Deconstructing Futures Returns: The Role of Roll Yield

Campbell White Paper Series

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Executive Summary

- **Futures and spot returns on the same underlying asset often diverge, and the magnitude of this divergence is known as the futures "roll yield."**
  - The cumulative impact of roll yield can be quite significant, in some cases being similar in magnitude to the entire gain or loss an investor experiences over the lifetime of a trade.
  - In spite of the importance of roll yield in futures markets and associated investments, misconceptions abound regarding its nature, measurement, and relevance.

- **This paper aims to demystify roll yield by connecting it to ideas familiar to investors and addressing common misunderstandings.**
  - The roll yield represents the net benefit or cost of owning the underlying asset beyond moves in the spot price itself. Therefore, the spot return and roll yield together comprise the total return experienced by an investor (net of financing costs).
  - The roll yield is *not* the result of "rolling" positions from one contract to the next. We demonstrate this by carefully walking through the life cycle of a futures trade.
  - There is a direct relationship between roll yield and the slope of the futures term structure.

- **The decomposition of a futures return into its spot return and roll yield components provides insights into the behavior of futures prices that have implications for both carry strategies and trend following strategies.**
  - Since these types of strategies are quite pervasive in the managed futures industry, fund managers and investors should have a strong working knowledge of these concepts.
  - At Campbell, many of these ideas are used in the ongoing development of new Trend Following strategies. They also serve as the foundation for some of the strategies included in Campbell PRISM, a quantitative trading program which utilizes a suite of non-trend based alpha strategies to exploit structural market opportunities.

Introduction

Consider the following scenario:

> On a snowy New Year's Day in 2012, an individual investor (we'll call him Spencer) takes a seat by the fireplace and opens his brokerage statement. He is relatively happy with what he sees: US stocks, which make up the vast majority of his assets, have doubled since the lows of March 2009. However, economic and political risks such as the European debt crisis continue to cause concern, and he wants to protect his gains.
>
> Spencer's friend Victor tells him about the VIX, an index of market volatility that tends to go up when the market goes down. Victor points out that while Spencer can't trade the VIX directly, he can trade VXX, an exchange-traded note (ETN) that is linked to the VIX. The following day, Spencer buys enough VXX to put his mind at ease. He trusts that, if stocks fall, VXX will provide some protection. Besides, the VIX level seems low enough (23.4, after peaking above 80 during the 2008 financial crisis) that Spencer figures there's not much downside.
>
> Six months later, Spencer sits by the pool and reviews his portfolio. He finds that his US stock investments have risen by about 6%. He notes that the VIX level is 19.6, a 16% drop. But he is surprised to find that his VXX investment is down 54%. Furthermore, he discovers that when the S&P 500 hit a rocky patch from mid-March to early-June (falling nearly 10%), VXX was essentially flat even though the VIX rose by 74%.
>
> Confused, Spencer searches the internet for "VXX." He reads that VXX actually tracks not the VIX itself, but "a constant one-month rolling long position in first and second month VIX futures contracts."[1] Further exploration leads Spencer to numerous references to "contango" and the dangers of "roll yield." Realizing that he does not understand what these concepts mean and how they affect his returns, he decides to close out his VXX position.

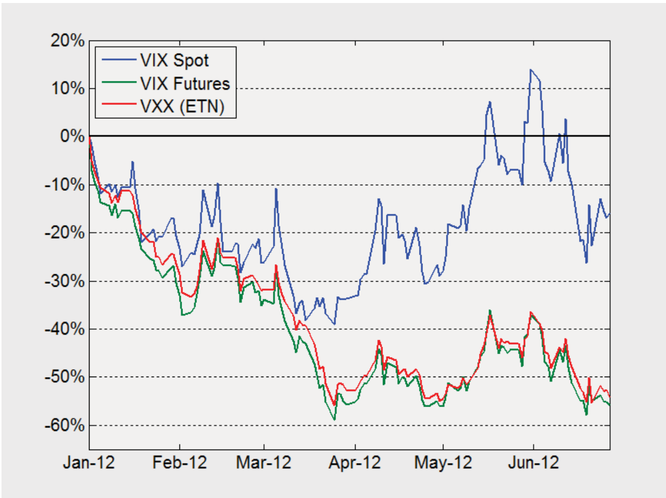
Why did Spencer's VXX investment behave so differently than the VIX? As Spencer discovered in his online search, many ETNs actually reflect an underlying investment in futures instruments. Indeed, the first panel of Exhibit 1 shows that VXX returns closely track VIX futures returns. While Spencer's VIX experience represents an extreme example of the futures-spot performance divergence, many investors have experienced similar disappointment (see, for example, the second panel of Exhibit 1)[2]. So perhaps the relevant question is: why do these futures positions behave differently than their equivalent spot index or spot instrument?

Over short periods of time, spot and futures returns tend to track each other closely. For example, the one-day price change of the most active VIX futures contract will typically have the same sign and similar magnitude to the price change of the VIX spot index. However, over longer holding periods the returns can differ significantly, as Spencer experienced. This futures-spot divergence is known as the futures "roll yield," which we define as the difference in return between a futures contract and its underlying asset.[3]

The impact of roll yield can be quite significant, in some cases being similar in magnitude to the entire gain or loss an investor experiences on the futures position. However, in spite of the importance of roll yield in futures markets (and associated investments), there is a significant lack of clarity on the issue. Misconceptions persist regarding roll yield's origin, measurement, impact and relationship to other concepts such as carry trading and trend following. One of the most pervasive misconceptions is that roll yield represents a realized gain or loss generated on the day of the contract roll, as a long investor sells the expiring contract and buys the new active contract (or a short investor takes the opposite steps). Another is that roll yield is an abstract concept and that accounting separately for roll yield and spot market returns is a pointless pursuit. Yet another misconception is that roll yield creates arbitrage opportunities: that an investor can lock in a guaranteed profit by going long markets with positive roll yield and short markets with negative roll yield.

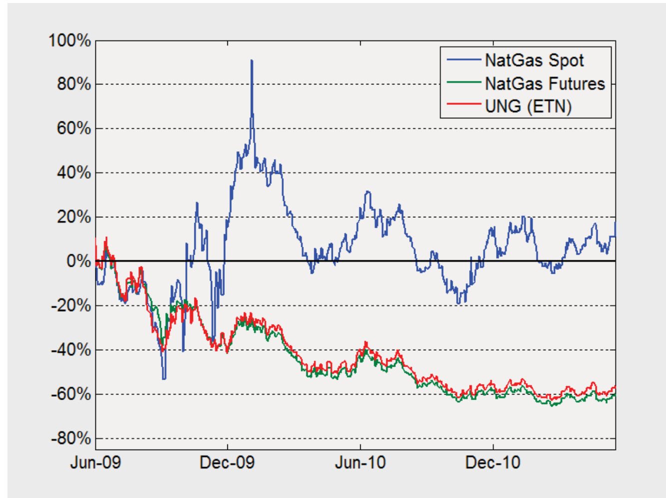
EXHIBIT 1: Comparison of the Spot, Futures, and ETN Performance for VIX and Natural Gas

(a) % Change in VIX and Investable VIX Products



Source: Bloomberg; cumulative performance of VIX spot, VIX joined active futures contract and VIX ETN (ticker: VXX) in the first half of 2012.

(b) % Change in Nat Gas Spot Price, Futures and ETN



Source: Bloomberg; cumulative performance of NG spot, NG joined active futures contract and NG ETN (ticker: UNG) from Jun-09 to May-11.

We seek to demystify roll yield. We begin by demonstrating that the total return of a futures investment incorporates both changes in the spot price as well as additional benefits or costs associated with owning the underlying asset, and is thus a more accurate representation of the total investable return on an asset than the change in spot price itself. This provides the conceptual motivation for understanding roll yield: it reflects the benefits and costs of owning an asset, beyond moves in the spot price.

We walk through the life cycle of a futures trade to show what happens when a position is rolled from one contract to the next. We relate roll yield to the shape of the futures term structure and to the notions of backwardation and contango. Finally, we show how roll yield information can be used to generate investment opportunities. Along the way, we address some of the common misconceptions related to roll yield's nature, measurement, and relevance.

Why Can't An Investor Simply Earn the Spot Return Directly?

At this point it might be natural to ask, why would an investor bother investing in futures at all, rather than simply buying the equivalent spot instrument and earning the spot return directly? The short answer is that it is generally not possible for an investor to capture spot price changes in isolation. In some markets, such as VIX, the spot instrument is not even directly investable.[4] In commodity markets, such as Corn and Gold, a spot investment implies a position in a physical asset, which may entail storage and transport costs, as well as insurance and financing costs. In financial markets such as stocks and currencies, an investor earns a cash flow such as dividends or a foreign deposit rate, while also paying a financing rate on the position.[5]

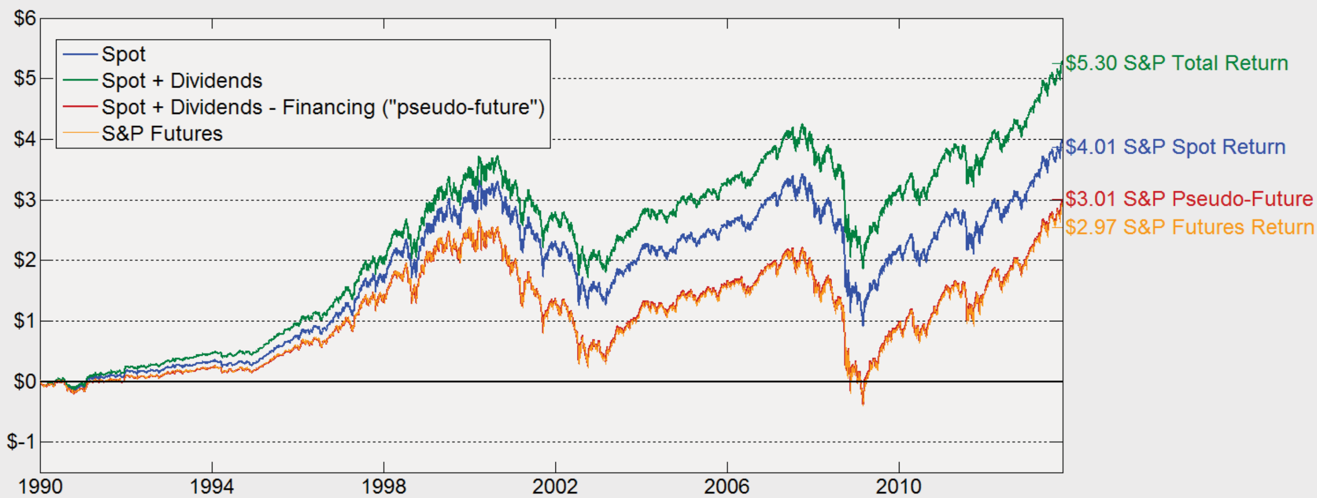
As an example, let's consider something familiar to many investors: the S&P 500 Index. The S&P 500 is regarded by many to be a barometer of the global economy. Major news outlets often begin their evening overview of the day's economic developments by announcing the S&P 500 Index return, perhaps including the month-to-date and year-to-date statistics as well. It is easy to forget that this headline return number does not correspond to the actual experience of any investor, as it does not account for dividends or the cost of financing the investment. However, as we will demonstrate in the next section, the performance of an S&P 500 futures position does account for these additional cash flows and costs, and thus fully represents the net benefit of owning the underlying stocks.

How Do We Relate the S&P Spot Return to Its Futures Price?

How much of an impact do these additional cash flows have on the S&P 500 Index return? The chart in Exhibit 2 shows the cumulative profit of an initial $1 invested in a hypothetical S&P 500 spot security (with no cash flows, and returns corresponding precisely to the spot price index) from 1990 through October 29, 2013. In that period, the S&P 500 climbed from 353.4 to 1771.95, so $1 invested in the hypothetical spot security (blue line) would have yielded a profit of $4.01.[6] This represents the spot return (which in this example is synonymous with capital gain). Note that this is a constant-share investment since we do not buy or sell any shares subsequent to the initial purchase.

EXHIBIT 2: Hypothetical Return of $1 Invested in the S&P 500 Index from 1990 through October 29, 2013

To approximate the Futures Return, we add dividend profits (not reinvested) to spot profits and deduct financing costs.
This incorporates the net carrying costs (dividends - financing) of owning the asset.
The resulting return stream (red line) closely tracks the actual S&P Futures Return (orange).



Source: Bloomberg, Campbell & Co.; Chart shows profit of $1 invested in 1990 (through October 29, 2013) in S&P 500 Index (blue line), S&P 500 Index + dividends (green line), S&P 500 Index + dividends less financing costs (red line), and S&P Futures (orange line).

An actual investment in the S&P 500 would accrue dividends over this period. We assume those dividends are not reinvested, since doing so would constitute an additional purchase of shares, and we want to keep the number of shares constant to maintain comparison with the constant-share hypothetical spot position. The profit of an initial $1 invested in the S&P 500, accruing but not reinvesting dividends, is represented by the green line in Exhibit 2. The impact of dividends is substantial; the same initial investment would have yielded a profit of $5.30 rather than $4.01 when dividends were excluded. However, we still have not considered the cost of financing, so we deduct borrowing costs from this profit.[7] The resulting return stream (red line) represents the P&L of the constant-share position, incorporating both the change in the Index value (spot price change) and the benefits and costs of owning the investment (dividends, borrowing costs).

Note that we label the red line a "pseudo-future." Why is this? It turns out that no-arbitrage considerations require this return stream to be equivalent to the gain/loss from the futures position (for further discussion, see Chapter 5 of Hull (2012)). Indeed, the cumulative profit of an equivalent-share position in the most active S&P futures contract (orange line) lines up quite closely with the S&P pseudo-futures profit.

What Does Any of This Have To Do With Roll Yield?

We have shown that the futures return reflects the P&L of an investment in the underlying, accounting for additional benefits and costs, and that this will typically differ from the spot return, particularly over long periods of time. Conceptually, we can decompose the futures return as

$$\text{Futures Return} = \text{Spot Return} + \text{Excess Benefit or Cost of Owning the Underlying Asset} \tag{1}$$

Here and in the discussion to follow, we use "return" to mean the change in the value of an instrument or index between two points in time, without dividing by the initial value. This simplifies the exposition in the paper.[8]

As noted before, we define roll yield as the difference between the futures and spot return, i.e.

$$\text{Roll Yield} = \text{Futures Return} - \text{Spot Return} \tag{2}$$

Comparing Equations 1 and 2 shows that **the roll yield is simply the excess benefit or cost of owning the underlying asset.** In our S&P 500 example, the roll yield reflects the dividend payments in excess of financing costs. Exhibit 3 provides more detail on the benefits and costs relevant to selected asset classes.

EXHIBIT 3: Benefits and Costs of Holding Selected Asset Classes

Asset Class	Benefits	Costs
Bonds	Current Yield (Bond Coupon)[9]	Financing Rate
Currencies	Foreign Deposit Rate	Local Deposit Rate
Stocks	Dividend Yield	Financing Rate
Volatility	Hedging Against Increases in Volatility*	Insurance Premium*
Commodities	Convenience Yield*	Storage; Transport; Insurance; Financing Rate

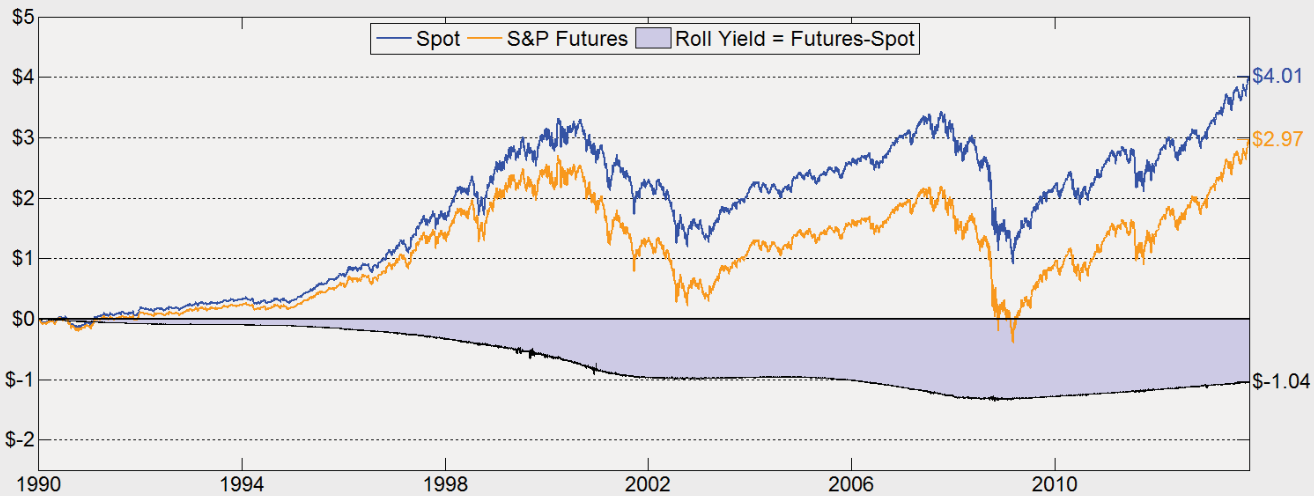
**Non-cash flow terms*

For financial assets, these represent actual cash flows, while other assets may have non-cash flow costs and benefits, like convenience yield in the case of commodities. Convenience yield reflects the benefits to holding a physical commodity, which tends to be more valuable when inventories are low or shortages are expected. For further discussion of convenience yield, see Gorton, Hayashi, and Rouwenhorst (2012).

Exhibit 4 shows this relationship between spot, futures, and roll yield for our S&P example. In this case, we can quantify the roll yield as -\$1.04 = (\$2.97 - \$4.01). Since for the S&P 500, roll yield is proportional to dividends minus financing costs, we can infer that over the period in this example, S&P dividends were less than the financing costs on average.

EXHIBIT 4: Spot, Futures, and Roll Yield

By comparing the Spot Return to the Futures Return, we can measure the Roll Yield.
During this period, the benefit from holding the S&P 500 (dividends)
was less than the average cost of financing the investment, so the overall roll yield was negative.



Source: Bloomberg, Campbell & Co.; Chart shows growth of $1 invested in 1990 (through October 29, 2013) in S&P 500 Futures (orange line) as well as the comparable growth of the S&P 500 index (blue line), assuming daily compounding. The cumulative roll yield (light blue) is also shown.

While this example is fairly intuitive, there are several complicating factors. Primarily, unlike the pseudo-futures contract in our S&P example, a real futures contract has an embedded expiration date. Consequently, periodic unwinding and re-establishing (or "rolling") of positions is required to maintain exposure to the underlying market.

The P&L implications of the roll event tend to be a source of confusion. A common misconception is that roll yield represents the profit or loss generated on the day of the contract roll. For example, if rolling a futures position requires you to sell the current contract and buy the next one at a higher price, it may appear that the roll transaction itself will cause a loss (since you are selling low and buying high). However, this is not the case. It is misleading to compare the price paid for the next contract to the price at which you sold the current contract since they are entirely different instruments. As we will demonstrate, the roll yield is not a result of the roll itself, but rather accumulates over the life of the trade as the futures price gradually converges to spot at expiration.[10]

Life Cycle of an S&P 500 Futures Trade:

In order to directly observe the impact of the roll event, let's follow along with an investor who is long a single S&P 500 futures contract.

> On March 8, 2013, a long-only investor in S&P, whom we will call Lois, decides she wants exposure to the S&P 500, and goes long one contract[11] of the March 2013 e-Mini (symbol: ESH3) at the closing price of 1549.50.[12] At this time, ESH3 is designated as the "front" contract since it is closest to its expiry of March 15, 2013. As the expiration date approaches, Lois wants to maintain her exposure to the S&P, so on March 14 she sells her position in ESH3 at the closing price of 1562.25, and simultaneously goes long one contract of June 2013 (symbol: ESM3) at the closing price of 1556.00. Now ESM3 becomes designated as the front

contract. This is called “rolling” the contract. On March 15, she still has exposure to the S&P 500, but she is holding a different instrument. On March 18, Lois decides to close out her position at a price of 1546.75.

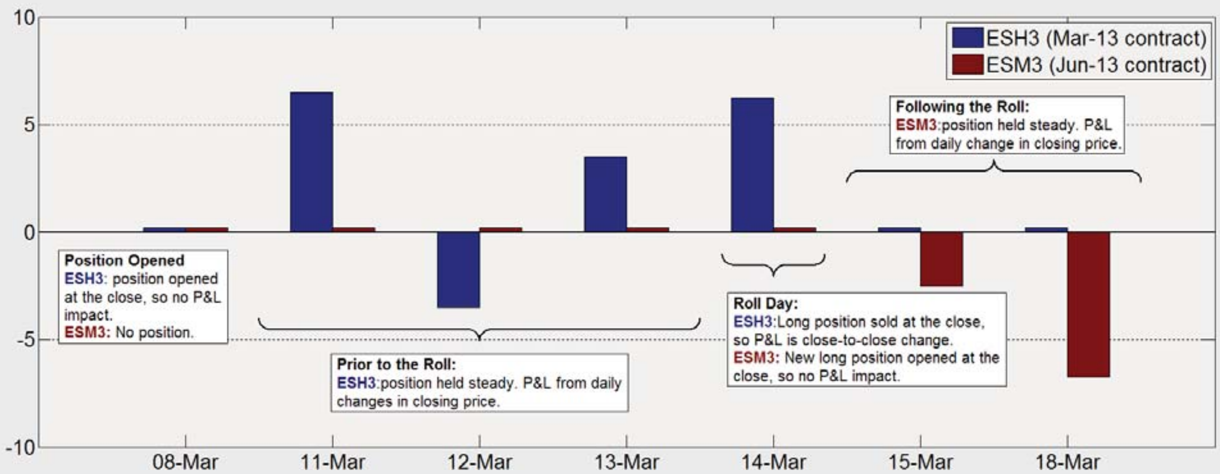
There are a few questions to consider here. What is Lois's cumulative P&L? How much, if any, of the P&L is directly attributable to the roll? And to what extent is her P&L different from simply comparing the front futures price on March 18 against the front futures price on March 8? In order to answer these questions, Exhibit 5 shows the relevant closing prices for ESH3 and ESM3 from March 8 through March 18, while Exhibit 6 shows the daily P&L for Lois's position in each contract.

EXHIBIT 5: Closing Prices of S&P 500 Futures Contracts

	08-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar	18-Mar
ESH3	1549.50	1556.00	1552.50	1556.00	1562.25	1557.08	N/A
ESM3	1544.50	1550.50	1546.75	1550.00	1556.00	1553.50	1546.75

EXHIBIT 6: Daily P&L from Long Position in S&P 500 Futures

On the roll day, Lois's P&L is due entirely to the change in price of ESH3.
There is no P&L impact from the price difference between ESH3 and ESM3.



Source: Bloomberg; Chart shows daily P&L for a long position in one contract of ESH3 opened at the closing price on March 8, 2013 and rolled into ESM3 at the closing price on March 14, 2013. ESM3 contract is sold at the closing price on March 18, 2013. As mentioned in the endnotes, for simplicity we say that one contract corresponds to one unit of the S&P 500 index.

Prior to the roll date (through March 13), the P&L from her futures position is due entirely to changes in the price of the ESH3 (March) contract, as shown in Exhibit 6.

On the roll date (March 14), Lois sells her long ESH3 position at the closing price, so that her P&L that day is also due to the close-to-close price change of ESH3. She locks in a cumulative P&L of 12.75, reflecting the difference between the ESH3 closing price on March 14 and March 8. She simultaneously goes long the ESM3 (June) contract; **since her execution price is the same as the closing price, there is no P&L impact on the roll day from ESM3**.

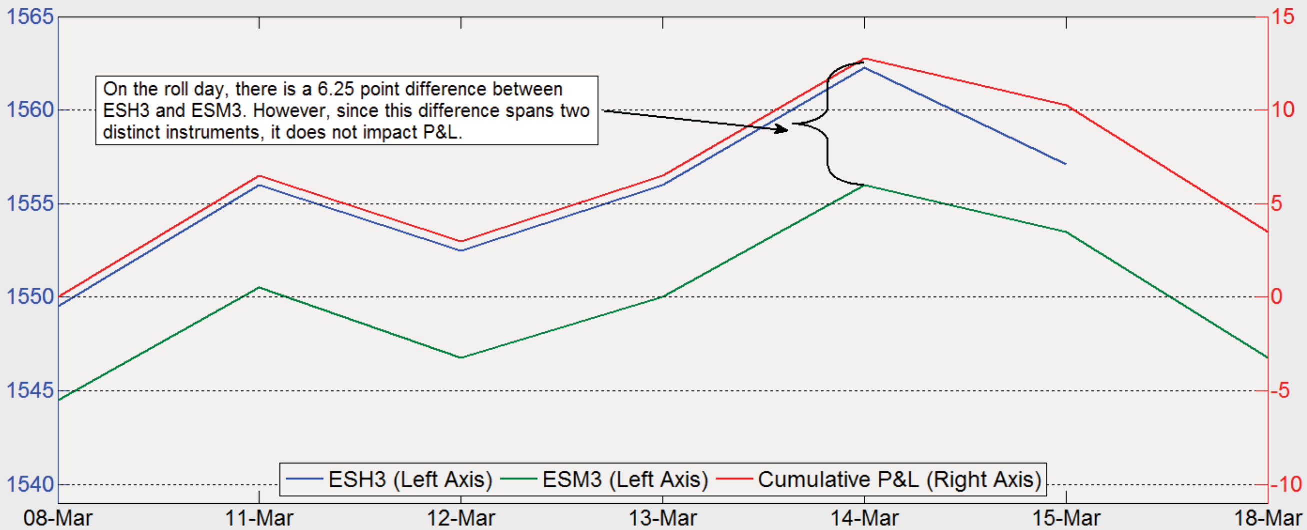
Following the roll date (March 15-18), the P&L from her position is due entirely to changes in the price of the ESM3 (June) contract. She closes her position in ESM3 at the closing price on March 18, locking in a cumulative loss of 9.25, reflecting the difference between the ESM3 closing price on March 18 and March 14. Lois's total profit is equal to the sum of the individual P&Ls from ESH3 (+12.75) and ESM3 (-9.25), or 3.50.

We see that nothing unusual happens on the roll day. So what gives rise to the common misconception that the rolls themselves directly impact P&L? To get some insight into this question, let's take a look at the data in a slightly different way and plot the ESH3 and ESM3 contracts on the same graph. Exhibit 7 shows the closing prices for the two contracts (ESH3 in blue and ESM3 in green), along with the cumulative daily P&L over the course of the transaction (in red).

On the roll day, there is a 6.25 point difference between ESH3 and ESM3. Some mistakenly believe that this is a true roll 'cost' [13], in the sense that there should be a P&L impact of 6.25 points from closing a position in the more expensive contract and opening a position in a less expensive contract. However, as we saw in Exhibits 6 and 7, this price difference spans two separate and distinct instruments, and it does not represent the P&L from holding the futures position.

EXHIBIT 7: Cumulative P&L from Lois's Position, and Contract Closing Prices

Despite a 6.25 point difference in contract price, P&L does not shift by 6.25 on the roll date.



Source: Bloomberg; Chart shows ESH3 and ESM3 closing prices (left axis) and cumulative P&L (right axis) for a long position in one contract of ESH3 opened at the closing price on March 8, 2013 and rolled into ESM3 at the closing price on March 14, 2013. ESM3 contract is sold at the closing price on March 18, 2013. As mentioned in the endnotes, for simplicity we say that one contract corresponds to one unit of the S&P 500 index.

As shown in Exhibit 7, there can be a substantial difference between the price of the contract we are rolling into (e.g. ESM3) and the price of the contract we are rolling out of (ESH3). The price difference does not directly impact the P&L, but it does make any type of analysis involving prices a bit problematic. To see this, let's say Lois is doing some quantitative study and would like to have a continuous stream of prices for the e-Mini over the time she had exposure. She tries the first thing that comes to mind and simply splices together the ESM3 and ESH3 price series, connecting them at the roll date. This would lead to the price series shown in blue in Exhibit 8.

This would be misleading, however, since it implies that Lois lost money on her position over the life of the trade, which did not happen. Therefore, splicing the front contract prices together does not properly account for the P&L attribution described above and is not an effective methodology. To correct this, we need to shift the closing prices of the "rolled-into" contract (ESM3) by the difference of prices on the roll date (i.e., 6.25). This roll adjustment produces the curve shown in dark green in Exhibit 8. The P&L implied by this artificially constructed price series exactly corresponds to the P&L

that Lois experienced. Even though this "joined" price series does not represent the price series of an actual contract, it accurately accounts for the P&L experienced by an investor in the futures market.

EXHIBIT 8: Lois's e-Mini Spliced Close and "Joined" Prices

To accurately measure the P&L from a futures position spanning roll dates, a "joined" futures price series can be created. This requires the closing prices of the "rolled-into" contract to be adjusted by the difference in contract price on each roll date.

Source: Bloomberg; Chart shows a hypothetical price series formed by splicing together the ESM3 and ESH3 futures prices, connecting them at the roll date (in blue), and a "joined" futures price series formed by shifting the closing prices of ESM3 by the difference in contract prices on the roll date (in green).

What Drives the Difference Between the Joined Price and Front Price?

We have shown that joining the front contract prices in a way that accounts for the rolls results in a price series that reflects the actual P&L of a futures investment, while naïve splicing of front contract prices does not. Exhibit 8 indicates that the roll adjustment is directly related to the shape of the futures term structure on the roll date: it is equal to the difference between the front and deferred contract prices on the roll date (6.25 points in Lois's case). Now we will integrate these concepts to better understand the drivers of the difference between the joined futures price and front futures price.

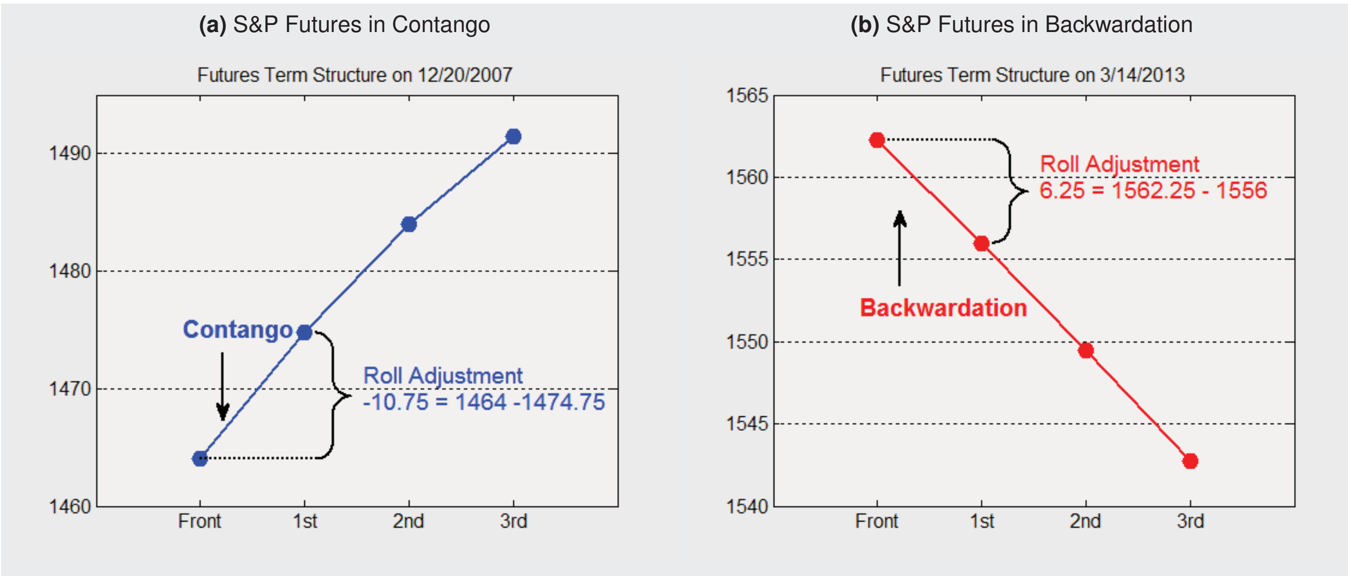
The difference between the joined and spliced prices accumulated over a period of time is called the cumulative roll adjustment, which is just the sum of roll adjustments at each roll date, i.e.

$$\text{Joined Price} = \text{Front Price} + \text{Cumulative Roll Adjustment} \tag{3}$$

Note that implicit in this calculation is a start and an end date over which the cumulative roll adjustment and joined prices are calculated. These dates are somewhat arbitrary but should encompass the time period of interest. On the start date (assuming it is not a roll date) the cumulative roll adjustment is zero, so initially the front and joined prices are equal, and diverge over time as the roll adjustments are applied. This behavior is why this method of calculating the joined price is called the forward difference adjustment[14].

Since each roll adjustment is directly related to the slope of the futures term structure, we see that the cumulative roll adjustment reflects an average of the term structure on the roll dates. For example, if the next contract expiring (the "deferred" contract) has on average a lower price than the front contract (as was the case for Lois's trade), then the cumulative roll adjustment over that period will be positive, making the joined price series "outperform" the spliced price series. This type of market is said to be in backwardation. Conversely, if the next contract expiring has on average a higher price than the front contract, then the cumulative roll adjustment over that period will be negative, making the joined price series "underperform" the spliced price series. This type of market is said to be in contango. Exhibits 9a and 9b show examples of both types of market conditions for the S&P 500.

EXHIBIT 9: Contango and Backwardation



Source: Bloomberg; Chart 9a shows S&P futures term structure on 12/20/2007; Chart 9b shows S&P futures term structure on 3/14/2013.

Suppose we assume that rolls occur an instant before expiry, where the spot price is approximately equal to the front contract price. Then Equation 3 becomes[15]

$$\text{Joined Price (Roll Date)} \approx \text{Spot Price} + \text{ Cumulative Roll Adjustment} \tag{4}$$

If we use Equation 4 to calculate the profit of a long futures position that is put on an instant before a roll, and unwound on a roll date an instant before the roll, we get

$$\text{Futures Return (Roll Date to Roll Date)} = \text{Spot Return} + \text{Cumulative Roll Adjustment} \tag{5}$$

Note that the cumulative roll adjustment now refers to the sum of the roll adjustments between the inception and closing out of the trade. Comparing this to Equation 2, we see that there is a direct correspondence between the cumulative roll adjustment and the roll yield[16] between roll dates, so we can write

$$\text{Roll Yield Between Roll Dates} = \text{Cumulative Roll Adjustment Between Roll Dates} \tag{6}$$

We know from previous arguments that the roll yield is equal to the cumulative excess benefit or cost of owning the underlying asset, which in the case of the e-Mini, is dividends less funding costs. **Therefore, if the roll yield (and**

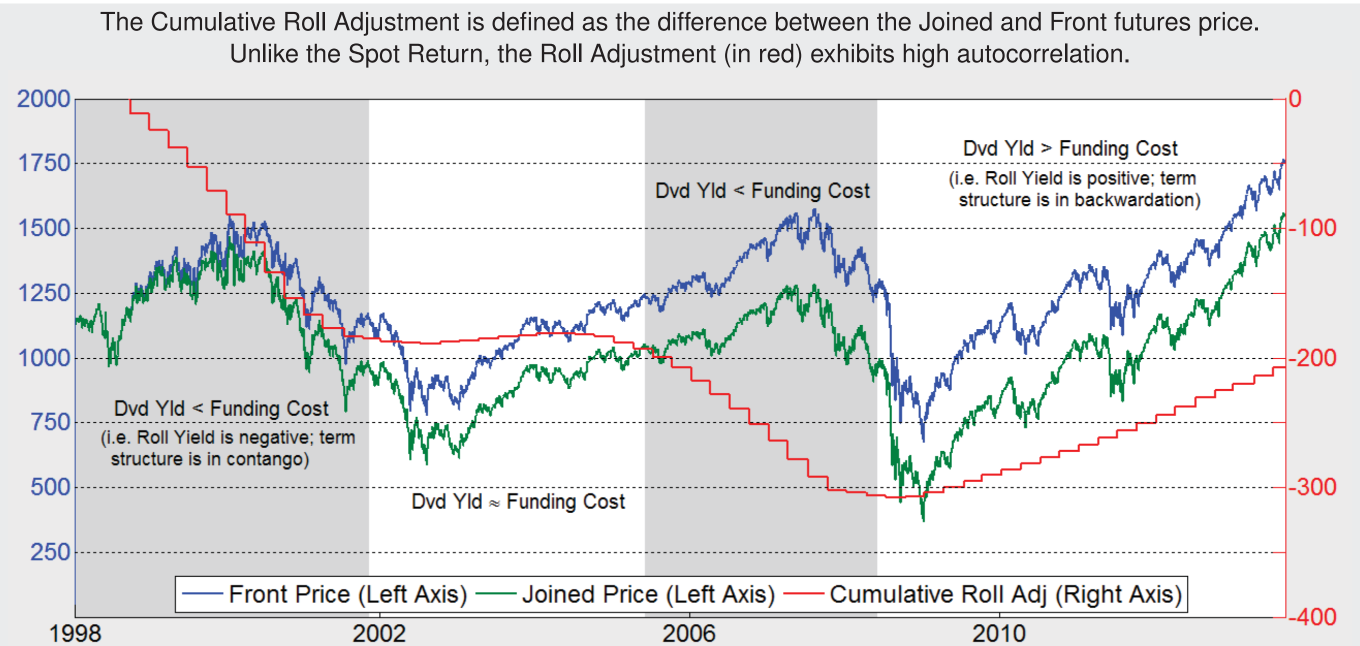
equivalently, the cumulative roll adjustment) for the e-Mini is positive, it means dividends exceed the funding costs on average, and if the roll yield/cumulative roll adjustment is negative, the dividends are less than the funding costs on average.

Going back to Exhibits 9a and 9b, on 12/20/2007 (as shown in Exhibit 9a), the June 2008 (1st deferred) contract had a higher price than the March 2008 (front) contract, meaning the market was in contango and dividends were expected to be less than funding costs. If we were to roll on that day, the roll adjustment would be negative. If dividends were to remain lower than funding costs (on average) over the life of the trade, then the roll yield would be negative and the futures investment would underperform the spot index. Conversely, on 3/14/2013 (as shown in Exhibit 9b), the June 2013 (1st deferred) contract had a lower price than the March 2013 (front) contract, meaning the market was in backwardation and dividends were expected to be greater than the funding costs. If we were to roll on that day, the roll adjustment would be positive. If dividends were to remain higher than funding costs (on average) over the life of the trade, then the roll yield would be positive and the futures investment would outperform the spot index. This is the situation that Lois found herself in during her e-Mini trade.

Why is the Cumulative Roll Adjustment a Useful Concept?

There should be nothing controversial about the mechanics of the decomposition in Equation 3, as it is true by construction. However, since the roll adjustment does not represent the return of any instrument, there has been some debate about the usefulness of such a decomposition. **The reason it is useful is that the two terms on the right hand side of Equation 3 can behave in dramatically different ways**.

EXHIBIT 10: Joined Futures Price versus Front Price (i.e. “spliced” price) for S&P 500 Index



Source: Bloomberg; Chart shows the S&P 500 Front price (in blue), the S&P Joined Futures (i.e. continuous contract) price (in green), and the cumulative roll adjustment (in red), calculated as the difference between the joined and front price. Data from March 1998 to November 2013.

Exhibit 10 depicts what Lois would have experienced had she held a long position in the front e-Mini contract from March 1998 until November 2013, rolling at appropriate times (shown by the green "Joined Price" curve corresponding to the futures return). It also shows the spliced e-Mini price (the blue "Front Price" curve). The cumulative roll adjustment (shown in red) is simply the difference between the two curves (Joined Price − Front Price). It looks like a staircase built by a drunken engineer because it is only nonzero on roll dates, and has extended periods where it is upwardly sloping, downwardly sloping, or flat. It is upwardly sloping when dividends exceed the funding costs, downwardly sloping when dividends are less than the funding costs, and flat when the two are nearly the same. Each step of the staircase represents the roll adjustment on a particular roll day.[17] Although the roll adjustment can fluctuate from period to period, the long term persistence of the roll adjustment across multiple roll days suggests that the roll yield is more predictable than the spot price. We have essentially decomposed the futures return into a part that looks very noisy and a part that looks very smooth.

To recap, we have seen that the roll adjustment offsets the artificial jump in the price of the front contract on the roll date induced by the change of the front contract designation. In Lois's case, the front contract an instant before she rolled was ESH3, and an instant after was ESM3. This created a jump in the front price equal to the difference in price between those contracts. This price jump does not correspond to a real P&L event, so we introduced the concept of a roll adjustment, which is calculated to exactly offset this artificial price jump, and when added to the front price gives us a "joined" price series that corresponds to Lois's cumulative return.

Implications for Trading Strategies

Now that we have laid the groundwork for an understanding of roll yield's role in futures returns, we discuss the practical implications in the sections below.

Trend Following Strategies

One of the most common strategy styles in the managed futures industry is trend following. The central idea behind trend following is that returns have some degree of persistence. Thus, if total returns have been generally positive over some historical period of time, a trend following strategy would go long that market, and conversely, if the total returns have been negative, the strategy would go short. Since for futures markets, the total return is reflected in the joined price series, we use joined prices in the calculation of the trend following signal.

If we put the word "persistence" in front of all the terms in Equation 5, then, in some general sense, we get[18]

$$\text{Persistence in Futures Return} = \text{Persistence in Spot Return} + \text{Persistence in Cumulative Roll Adjustment} \qquad (7)$$

This shows that all else being equal, the stronger the persistence in the cumulative roll adjustment, the stronger the persistence in the futures return. Therefore, Equation 7 makes clear that trend following strategies have a strong connection with the behavior of the roll adjustment. In fact, our previous white paper[19] showed that nearly half of the cumulative performance of a benchmark trend following strategy was attributable to roll yield. Thus, managers employing trend following strategies and their investors should have a strong working knowledge of the concepts presented in this paper.

Carry Strategies

It would be very nice if we could get direct exposure to the roll adjustment due to its high persistence through time. Unfortunately, this is impossible, since it does not represent the return of any instrument. However, what if the price changes of the front contract, i.e. the "noisy" part of the decomposition, averaged out to zero over the long term? Under those conditions, Equation 3 gives

$$\text{Futures Return Over Life of Trade} \approx \text{Roll Adjustment over life of Trade} \tag{8}$$

We want to emphasize that Equation 8 only holds if the front contract price change is small compared to the roll adjustment, which would typically only happen over long time horizons. Nevertheless, it immediately suggests an actionable trading strategy, called the 'Carry' trade:

Under certain conditions, the roll adjustment contains information about the expected profit over the long term. If the sign and magnitude of the roll adjustment are not expected to change quickly over time (as was the case for the S&P example), then we can use today's roll adjustment as an estimate for the roll adjustments going forward. Thus, using Equation 8, we can write

$$\text{Futures Return Over Life of Trade} \approx \text{Todays' Roll Adjustment} \times \text{Time in Trade} \tag{9}$$

We can exploit this by going long markets for which the current roll adjustment is positive (i.e. those in backwardation) and going short markets for which the current roll adjustment is negative (i.e. those in contango).

We are *not* claiming that we are obtaining direct exposure to the roll adjustment. What we are saying is that under a very specific set of assumptions, and over a long period of time, the roll adjustment can behave on average like a 'real' P&L in a sense captured by Equation 8.

The carry trade is not riskless, however. Let's revisit Equation 9, putting back in the spot return to get[20]

$$\text{Futures Return} \approx \text{Spot Return} + \text{Today's Roll Adjustment} \times \text{Time} \tag{10}$$

As long as the cumulative roll adjustment exceeds any adverse moves in the spot price, the carry trade will be profitable. Thus we can think of the roll adjustment as a "buffer" against adverse spot price moves.

Furthermore, Equation 10 shows that the risk adjusted performance of a carry strategy will depend on the relative magnitude of the roll adjustment vs. the volatility of spot moves. Therefore, one can improve performance by reducing the impact of adverse spot price movements in a way that does not significantly degrade the portfolio-level cumulative roll adjustment.

Equation 10 and the subsequent discussion provide a framework to develop 'enhanced' carry strategies through the prediction and mitigation of adverse spot price moves. Using this framework, Campbell has developed a variety of strategies in the Enhanced Carry investment style which are deployed both in the flagship Managed Futures program as well as the PRISM portfolio, which comprises only non-trend strategies.

Conclusions

This paper was intended to serve as an introduction to the concept of roll yield. We have demonstrated that roll yield is directly related to:

1. The difference between spot and futures returns
2. The net benefit or cost of owning the underlying asset beyond moves in the spot price itself
3. The futures term structure

We have also shown that the decomposition of the futures return into spot return and roll yield provides insights into the behavior of futures prices that have implications for both carry strategies and trend following strategies. Since these types of strategies are quite pervasive in the managed futures industry, fund managers and investors should have a strong working knowledge of these concepts.

At Campbell, many of these ideas are used in the ongoing development of new Trend Following strategies. They also serve as the foundation for some of the strategies included in Campbell PRISM, a quantitative trading program which utilizes a suite of non-trend based alpha strategies to exploit structural market opportunities.

Appendix: Accounting for the Spot/Futures Basis

Extensions to Equation 3 and their Implications

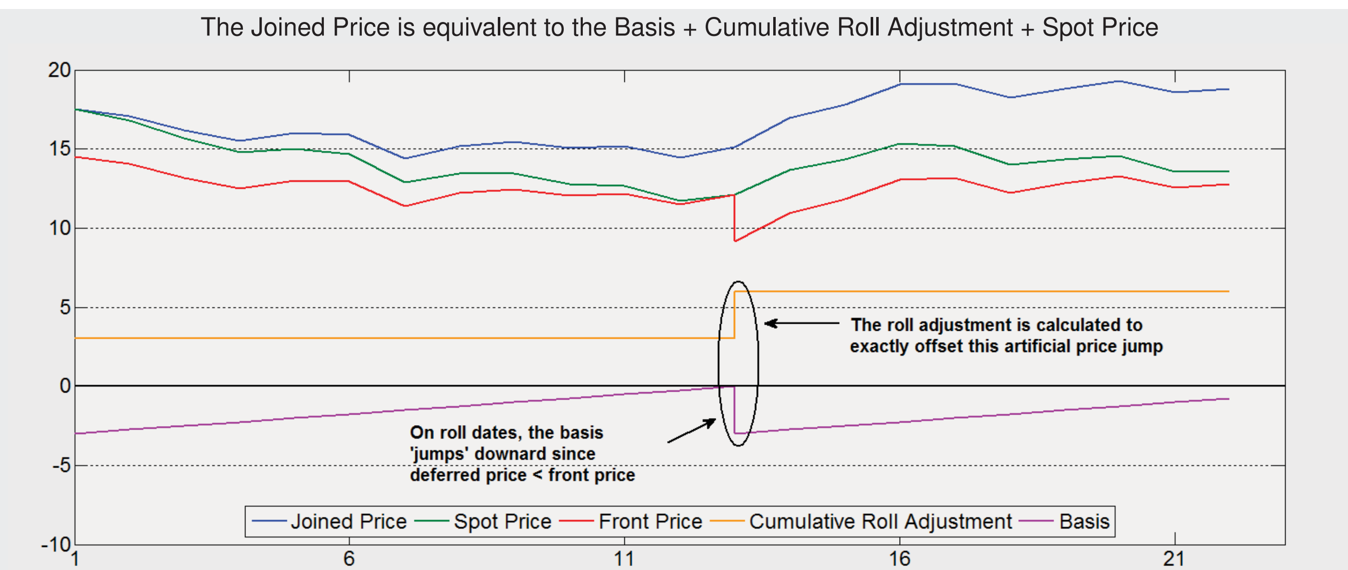
In the main text, we showed how to transform the front futures price series into a joined series. For simplicity, we tended to focus on roll dates (at expiration) when spot price ≈ futures price (e.g. Equation 4). For many purposes, this is sufficient, but sometimes a more precise decomposition is needed that is valid on non-roll dates. We will rewrite Equation 3 as

$$\text{Joined Price} = \overbrace{\text{Spot Price} + \underbrace{\text{Front Price} - \text{Spot Price}}_{\textbf{Spot/Futures Basis}}}^{\text{These cancel out}} + \text{Cumulative Roll Adjustment} \qquad (11)$$

In the above equation, we have introduced the concept of the spot/futures basis, which is simply the difference between the prevailing front futures price and the spot price. For markets in backwardation the basis is generally negative, while for markets in contango, the basis is generally positive.[21]

We introduce a fictitious futures market which is perpetually in backwardation, with the deferred contract always three points lower than the front contract, and where the spot price undergoes random movements.[22] An investor, Liam, decides to go long this market on the day the front month expires, when the spot price is 17.5 (equal to the expiring front contract price) and the new front contract (Liam's initial investable instrument) is priced at 17.5 - 3 = 14.5. Exhibit 11 shows the underlying spot price, basis, roll adjustments, and the joined close as Liam maintains his long exposure.

EXHIBIT 11: Decomposition of Joined Price - Spot, Basis and Roll Adjustment Contributions



Source: Campbell & Co.; Chart shows Spot price, Basis, Front Price, Cumulative Roll Adjustment, and Joined Price for a hypothetical market for which the deferred contract price is always 3 points less than the active (front) contract price. X-axis represents time in months. Roll dates occur every 12 months, beginning in month 1.

Note that if we sum the spot (green), basis (purple), and roll adjustment (orange) curves together, we get the joined prices (blue). The basis starts at -3 immediately after each roll, and slowly accretes to zero immediately prior to the next roll, as the front futures price converges to the spot price.[23]

Now, let's go back to Equation 11 above:

$$\text{Joined Price} = \underbrace{\text{Spot Price}}_{\text{Noisy, Unbounded}} + \underbrace{\text{Basis}}_{\text{Bounded}} + \underbrace{\text{Cumulative Roll Adjustment}}_{\text{Strong Momentum Characteristics}} \tag{12}$$

This looks very similar to Equation 4, which combined the spot and basis terms together. We can make similar observations about this decomposition as well. The spot price term is the noisy part. The basis term is bounded, as illustrated in Exhibit 11. The cumulative roll adjustment tends to have strong trend behavior (since the futures term structure tends to be similar from one roll date to the next).

Conceptually, the return due to the impact of backwardation/contango is represented by the sum of the basis and the roll adjustment. Using the same arguments as before, we can see that over the long term, the basis contribution will be negligible, so the roll adjustment can serve as a proxy for the impact of the term structure on futures returns. However, the true impact of backwardation/contango can only be captured by considering the basis as well. Furthermore, unless the spot price has a strong drift, the cumulative roll adjustment will be the dominant factor driving the futures return.

Comparing Equation 12 to the defining equation for roll yield (Equation 2), we get

$$\text{Roll Yield} = \text{Basis Return} + \text{Cumulative Roll Adjustment} \tag{13}$$

Note that this differs from Equation 6 in that we are no longer restricted to roll dates. In fact, Equation 13 holds over any time period and roll schedule.

Since the basis is bounded by the shape of the term structure, the basis return will also be bounded. Thus over long periods of time the cumulative roll adjustment will dominate, and we have

$$\text{Roll Yield} \approx \text{Cumulative Roll Adjustment} \tag{14}$$

where equality holds if the basis return is zero. This would be the case if we only look at the roll yield between roll dates (where we roll at expiration), which was the set of assumptions underlying Equation 6.

Implications for Carry Strategies

In the main text, the description of the carry strategy assumed long holding horizons in which positions spanned several roll dates. However, many asset managers (including Campbell) continuously observe market conditions and adjust positions appropriately, making the carry strategy much more dynamic in nature. Equation 12 gives the prescription for how to adapt our previous discussion to cover more frequent trading. The return on a Futures position between now and the next roll date (in which case the roll adjustment is zero), is given by

$$\text{Futures Return} = \text{Spot Return} + \text{Basis Return} \tag{15}$$

If this trade is held to expiry, when the basis becomes zero (because of futures-spot convergence), the basis return is equal to the negative of the starting basis (zero minus the starting basis), and we have

$$\text{Futures Return (Today to Expiry)} = \text{Spot Return} - \text{Today's Basis} \tag{16}$$

which is the intra-roll-date formulation of Equation 10. Under the usual carry strategy assumption that the spot return averages zero, we have

$$\text{Futures Return (Today to Expiry)} \approx -\text{Today's Basis} \tag{17}$$

So we can continuously monitor the spot/futures basis in order to more efficiently capture carry strategy returns. The points in the main text about mitigating the adverse spot risk inherent in Equation 16 still apply.

Notes

1 For additional information on VXX, please see the most recent prospectus (www.ipathetn.com/static/pdf/vix-prospectus.pdf).

2 It's not all bad; there are certainly cases when the futures investment returns exceed the spot returns.

3 We would prefer to call the difference between the futures and spot return the "roll return" and denote the roll return per unit time as the "roll yield," analogous to dollar dividend vs. dividend yield. However, roll return and roll yield are used interchangeably throughout the industry so we keep to that terminology here.

4 For further discussion, see Whaley (2009).

5 The financing cost applies in the case of an "unfunded" position (no upfront capital required from the investor). For a fully funded position, the financing cost can be viewed as the opportunity cost of the investor's capital.

6 1771.95/353.4 - 1 = 4.01

7 A futures contract requires no cash outlay, save the margin requirement, so it is an unfunded position where the underlying dollar exposure is matched to an equivalent amount of debt. Therefore, we calculate the financing costs per unit of time as the risk free rate multiplied by the current dollar value of the constant-share S&P 500 spot position.

8 These results also hold if one calculates return in a more traditional way by dividing by some denominator, but it unnecessarily complicates the discussion.

9 In fixed income markets, there is an additional component to returns called the yield curve "rolldown" (unrelated to futures roll yield) which occurs over time as the bond cash flows experience different points along the yield curve.

10 In saying that the futures price converges to the spot price at expiration, we are somewhat idealizing the situation. Each sector has its own idiosyncrasies that make this statement inexact. For example, the expiration prices of the S&P 500 e-Mini and VIX futures are calculated using a special opening quotation methodology that may give a result that does not exactly correspond to the underlying spot price.

11 For simplicity, we say that one contract corresponds to one unit of the S&P 500 index. The actual e-Mini contract gives exposure to 50 units of the underlying spot index.

12 To simplify the discussion, we assume throughout this paper that all trades are done without commissions, slippage, or other transaction costs.

13 Or, in this example, a roll gain.

14 This roll adjustment method is widely used by futures market participants, but it is not the only possible adjustment method. For example, you could force the front and joined prices to be equal at the end of the period, and then allow the divergence to happen as one goes "back in time." This methodology gives identical P&L results but is called the backward difference adjustment. For further discussion of these and other methods, see Masteika et al (2012).

15 See the appendix for a more precise decomposition into spot price, spot/futures basis, and the cumulative roll adjustment.

16 Note that the futures and spot return are defined to be the changes in the joined price and spot price, respectively.

17 We can observe the term structure instantaneously, but can only infer the roll yield/return ex-post by examining the cumulative difference between the futures and spot returns.

18 Here we suppress the "roll date to roll date" in Equation 5. This is reasonable to do when the historical period in question spans several roll dates. See the appendix for a more detailed discussion.

19 Prospects for CTAs in a Rising Rate Environment, Campbell White Paper Series, January 2013.

20 See the section “Implications for Carry Strategies” in the appendix for a more complete discussion.

21 In the main text of the paper, we define backwardation/contango based on the price of the front vs. deferred contract. It can also be defined based on the spot price vs. front contract. These two definitions generally lead to the same classification if the term structure has a consistent slope.

22 Technically, a driftless brownian walk.

23 As noted earlier, in some cases the convergence of futures price to spot at expiration is only approximate.

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