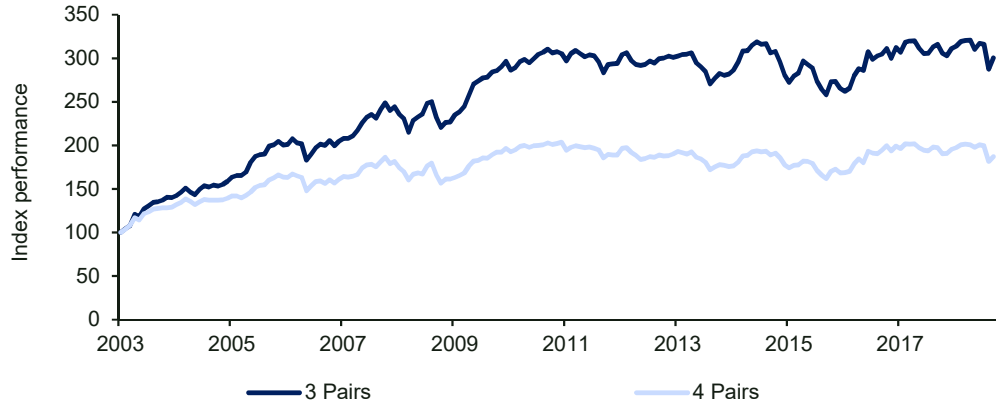
Figure 18: Performance summary for EM-only Carry strategies

Strategy
Concentrated carry
Carry: EM-only
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

	Number of pairs			
	1	2	3	4
Full sample (Jan 2003 - Sep 2018)				
Annualized implied carry	16.3%	13.5%	11.5%	9.9%
Annualized return	13.0%	9.4%	7.3%	4.1%
Annualized volatility	17.4%	12.2%	10.3%	9.1%
Sharpe ratio	0.75	0.77	0.71	0.45
Max drawdown	-46.1%	-19.9%	-19.1%	-20.6%
Skew	-0.71	-0.16	-0.05	-0.36
Max monthly gain	14.8%	15.8%	12.1%	8.5%
Max monthly loss	-26.4%	-12.9%	-9.3%	-9.5%

Source: Bloomberg

Figure 19: EM-only Carry strategies

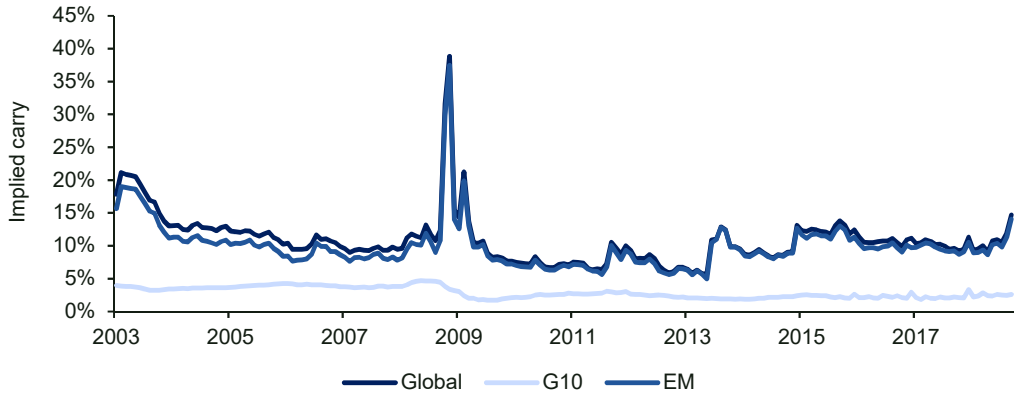


Source: Bloomberg

The G10-only Carry portfolios (Figure 16 and Figure 17) display both worse returns and downside characteristics than the global Carry portfolios. The EM-only Carry portfolios display better risk-adjusted returns than the G10-only portfolios[4].

Part of the performance difference between the G10-only and EM-only portfolios and the similarity of downside risk between the EM-only and global portfolios can be explained by the large dispersion of interest rates in the EM universe. Strikingly, the amount of carry accrued in an EM portfolio is almost identical to a global portfolio and 4x larger than the G10 portfolio (Figure 20).

Figure 20: Available implied carry for 4-pair portfolios



Source: Bloomberg

Two other differences between the G10-only and EM-only strategies are worth noting: their robustness to the number of constituent pairs and the magnitude of their drawdowns in 2008.

The G10-only portfolio display expected behavior as more pairs are added (declining carry, returns and volatility) and the 2-5 pair implementations' risk-adjusted performance is fairly robust to the number of pairs selected. On the other hand, the EM-

[4] Due to data availability, the EM strategy begins in January 2003 and has a maximum of 4 currency pairs.

only strategy shows a large difference between the 3-pair and 4-pair implementations; perhaps implying a larger degree of idiosyncratic currency risk in the EM-universe.

Secondly, the EM-only portfolios, by investing and funding in developing market currencies, avoided the large carry trade unwind in 2008 that affected the G10-only portfolio (and, to an extent, the global carry portfolio). This indicates the funding currencies in the EM portfolio were not "flight-to-quality" assets in a similar vein to the Japanese yen or Swiss franc. By removing this imbalance between the investment and funding legs of the portfolio, the EM-only carry portfolios were effectively able to hedge or avoid this global macroeconomic risk.

This G10/EM classification for currencies is taken from practitioners' historical precedence. Aspects such as economic development, capital controls and the degree of central bank currency intervention all contributed to an overall categorization of developed (G10) or emerging (EM). While useful, it is static—having been defined in the in 1990s. This raises a larger question of whether the current classification can be improved upon. One possibility is using a k-mean (clustering) approach to construct investment 'peer groups' using economic growth, long term interest rates, market access metrics and possibly returns. These groups can be updated periodically to reflect the changing dynamics of the currency markets. We will discuss the implications of this classification approach in upcoming publications.

Carry-to-risk

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

We repeat the procedure used for the set of carry maximization strategies, but now refine our signal to incorporate spot return volatility. The new signal is given by:

$$Signal = \frac{Carry}{Spot\ Volatility}$$

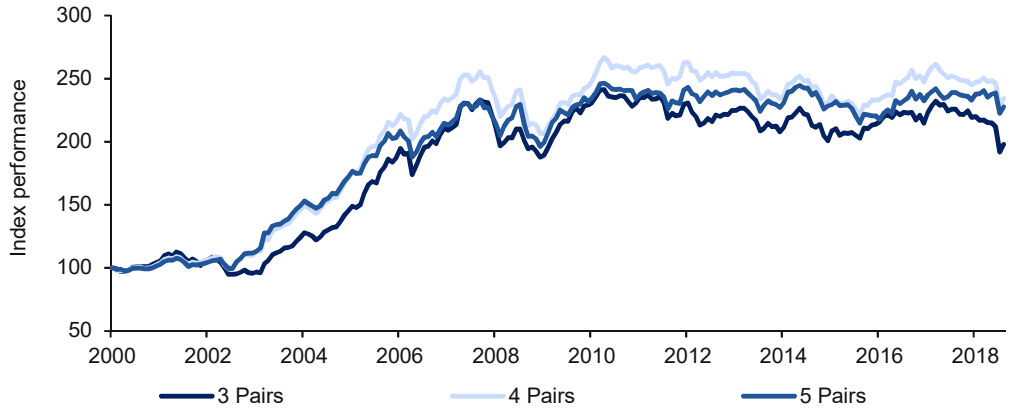
Comparing the carry-to-risk portfolio ('Carry-to-risk') performance versus the Carry portfolio, we see evidence to support the claim that these differences in implementation simply allow investors to choose among the fundamental trade-offs of the carry trade (Figures 4-6). The adjusted signal: (1) reduces the carry, returns and volatility (2) risk-adjusted returns are approximately unchanged and (3) maximum drawdown/volatility is approximately unchanged.

Figure 21: Performance summary for Carry-to-risk strategies

	Number of pairs				
	1	2	3	4	5
Full sample (Feb 2000 - Sep 2018)					
Annualized implied carry	13.2%	11.5%	10.2%	9.4%	8.6%
Annualized return	9.7%	4.5%	3.7%	4.7%	4.5%
Annualized volatility	11.7%	9.8%	8.4%	7.7%	7.4%
Sharpe ratio	0.83	0.46	0.45	0.61	0.61
Maximum drawdown	-22.7%	-26.5%	-20.5%	-19.3%	-15.8%
Skew	-0.26	-0.79	-0.54	-0.38	-0.06
Maximum monthly gain	13.7%	9.5%	7.4%	8.0%	10.1%
Maximum monthly loss	-14.7%	-13.0%	-9.4%	-7.6%	-6.9%

Source: Bloomberg

Figure 22: Carry-to-risk strategies



Source: Bloomberg

Inverse volatility-weighted portfolios

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

Assigning equal notional weights to currency pairs within the carry portfolio can lead to an unequal pairwise contribution to portfolio volatility. Typically, the pairs with higher volatility tend to dominate portfolio risk. One way to correct for this potential imbalance, and to improve the diversification benefits among the portfolio's constituents, is to size positions inversely proportional to volatility ('Risk balanced carry'). The weight for pair *i* is given by:

$$\omega^i = \frac{\frac{1}{\sigma^i}}{\sum_{i=1}^{N} \frac{1}{\sigma^i}}$$

; Where σ is the realized volatility of the pair's excess returns.

Given the generally positive relationship between carry and volatility (Figure 4), volatility-weighting the currency pairs tends to lower exposure to the pairs with higher carry, thus suppressing the overall carry available in the portfolio. Once again, this is largely an exercise in choosing among these now-familiar trade-offs.

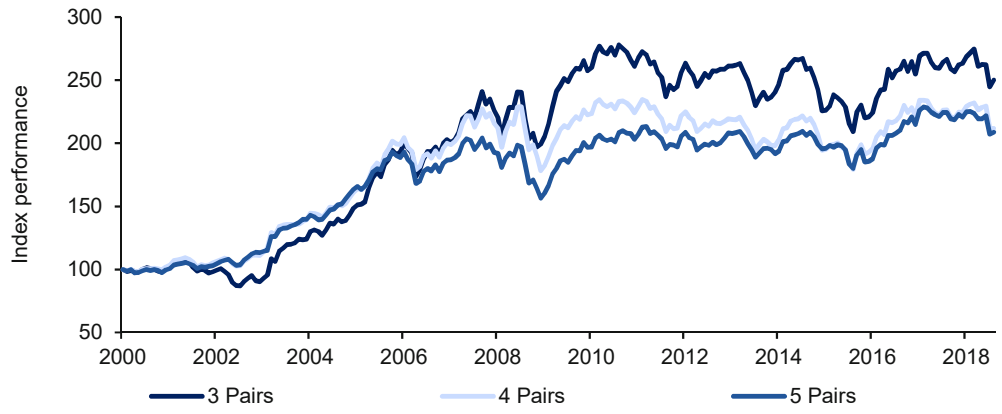
Performance statistics (Figures 23 and 24) indicate very similar results to the equal notional-weighted portfolios, with slightly inferior—though perhaps not statistically significantly so—risk-adjusted returns.

Figure 23: Performance summary for Risk balanced carry strategies

	Number of pairs				
	1	2	3	4	5
Full sample (Feb 2000 - Sep 2018)					
Annualized implied carry	16.9%	13.6%	11.6%	10.0%	8.9%
Annualized return	14.1%	7.3%	5.1%	4.1%	4.0%
Annualized volatility	19.9%	12.8%	11.0%	9.5%	8.5%
Sharpe ratio	0.71	0.57	0.46	0.43	0.48
Maximum drawdown	-45.3%	-24.3%	-24.8%	-23.5%	-23.3%
Skew	-0.63	-0.26	-0.05	-0.26	-0.46
Maximum monthly gain	23.0%	16.2%	13.5%	10.3%	9.5%
Maximum monthly loss	-27.1%	-13.1%	-9.6%	-7.9%	-8.5%

Source: Bloomberg

Figure 24: Risk balanced carry strategies



Source: Bloomberg

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

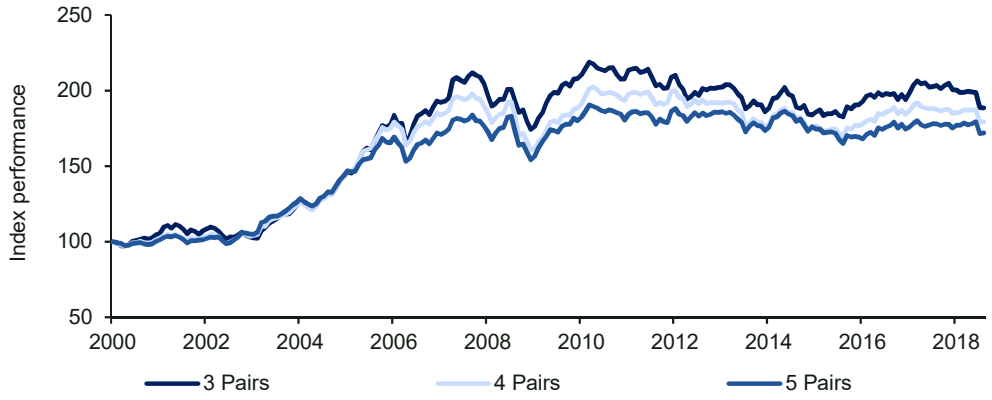
Finally, we compute a set of risk-balanced (i.e. inverse volatility-weighted) carry-to-risk signal portfolios ('Risk balanced carry-to-risk') to investigate any potential interaction effect generated by a risk-based weighting methodology and signal (Figures 25 and 26).

Figure 25: Performance summary for Risk balanced carry-to-risk

	Number of pairs				
	1	2	3	4	5
Full sample (Feb 2000 - Sep 2018)					
Annualized implied carry	13.2%	10.6%	9.1%	8.1%	7.6%
Annualized return	9.7%	4.8%	3.5%	3.2%	3.0%
Annualized volatility	11.7%	8.8%	6.8%	6.2%	6.0%
Sharpe ratio	0.83	0.54	0.51	0.51	0.49
Max drawdown	-22.7%	-21.2%	-17.7%	-18.7%	-16.0%
Skew	-0.26	-0.71	-0.29	-0.50	-0.30
Max monthly gain	13.7%	8.0%	6.0%	5.2%	6.0%
Max monthly loss	-14.7%	-12.9%	-7.3%	-6.7%	-5.7%

Source: Bloomberg

Figure 26: Risk balanced carry-to-risk



Source: Bloomberg

These results are similar to earlier comparisons and once again show similar risk, return, Sharpe ratio and drawdown profiles.

Summarizing performance

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

The results of the trade-offs that carry investors need to make are highlighted in Figure 27. All five strategy implementations offer similar long-term risk-adjusted returns, but we see significant differences in returns (and volatility). This suggests that if leverage or other institutional constraints (e.g. limits on portfolio concentration) are applicable then investors' desired level of expected return and/or risk budgets would dictate which implementation of currency carry they would find suitable.

Figure 27: Performance summary of 5-pair carry portfolios

	Concentrated carry	Carry	Carry-to-risk	Risk balanced carry	Risk balanced carry-to-risk
Full sample (Feb 2000 - Sep 2018)					
Annualized implied carry	15.7%	9.4%	8.6%	8.9%	7.6%
Annualized return	10.0%	5.2%	4.5%	4.0%	3.0%
Annualized volatility	18.0%	9.2%	7.4%	8.5%	6.0%
Sharpe ratio	0.56	0.56	0.61	0.48	0.49
Max drawdown	-39.6%	-20.9%	-15.8%	-23.3%	-16.0%
Skew	-0.42	-0.40	-0.06	-0.46	-0.30
Max monthly gain	22.7%	11.2%	10.1%	9.5%	6.0%
Max monthly loss	-24.8%	-10.0%	-6.9%	-8.5%	-5.7%

Source: Bloomberg

Figure 28 shows the correlations of these strategies over the 18-year back-test period. The full sample correlations indicate high co-movement of strategy returns—ranging from 0.6 to 0.98. The correlation amongst the diversified carry implementations is even higher (0.85-0.98).

Figure 28: Correlations of 5-pair carry portfolios

	Concentrated carry	Carry	Carry-to-risk	Risk balanced carry	Risk balanced carry-to-risk
Concentrated carry	1				
Carry	0.76	1			
Carry-to-risk	0.70	0.89	1		
Risk balanced carry	0.68	0.98	0.88	1	
Risk balanced carry-to-risk	0.60	0.85	0.96	0.88	1

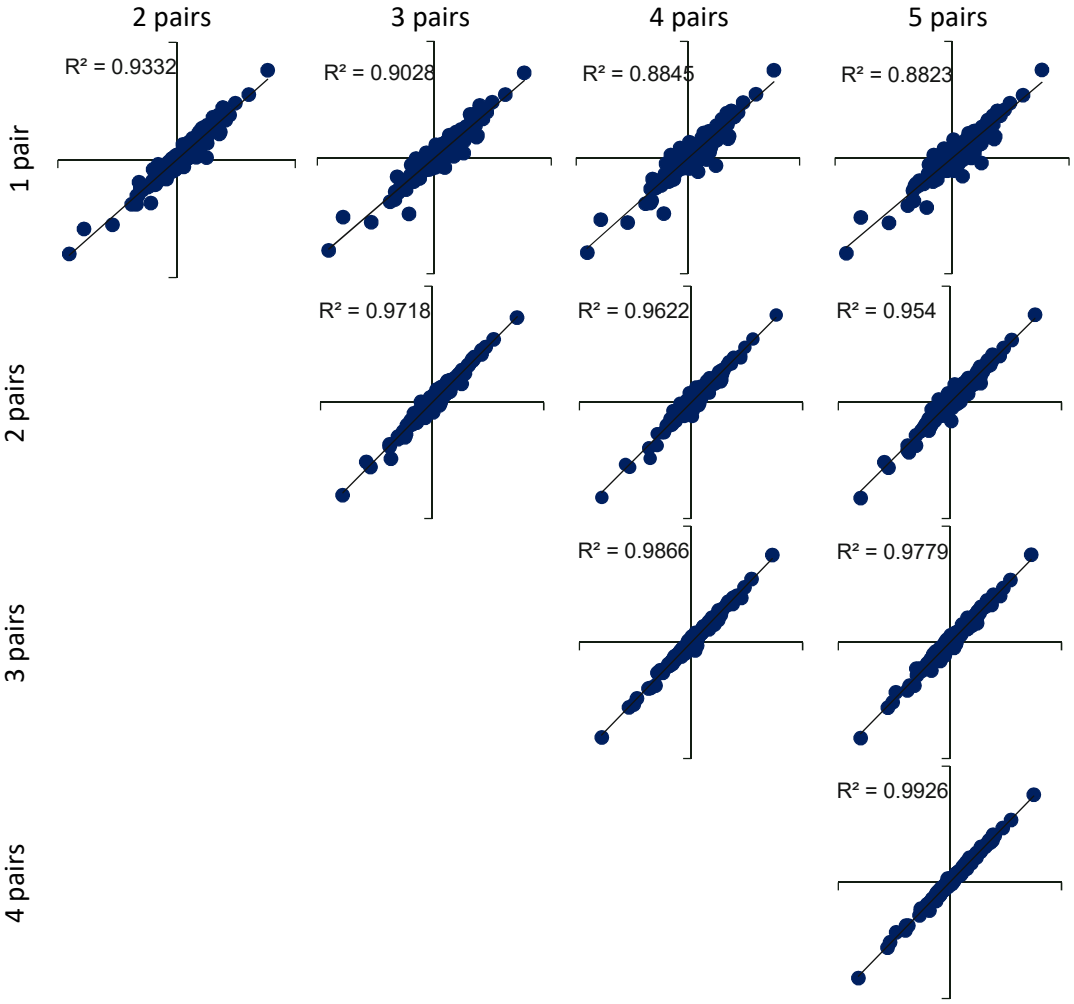
Source: Bloomberg

Next, we look at the correlations between portfolios (varying the number of pairs) for a given strategy. Here, for brevity, we present this analysis only for the first three strategies in Figure 2. When extended to the remaining two strategies, the results are similar.

Figures 29-31 show scatter plots of monthly returns of implementations of a given strategy, but with a varying number of constituent currency pairs. For ease of visual comparison, all scatter plots maintain the same range (30% to +30%) along the X- and Y-axes.

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

Figure 29: Scatter plots of monthly returns: Concentrated carry, X-pairs vs Y-pairs

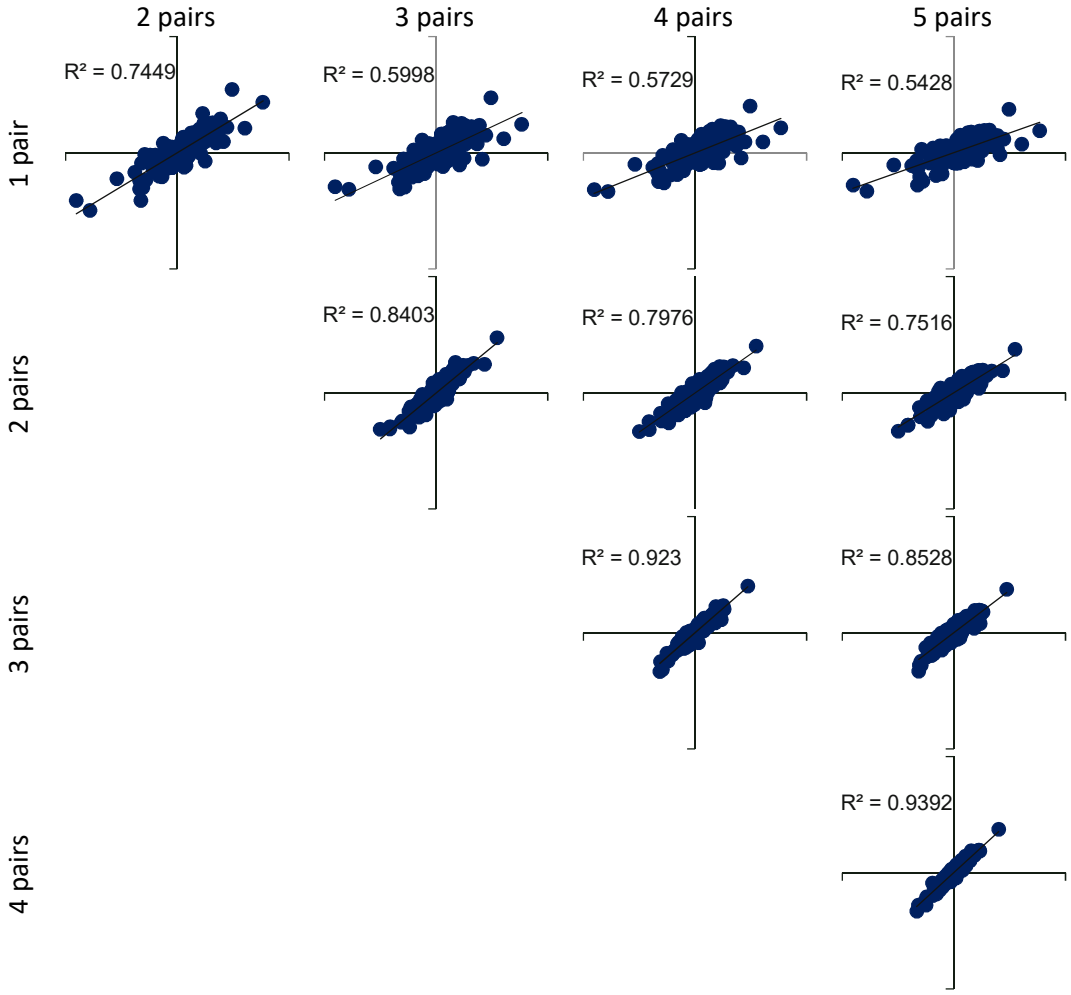


Source: Bloomberg

The Concentrated carry strategy portfolios display a high level of correlation, given the concentration in the investment currency (Figure 10). This re-confirms that these strategies' performance is robust to the number of currency pairs selected.

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

Figure 30: Scatter plots of monthly returns: Carry, X-pairs vs Y-pairs

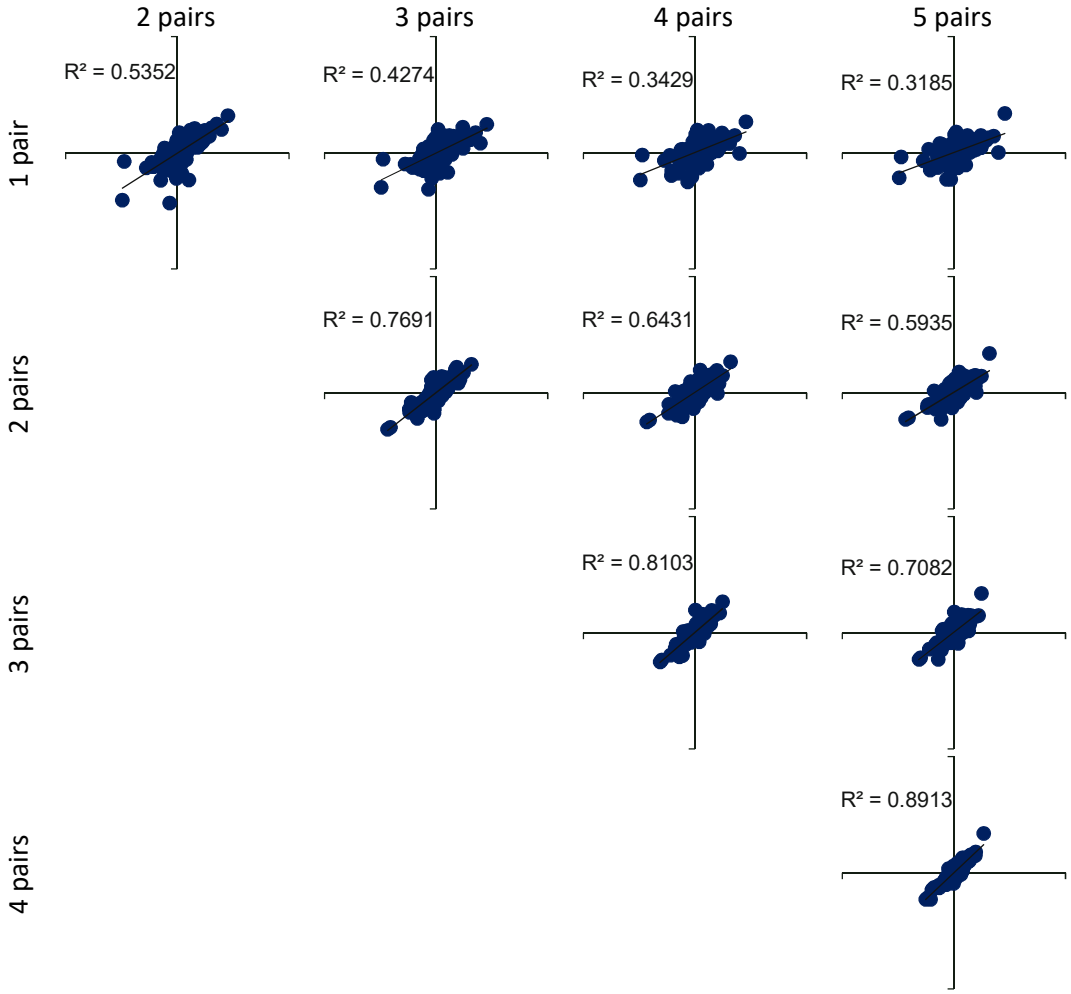


Source: Bloomberg

Pairwise correlations for Carry strategy portfolios with a different number of constituent pairs are lower than in the Concentrated carry case, but are high in absolute terms. Given most carry strategies employ between 3-5 pairs for liquidity and diversification purposes, we see correlations of in excess of 92% (R^2 of 0.85-0.95).

Strategy
Concentrated carry
Carry
Carry-to-risk
Risk balanced carry
Risk balanced carry-to-risk

Figure 31: Scatter plots of monthly returns: Carry-to-risk, X-pairs vs Y-pairs



Source: Bloomberg

Finally, the Carry-to-risk strategy displays a similar correlation pattern—rising from the top-left to the bottom-right—as the number of constituent pairs is increased. The correlations are lower than either of those of the Concentrated carry or Carry strategies but remain high, especially for the 3-5 pairs portfolios (84%-94%).

In the sections above, we have discussed both optimized and rules-based approaches. It should be noted the Optimized carry portfolio has a correlation of at least 0.5 versus the rules-based diversified carry portfolios and displays similar risk-adjusted returns. However, despite the explicit use of correlations to control portfolio risk, the strategies based on rules-based diversification appear to display lower drawdown/volatility ratios and less negative skewness. This might be related to the empirical observation that pairwise correlation display structure breaks in times of market stress—leading to poor covariance forecasts. We intend to explore this in subsequent publications.

Extensions

Based on the strategies above, there are two natural extensions. The first is combining the optimized and rules-based approaches and second to extend portfolio construction to include a yield-based weighting scheme.

Correlation-adjusted carry

Using the diversified carry implementation (long/short the five currencies with the highest/lowest yields) as our starting point, we use the optimizer to allocate across these five pairs. That is, rather than allocating equal notional-weights or equal volatility-weights to these five pairs, we let the optimization process determine the set of weights that maximize carry to portfolio volatility.

Yield-weighted carry

This strategy takes the long carry position in all 300 unique pairs in the 25 currency universe; with the weights proportional to the pairwise implied carry[5]. The signal-based weighting scheme can be viewed as an alternative to the Carry strategy, each of them using slightly different approaches to maximize yield. This is confirmed by the full-sample correlation of 0.9 between the two strategies. Note that while this approach consider 300 pairs each month, positions can be netted for investment purposes to reduce the number of transactions.

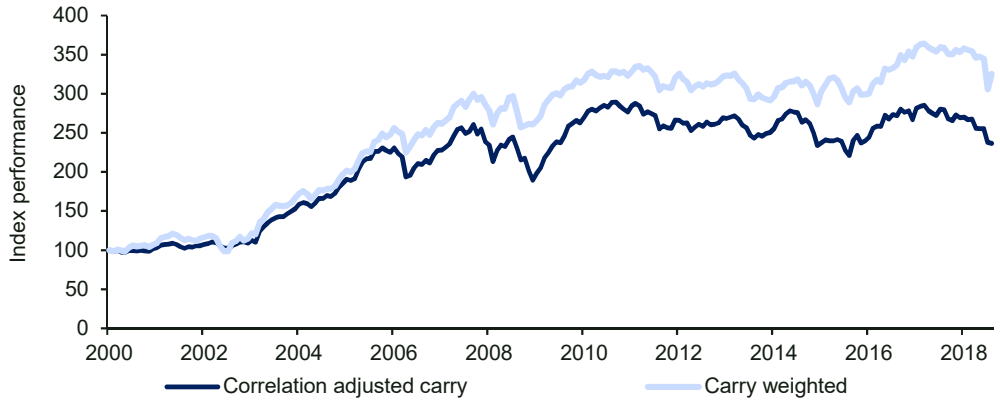
Figure 32: Performance summary for Correlation-adjusted carry and Carry-weighted portfolios

	Correlation-adjusted carry	Carry-weighted
Full sample (Feb 2000 - Sep 2018)		
Annualized implied carry	11.4%	11.3%
Annualized return	4.7%	6.6%
Annualized volatility	10.5%	10.4%
Sharpe ratio	0.45	0.63
Max drawdown	-27.3%	-18.8%
Skew	-0.32	-0.20
Max monthly gain	13.0%	12.5%
Max monthly loss	-11.7%	-11.4%

Source: Bloomberg

[5] With 25 currencies in the universe, there are 600 possible permutations of currency pairs. Accordingly, 300 of those pairs will have a positive implied carry. To be clear: the implied carry of a long Currency A, short Currency B position will be equal in magnitude and opposite in sign to that of a long Currency B, short Currency A position.

Figure 33: Correlation-adjusted carry and Carry-weighted portfolios



Source: Bloomberg

While both strategies have similar levels of carry and are highly correlated, the Carry-weighted portfolio seems superior from a risk-adjusted return and drawdown standpoint.

Conclusion

There are multiple ways to construct carry strategies. The evidence suggests that for a given investment universe, even though individual strategies can differ in the implementation choices, the resulting returns profiles are similar and positively correlated. However, the resulting strategies do have different average returns and volatilities. Furthermore, changing the investment universe significantly (e.g. including more currencies or excluding some of the 25 chosen currencies) could change the results meaningfully.

The ability to specify a single benchmark for all possible strategy implementations for a large, liquid set of currencies depends on the comparison of four performance attributes: the Sharpe ratio, correlations, volatility and behavior in the tails. Having reviewed five broad types of strategies, we conclude that a single benchmark can be used to broadly represent the currency carry factor. This can be used to determine whether an active manager is adding alpha, for example. However, since the various strategy implementations result in significant differences in the level of returns and volatilities, simple returns and attribution benchmarking should involve volatility targeting or scaling to make results comparable.

Having evaluated the strategies on performance statistics and degree of parametrization, the Carry strategy is the simplest and most parsimonious implementation while maintaining performance characteristics that are similar to other, more complex, implementations. Given the simplicity of construction and implementation, it is a good candidate for use as a benchmark for this investment style.

Further research is warranted in several areas: alternative classifications for the investment universe, investigating the use of shrinkage estimate to construct robust covariance estimate for optimized strategies and examining the introduction of sentiment signals such as risk reversals to mitigate downside risk.

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Appendix

A: Details of the Bloomberg FX Forward Indices

Currency	Bloomberg Ticker	Market	NDF	Base Date	G10/EM Carry Inclusion
AUD	BTSFAUUS Index	G10	No	1/4/1999	2/8/2000
CAD	BTSFCAUS Index	G10	No	1/4/1999	2/8/2000
CHF	BTSFCHUS Index	G10	No	1/4/1999	2/8/2000
EUR	BTSFEUUS Index	G10	No	1/4/1999	2/8/2000
GBP	BTSFGBUS Index	G10	No	1/4/1999	2/8/2000
JPY	BTSFJPUS Index	G10	No	1/4/1999	2/8/2000
NOK	BTSFNOUS Index	G10	No	1/4/1999	2/8/2000
NZD	BTSFNZUS Index	G10	No	1/4/1999	2/8/2000
SEK	BTSFSEUS Index	G10	No	1/4/1999	2/8/2000
CZK	BTSFCZUS Index	EM	No	1/4/1999	2/8/2000
HUF	BTSFHUUS Index	EM	No	12/5/2008	1/9/2010
ILS	BTSFILUS Index	EM	No	7/6/2005	8/10/2006
MXN	BTSFMXUS Index	EM	No	1/4/1999	2/8/2000
PLN	BTSFPLUS Index	EM	No	6/26/2001	7/31/2002
RUB	BTSFRUUS Index	EM	No	6/17/2005	7/22/2006
SGD	BTSFSGUS Index	EM	No	1/4/1999	2/8/2000
TRY	BTSFTRUS Index	EM	No	10/10/2001	11/14/2002
ZAR	BTSFZAUS Index	EM	No	1/4/1999	2/8/2000
BRL	BTSFBRUS Index	EM	Yes	1/2/2001	2/6/2002
IDR	BTSFIDUS Index	EM	Yes	6/6/2005	7/11/2006
INR	BTSFINUS Index	EM	Yes	12/5/2008	1/9/2010
KRW	BTSFKRUS Index	EM	Yes	12/5/2008	1/9/2010
PHP	BTSFPHUS Index	EM	Yes	1/5/2004	2/8/2005
TWD	BTSFTWUS Index	EM	Yes	1/19/1999	2/23/2000

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