Enhancing commodity factor returns along the futures curve

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Abstract

This thesis investigates the potential of roll-yield, also known as commodity Carry, to enhance the risk-return characteristics of traditional commodity factor strategies. This thesis utilizes backtests and OLS regressions to provide empirical evidence that information on the shape of the futures curve has the ability to simultaneously increase the returns and decrease the risk of commodity factor strategies. Furthermore, these enhanced strategies generate an abnormal return that cannot be explained by the growth in the commodity market or returns to basic commodity factor strategies. Nonetheless, there is no conclusive evidence that commodity Carry is the theoretical reason behind the improved risk-return characteristics of these strategies. The results presented in this thesis suggest that commodity factor strategies should not only invest in nearest maturity contracts, but also consider other maturities along the futures curve. On top of that, the enhanced commodity factor strategies proposed in this thesis display little to no correlation with equity and bond markets and are resistant to periods of high financial stress. Therefore, these strategies could also be used in the wider context of portfolio management to optimize traditional portfolios.

1. Introduction

Factor investing and Carry investing are two of the most common trading strategies[1]. These strategies can be applied across all major asset classes, including equities, commodities, currencies, and fixed income (Asness, Moskowitz & Pedersen, 2013; Roberts, 2017). At first sight, factor investing and Carry investing appear to have little to do with one another.

The main goal of factor investing is to optimize the allocation of capital to different assets to maximize the risk-return payoff of a portfolio through the directional movements of the assets in said portfolio. In a factor portfolio, investors profit from upwards price movements in longed assets and downwards price movements in shorted assets.

The main goal of Carry investing is to optimize the allocation of capital to different assets to maximize the risk-return payoff of a portfolio through the income generated by the assets in said portfolio. In a Carry portfolio, investors profit when relevant market conditions remain stable throughout the investment period so that they can collect income on those assets (Maeso & Martellini, 2016; Roberts, 2017).

Directional movements can either favorably or adversely impact the performance of a Carry strategy. For instance, take a look at an equity dividend strategy. Here investors invest in assets with high dividends, expecting to collect those dividends. If the prices of the stocks do not move, investors simply gain the dividends. However, if the stock price rises, investors gain more than expected and if the stock price declines, investors gain less than expected or even lose.

As different asset classes have different applicable factors and different definitions of factors and Carry, this thesis limits itself to only one asset class, namely commodities. Commodities are chosen as they are less researched than the other asset classes, have a strong history in technical trading, and, most importantly, are cheap and easy to trade both in long and short positions due to being traded as futures contracts. This last point ensures that the strategies proposed in this thesis are widely realizable with minimal trading costs and restrictions.

[1] For the purpose of this thesis, Carry is considered separate from all other factors. It is instead considered a feature that can potentially enhance the risk-return tradeoff of different factors. Concretely for commodities, carry is a feature that is present along the futures curve, while factors apply to a specific maturity.

This thesis aims to blend the two types of strategies introduced above by using information on Carry to enhance returns to factor strategies. Concretely, this thesis investigates whether Carry information can be used to apply factor strategies along the commodity futures curves to increase returns and/or reduce volatility.

2. Theoretical framework

This section starts with a review of the current body of research on factor and Carry investing. Next to this, an overview of the application of these strategies on commodities is presented. Finally the research question and hypotheses that follow from this theoretical framework are outlined.

2.1. Factor investing

Value and Momentum are everywhere, including in commodities (Asness, Moskowitz & Pedersen, 2013). Value and Momentum are the two most well-known examples of the more general concept of factors. A factor is a driver or risk behind asset returns and is often applicable across asset classes. For the purpose of trading strategies, a signal has to be constructed that allows for a comparison between assets based on a factor. From here on, these signals will be called factor scores. Different trading strategies can be constructed on top of a factor, most commonly by going long/short or long-only in assets depending on their relative factor score.

In a subsequent step, so-called Smart Beta portfolios combine multiple single-factor strategies in an attempt to outperform the general market. This can give rise to highly complex portfolios such as the Parametric Portfolio Policies (PPP) where the Size, Value, and Momentum factor are exploited to optimize asset allocation and deliver market outperformance (Brandt, Santa-Clara & Valkanov, 2009). It has also been shown that a factor-based commodity portfolio outperforms widely used commodity benchmarks and its returns cannot simply be explained by the long-term upwards trend of commodity prices (Sakkas & Tessaromatis, 2020).

2.1.1. Common commodity factors

There are a number of common commodity factors, most notably Basis, Momentum, Value and Basis-Momentum. Basis represents the difference between the local spot-price of a commodity and the price of the nearest futures contract, also called the front contract (Chicago Board of Trade, 2013). As the target strategies developed in this thesis do not trade front contracts, the Basis factor is considered out of scope.

Among the remaining three factors, the literature shows that Basis-Momentum and Momentum portfolios display the highest return to risk ratios, while Value displays the lowest return to risk ratio (Sakkas & Tessaromatis, 2020). Furthermore, Basis-Momentum is the strongest single-factor predictor of commodity returns among the three (Boons & Prado, 2019; Sakkas & Tessaromatis, 2020).

The Momentum effect is defined as "the relation between an asset's return and its recent relative performance history" according to Asness et al. (Asness, Moskowitz & Pedersen, 2013).

For the purposes of this thesis, a simple risk-adjusted return metric is used as the Momentum score. The Momentum score is defined as the return of an asset over a period divided by the volatility of that asset over said period. Assume that for an asset A, the price at time T is represented by $\mathrm{P_T}$ and the volatility of returns between time T1 and T2 is represented by $\sigma_{[\mathrm{T2;T1}]}$ (where T1 > T2), then the Momentum score for asset A between time T1 and T2 is represented by:

$$\frac{\mathrm{P_{T1}} - \mathrm{P_{T2}}}{\mathrm{P_{T2}} \cdot \sigma_{[\mathrm{T2;T1}]}}, \qquad \text{where } \mathrm{T1} > \mathrm{T2}$$

Next, the Value effect is defined as "the relation between an asset's return and the ratio of its "long-run" (or book) value relative to its current market value" according to Asness et al. (Asness, Moskowitz & Pedersen, 2013). Unlike the Momentum factor, there is no standard factor score that is applicable across all asset classes. This is due to the fact that different asset classes have different definitions of long-run value.

For the purposes of this thesis, a metric based on the suggestion of Asness et al. is used as the Value score (Asness, Moskowitz & Pedersen, 2013). Assume that for an asset A, the price at time T is represented by $\mathrm{P_T}$ and the average price at time T over the past N days is represented by $\mu(\mathrm{P})_{\mathrm{T,N}}$, then the Value score for asset A at time T1 versus the long-run value at time T2 is represented by:

$$\ln\left(\frac{\mu(\mathrm{P})_{\mathrm{T2,N}}}{\mathrm{P_{T1}}}\right), \qquad \text{where } \mathrm{T1} > \mathrm{T2}$$

The Value metric proposed above will be higher, the lower the current price is relative to the long-run average. In other words, a high score corresponds to a "cheap" commodity while a low score corresponds to an "expensive" commodity. Intuitively, this metric represents the negative returns of a commodity to the long-term average price (Asness, Moskowitz & Pedersen, 2013).

Finally, Basis-Momentum is defined as "the difference in momentum between first- and second-nearby futures" (Boons & Prado, 2019). Basis-Momentum looks at the term structure of commodity futures rather than focusing on a single maturity. The factor aims to measure changes in the slope of the futures curve (Boons & Prado, 2019).

Different maturity contracts can display different volatilities (Samuelson, 1965; Daal, Farhat & Wei, 2006). Therefore, to calculate a Basis-Momentum score, volatility should not be taken into account when calculating the Momentum score of contracts with different maturities. The unadjusted Momentum score is simply defined as the return of a contract with a specific maturity over a certain period. Assume that for an asset A, the unadjusted Momentum score between time T1 and T2 based on a contract of maturity M is $\mathrm{MOM}_{[\mathrm{T2};\mathrm{T1}],\mathrm{M}}$ (where T1 > T2), then the Basis-Momentum score for asset A between time T1 and T2 and maturity M1 and M2 is represented by:

$$\mathrm{MOM}_{[\mathrm{T2};\mathrm{T1}],\mathrm{M1}} - \mathrm{MOM}_{[\mathrm{T2};\mathrm{T1}],\mathrm{M2}}, \qquad \text{where } \mathrm{T1} > \mathrm{T2} \text{ and } \mathrm{M1} < \mathrm{M2}$$

The Basis-Momentum score can also be directly expressed in terms of the returns to the different maturities. Assume that for an asset A, the price at time T for a maturity M is represented by $\mathrm{P}_{\mathrm{T},\mathrm{M}}$, then the Basis-Momentum score for asset A between time T1 and T2 and maturity M1 and M2 is represented by:

$$\frac{\mathrm{P}_{\mathrm{T1},\mathrm{M1}} - \mathrm{P}_{\mathrm{T2},\mathrm{M1}}}{\mathrm{P}_{\mathrm{T2},\mathrm{M1}}} - \frac{\mathrm{P}_{\mathrm{T1},\mathrm{M2}} - \mathrm{P}_{\mathrm{T2},\mathrm{M2}}}{\mathrm{P}_{\mathrm{T2},\mathrm{M2}}}, \qquad \text{where } \mathrm{T1} > \mathrm{T2} \text{ and } \mathrm{M1} < \mathrm{M2}$$

2.2. Carry investing

Next to risk factors, there is also the concept of (global) Carry. Simply put, Carry is the income generated by an asset if relevant market conditions do not change. Carry is present in many asset classes such as equity dividend yield, bond yield, and commodity futures roll-yield. Due to its nature, Carry returns can be heavily impacted by changes in the relevant market conditions (Maeso & Martellini, 2016; Roberts, 2017).

2.2.1. Commodity Carry

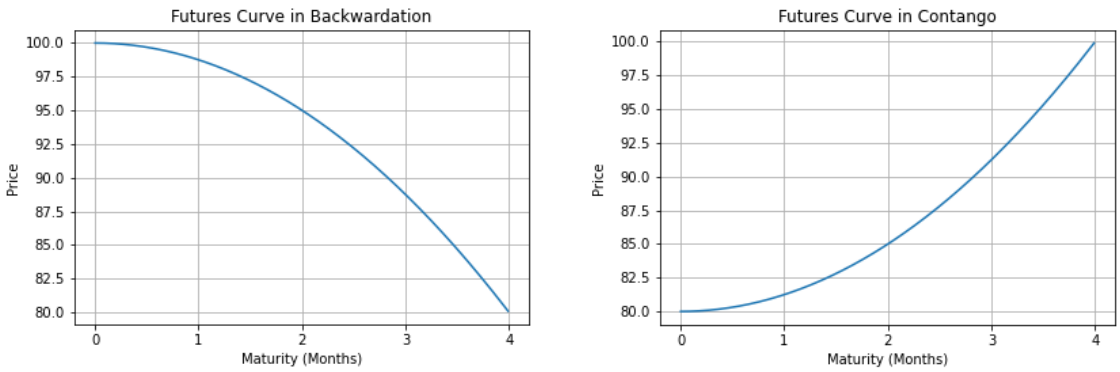
Commodity Carry, also called roll-yield, is captured by buying and selling futures contracts along the entire futures curve. Theoretically, the price of a commodity futures contract is determined by two opposing drivers. On the one hand, there is the convenience yield. This represents all the non-cash benefits of maintaining a physical inventory of the commodity, for example accommodating to increased demands and benefitting from price rises. This drives the price of later maturity contracts down. On the other hand, there is the inventory cost. This includes costs such as financing, storage, insurance and transport. This drives the price of later maturity contracts up (Roberts, 2016).

A commodity futures term structure can be in one of three states: backwardation, flatness or contango. If the convenience yield exceeds the inventory cost, the commodity will be in backwardation. This means that a contract with a later maturity will be cheaper relative to a contract with an earlier maturity. In other words, the futures curve will be downwards sloping. As a result, the a priori Carry of the later maturity contract will be positive.

Contrarily, if the inventory cost exceeds the convenience yield, the commodity will be in contango. This means that a contract with a later maturity will be more expensive relative to a contract with an earlier maturity. In other words, the futures curve will be upwards sloping. As a result, the a priori Carry of the later maturity contract will be negative.

Finally, if the convenience yield and inventory cost balance, the futures curve will be flat and no a priori Carry will be present. Examples of backwardated and contangoed futures curves can be found in Figure 1.

Figure 1: Futures curves in backwardation and contango. Positive Carry can be collected by going long on one of the contracts in a backwardated curve, assuming that the curve remains constant during the holding period. For instance, if the 2 month maturity contract is bought and the curve remains constant, its price will roll up the curve as time progresses. This happens because as time progresses, the maturity of the contract decreases and hence its price moves to the left on the curve. The opposite trade allows negative Carry to be collected in a contangoed curve.



In practice, commodities can be in different states in different places on the term structure. For instance, a commodity could be in contango in early maturities and flat in late maturities. For the purpose of this thesis, only first and second maturity contracts are explored so this complexity can be ignored. An outline of a basic commodity Carry strategy can be seen in Algorithm 1. This strategy incorporates no attempts to hedge against adverse movements of the futures curves.

Algorithm 1: Pseudo-code for a basic commodity Carry strategy. This algorithm trades on second maturity contracts. The first step outlines the configuration choices of the algorithm, while the other steps outline the implementation of the algorithm. This algorithm assumes that all gains/losses are paid out after every holding period. For a total return version of the algorithm, the exposure E should be adjusted according to the gains/losses of the previous period.

1. Select a holding period P, a universe of commodities U, a target exposure E, and the number of contracts to go long (L) and short (S) on
2. At the beginning of every period P, rank all the commodities in U according to the a priori Carry of the second maturity contracts
3. Buy an equal exposure totaling E/2 for each of the L contracts with the most positive a priori Carry and sell an equal exposure totaling E/2 for each of the S contracts with the most negative a priori Carry
4. At the end of every period P, close down all positions and go back to step 2

2.3. Combining Carry and factor investing

Carry is sometimes considered as a factor on its own. However, it is different from most other factors in the sense that it captures more of a fundamental characteristic of an asset, namely relying on the income generated by the asset to generate returns. Other factors are more looking at technical aspects of an asset, relying on price movements to generate returns (Olszweski & Zhou, 2013).

Both in foreign currency markets, hereafter referred to as FX, (Olszweski & Zhou, 2013) and commodity markets (de Groot, Karstanje & Zhou, 2014) there is evidence that combining the Momentum factor with a Carry strategy enhances risk-adjusted returns over both the Momentum-only or Carry-only strategy.

de Groot, et al. identify four reasons why the futures curve potentially contains valuable information to enhance momentum strategies: “contracts further along the curve could (i) exhibit more attractive roll yields, (ii) exhibit lower volatility, (iii) expand the opportunity set of our investable universe and (iv) lower the turnover of the portfolios” (de Groot, Karstanje & Zhou, 2014).

There is also some empirical evidence that the futures curve contains valuable information to enhance returns to commodity strategies. Regarding the first reason stated above, second and third generation commodity indices incorporate roll-yields into their trading rules and are shown to outperform first generation, long-only commodity indices that exclusively invest in the nearest contracts (Miffre, 2012). Similarly, taking roll-yield into account when rolling over futures contracts improves returns over a classical roll-over that simply buys the subsequent contracts (Mouakhar & Roberge, 2009).

Regarding the second reason stated above, there is only weak evidence that this in fact holds. A seminal paper from Samuelson proposes the maturity effect. This states that the volatility of futures prices should increase as a contract approaches its expiration (Samuelson, 1965). However, more recent empirical research shows “that the maturity effect is absent in the majority of contracts. In addition, the maturity effect tends to be stronger in agricultural and energy commodities than in financial futures” (Daal, Farhat & Wei, 2006).

As these results are general to commodities and not just to momentum strategies, one aim of this thesis is to investigate whether the futures curve can be used to enhance other factor strategies besides from Momentum. This thesis primarily focuses on exploiting the first two reasons stated above to enhance factor strategies. This gives rise to a basic outline for a single-factor Carry strategy as seen in Algorithm 2

Algorithm 2: Pseudo-code for a basic commodity single-factor Carry strategy. This algorithm trades on first and second maturity contracts. The first step outlines the configuration choices of the algorithm, while the other steps outline the implementation of the algorithm. This algorithm assumes that all gains/losses are paid out after every holding period. For a total return version of the algorithm, the exposure E should be adjusted according to the gains/losses of the previous period.

1. Select a holding period P, a universe of commodities U, a target exposure E, and the number of contracts to go long (L) and short (S) on
2. At the beginning of every period P, rank all the commodities in U according to their factor scores. The factor score is defined as the average factor score of the first and second maturity contracts
3. Buy an equal exposure totaling E/2 for each of the L contracts with the highest factor score and sell an equal exposure totaling E/2 for each of the S contracts with the lowest factor score
    a. For each of the L contracts, select the second maturity contract if its Carry is strictly positive, otherwise select the first maturity contract
    b. For each of the S contracts, select the second maturity contract if its Carry is strictly negative, otherwise select the first maturity contract
4. At the end of every period P, close down all positions and go back to step 2

2.4. Research question and hypotheses

Based on this literature review, the following research question arises: “Does information on roll-yields enhance commodity factor strategies over commodity factor strategies that exclusively invest in nearest maturity contracts?” This question will be tested through three hypotheses:

H1: Some single-factor Carry strategies have superior risk-return characteristics over their corresponding single-factor strategies

H2: Some single-factor Carry strategies have superior risk-return characteristics over the basic commodity Carry strategy

H3: Some single-factor Carry strategies generate alpha that cannot be explained by the individual factors, the general commodity market, and commodity Carry

The first hypothesis aims to test whether incorporating roll-yield information into factor strategies improves their risk-return characteristics. The second hypothesis aims to test whether incorporating roll-yield information into factor strategies outperforms only taking roll-yield into account. Finally, the third hypothesis aims to test whether incorporating roll-yield information into factor strategies actually generates any abnormal returns that are not explicable by the individual components on which the strategies are based.

The basic commodity Carry strategy is outlined in Algorithm 1, while the basic single-factor Carry strategy is outlined in Algorithm 2. The basic single-factor strategy is similar to Algorithm 2, but it omits step 3.a. and 3.b. and instead only invests in one specific maturity.

3. Data description

The raw dataset used within this thesis is retrieved from Refinitiv Eikon (Thomson Reuters Eikon, 2022A). It consists of daily closing prices and accumulated volumes from 27 different commodity futures[2]. This ensures that the commodity universe used in this thesis is a broad and diverse representation of the entire commodity market.

For each contract, data is retrieved on the 4 nearest maturities. In total, the dataset contains 169,158 rows, from here on referred to as data points, where each row contains data for one commodity across the 4 nearest maturities. The earliest data point dates from 26 Sep 1991, while the latest data point dates from 31 Dec 2021.

The dataset holds 10 columns, from here on referred to as variables, for each data point:

- the **Instrument** variable holds the ticker of each commodity on Refinitiv Eikon
- the **Date** variable holds the date of the data point
- the **C1 - Close Price** variable holds the closing price of the front contract
- the **C1 - Accumulated Volume** variable holds the daily accumulated volume of the front contract
- the **C2 – Close Price** variable holds the closing price of the second nearest maturity futures contract
- the **C2 – Accumulated Volume** variable holds the daily accumulated volume of the second nearest maturity futures contract
- the **C3 – Close Price** variable holds the closing price of the third nearest maturity futures contract
- the **C3 – Accumulated Volume** variable holds the daily accumulated volume of the third nearest maturity futures contract
- the **C4 – Close Price** variable holds the closing price of the fourth nearest maturity futures contract
- the **C4 – Accumulated Volume** variable holds the daily accumulated volume of the fourth nearest maturity futures contract

[2] These 27 commodities represent the constituents of the Refinitiv/CoreCommodity CRB Index (Refinitiv and CoreCommodity Indexes, 2021), the S&P GSCI Index (S&P Dow Jones Indices, 2022A), and the Bloomberg Commodity Index (Bloomberg, 2019) for which there was also data available on Refinitiv Eikon.

3.1. Data structure

3.1.1. Benefits

Refinitiv Eikon offers data on so-called continuous futures contracts. These are artificial time series that represent the closing prices and accumulated volume of a futures contract with a fixed maturity relative to the requested date. For instance, as of 11 May 2022, the nearest continuous contract for Sugar No. 11, denoted by SBc1, represents the closing price and accumulated volume of the JUL22 contract. 2 months later, when the JUL22 contract has expired, SBc1 will represent the OCT22 contract. Similarly, as of 11 May 2022, the second-nearest continuous contract for Sugar No. 11, denoted by SBc2, represents the OCT22 contract. 2 months later, when the nearest continuous contract has rolled over, all subsequent continuous contracts roll over. Hence, SBc2 will represent the MAR23 contract.

As a result, Refinitiv Eikon is able to deliver continuous time series on futures data. This makes any analysis easier as standard time series techniques can be used for trade signal construction rather than having to deal with the complexity of discontinuous gaps whenever a futures contract expires.

3.1.2. Drawbacks

While the data structure helps with signal construction, it adds a layer of complexity to backtesting trading strategies on futures contracts. In real life, futures do expire and have to be rolled over before the expiration date if exposure to a commodity wants to be maintained. If these rollovers are not simulated in a backtest, this would lead to incorrect results and strategies that are impossible to implement in practice. For instance, assume that on the day of a rollover there is a 3% price difference between the front contract and second nearest maturity contract and there is a long position on the front contract. The continuous contract would show an incorrect 3% gain as the data switches from the front contract to the second nearest maturity contract. If, however, a rollover of the front contract into the second nearest maturity contract is simulated, this 3% gain would be correctly ignored.

The drawback outlined above is especially important for commodity Carry strategies as the price difference between contracts of different maturities is what they try to capture. In case of commodities that remain in contango or backwardation throughout the holding period, gains would be overstated.

3.1.3. Solutions

There are a number of ways to deal with the drawbacks mentioned above. First, in an attempt to minimize trading costs, the rebalancing of a trading strategy can be timed around the expiration of the contracts. Concretely, this means that the positions of a portfolio are sold a few days before they expire and new positions are calculated and entered after the contracts have rolled over. While this is an option, it would lead to more complicated strategies as the expiration dates of different futures contracts do not all line up.

A second option is to completely exit each position a few days before it would expire and re-enter the new position after the rollover has taken place. The main advantage of this option is that it allows for clear and easy to implement rebalancing rules. The main disadvantages are the increased trading costs due to potential sales and purchases of contracts within a rebalancing period and the opportunity costs incurred by exiting positions for a number of days around their rollover. This second option is the method of choice for the strategies developed within this thesis. Concretely, a position is exited 3 (trading) days before a rollover and re-entered 3 (trading) days after a rollover. The expiration rules and delivery months of each futures contract from the dataset can be found in Appendix 1.

3.2. Data cleaning

Table 1: Overview of the different commodities in the cleaned dataset, including their classification, description in English, Refinitiv Eikon ticker, and the first year for which the data is registered in the cleaned dataset.

Classification	Description	Ticker	Start Date
Agriculture	Sugar No. 11	SB	1992
Agriculture	Sugar White	LSU	1992
Agriculture	Coffee “C”	KC	1992
Agriculture	Arabica Coffee 4/5	ICF	2000
Agriculture	Cotton No. 2	CT	1992
Agriculture	Chicago Wheat	W	1992
Agriculture	Kansas Wheat	KW	1992
Agriculture	Corn	C	1992
Agriculture	Soybeans	S	1992
Agriculture	Cocoa	CC	1992
Livestock	Live Cattle	LC	1992
Livestock	Lean Hogs	LH	1992
Livestock	Feeder Cattle	FC	1992
Base Metals	COMEX Copper	HG	1992
Base Metals	SHFE Aluminum	SAF	1996
Base Metals	SHFE Zinc	SZN	2008
Base Metals	SHFE Nickel	SNI	2016
Base Metals	SHFE Lead	SPB	2012
Precious Metals	COMEX Gold	GC	1992
Precious Metals	COMEX Silver	SI	1992
Energy	WTI Crude Oil	CL	1992
Energy	Natural Gas	NG	1992
Energy	Brent Crude Oil	LCO	1992
Energy	Low Sulphur Gasoil	LGO	1992
Energy	RBOB Gasoline	RB	2007
Energy	ULS Diesel	HO	1992
Energy	Heating Oil - Low Sulphur	LHO	2007

As Refinitiv Eikon already provides clean, high quality data, only minimal data cleaning is needed. First, all None values are deleted from the dataset. These values occur when at least one of the maturities does not contain data on Refinitiv Eikon. They are removed as they would prohibit the calculation of the Carry signal.

Second, for each commodity, only those data points are retained from the moment that the data points are consistently registered for (nearly) each trading day. This results in a cleaned dataset with 166,581 data points.

Finally, adjusted returns are calculated for each commodity. These adjusted returns incorporate the chosen rebalancing rules outlined in Section 3.1.3 and use the expiration rules listed in Appendix 1. An overview of the different commodities and the starting year of their data history is shown in Table 1.

4. Empirical framework

The research question and hypotheses are investigated through two sets of strategies and corresponding backtests. First, two benchmark strategies are created, namely the basic commodity Carry strategy from section 2.2.1 and an equal-weighted long-commodity strategy. Second, single-factor Carry strategies are created based on the Momentum, Value, and Basis-Momentum factors. For each of the three factors, a factor-only strategy is also created as a benchmark for the factor-Carry strategies.

Each of these two sets of strategies is backtested over the same 25 to 30 year period (depending on the strategy), from 1992 to 2021. The strategies are then compared on a number of criteria to assess both their returns and risk. These criteria include absolute return, volatility, maximum drawdown, and Sharpe Ratio. The 1 year US Treasury rate is used as a metric for the risk-free rate in the Sharpe Ratio calculations. This data is collected through multpl and scraped directly from the U.S. Department of Treasury (multpl, 2022). Furthermore, the single-factor strategies are regressed against the benchmark strategies to check for the potential presence of alpha in these strategies.

This quantitative analysis is complemented with a more qualitative analysis into the behavior of these strategies during notable periods of financial stress such as the dot-com bubble of the early 2000s, the financial crisis of 2008 and the Covid crisis of 2020. Next to this, a brief look at how these strategies relate to other major asset classes, such as bonds and equities, provides more context on the potential place of these strategies in the wider investment universe.

5. Empirical Results

Before going over the different benchmark and experimental strategies developed below, a number of critical assumptions need to be outlined. While the assumptions taken below do not drastically impact the empirical results, they are important to consider for a real world implementation of the strategies.

First of all, none of the strategies take trading costs into account. As a result, the returns presented in this thesis will be slightly higher than a real-world setting.

Second, the strategies assume that the size of the traded futures contracts is irrelevant. In a real-world setting, contract sizes can complicate asset allocations of a strategy as it might not always be possible to get the exact exposure that is suggested by the algorithm.

Third, all relative-value strategies developed below work on a top third versus bottom third basis. Concretely, for the factor (and carry) strategies the assets with the top third factor score (carry score) are longed and the assets with the bottom third factor score (carry score) are shorted. An equal exposure is invested into the long and short legs of the strategies.

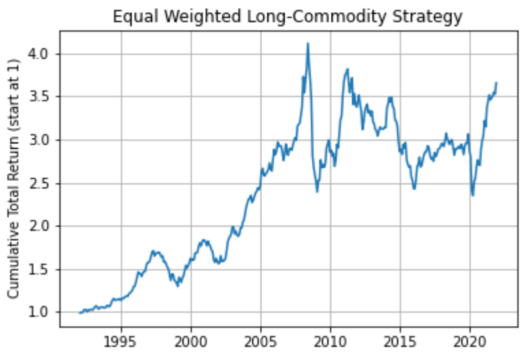
Finally, although the strategies are implemented through futures and therefore leverage is cheap, no leverage is applied in any of the strategies. Concretely, this means that if \$100 is invested in a strategy in any given period, this corresponds to a total absolute notional value across all positions of \$100. Returns are calculated based on the total portfolio market value in each period. A detailed example of the return calculations can be found in Appendix 2.

5.1. Benchmark strategies

Two benchmark strategies are constructed. First, a basic commodity Carry strategy is implemented as outlined in Algorithm 1. For this implementation, Carry is calculated as the percentage difference in price between the first and second maturity futures contracts of a commodity. The configuration of this algorithm is set so that the universe consists of the commodities listed in Table 1, the strategy is rebalanced every month on the first trading day of the month, exposure is set to 100% of the market value of the portfolio, and finally each period the commodities with the top third Carry are longed and the commodities with the bottom third Carry are shorted. For this strategy, no leverage is applied.

Second, an equal weighted long-commodity strategy is implemented. This strategy acts as a benchmark for the commodity markets. The configuration of this algorithm is set so that the universe consists of the commodities listed in Table 1, the strategy is rebalanced every month on the first trading day of the month, and finally each period an equal sized long-exposure to each commodity from the universe is selected. For this strategy, no leverage is applied. Figure 2 shows the cumulative total return of both benchmark strategies from 1992 to 2021.

Figure 2: Cumulative total return of the benchmark strategies. The total return is calculated by simulating the performance of a portfolio where any gains or losses from the previous period are re-invested into the next period.



5.2. Single factor Carry strategies

Three distinct single-factor Carry strategies are constructed by individually combining Momentum, Value, and Basis-Momentum with Carry.

Each strategy is constructed by implementing Algorithm 2. The configuration of this algorithm is set so that the universe consists of the commodities listed in Table 1, the strategy is rebalanced every month on the first trading day of the month, exposure is set to 100% of the market value of the portfolio, and finally each period the commodities with the top third Factor score are longed and the commodities with the bottom third Factor score are shorted. For this strategy, no leverage is applied.

Since these strategies are implemented through futures contracts, it is important to consider the cash that is not used for margin requirements in the return calculations. According to the CME Group, margin requirements on futures typically make up only 3-12% of the notional value of a contract (CME Group, 2022). For the backtests, returns are calculated based on the market value of the portfolio. This consists of three components: uninvested cash, cash put up as margin, and the profit & losses, or P&L, on the open futures positions. Uninvested cash is put in a cash account that yields the risk-free rate. Remaining conservative in the backtest, 70% of the total cash in the portfolio is assumed to be invested in a cash account, leaving 30% available to put up as margin. The 1 year US Treasury rate is used as the risk-free rate for these calculations.

5.2.1. Momentum-Carry

The first implementation of Algorithm 2 is the Momentum-Carry strategy. For this implementation, Carry is calculated as the percentage difference in price between the first and second maturity futures contracts of a commodity. The Momentum score is calculated as outlined in Section 2.1.1 with a lookback period of 1 month and a lag of 1 trading day to the day in which the strategy invests.

Figure 3 shows the cumulative total return of the Momentum-Carry strategy from 1992 to 2021. It also shows the cumulative total return of the Momentum strategy as a comparison, where the Momentum strategy is defined to be exactly the same as Momentum-Carry strategy, with the exception that Carry is not taken into account. The Momentum strategy is shown both for first maturity (C1) and second maturity (C2) contracts. In addition, Table 2 shows a comparison of the risk-return tradeoff of the Momentum-Carry strategy to its benchmarks.

Figure 3: Cumulative total return of the Momentum (top) versus Momentum-Carry (bottom) strategies. The total return is calculated by simulating the performance of a portfolio where any gains or losses from the previous period are re-invested into the next period. From these charts, the Momentum-Carry appears as a less volatile version of the Momentum strategy.

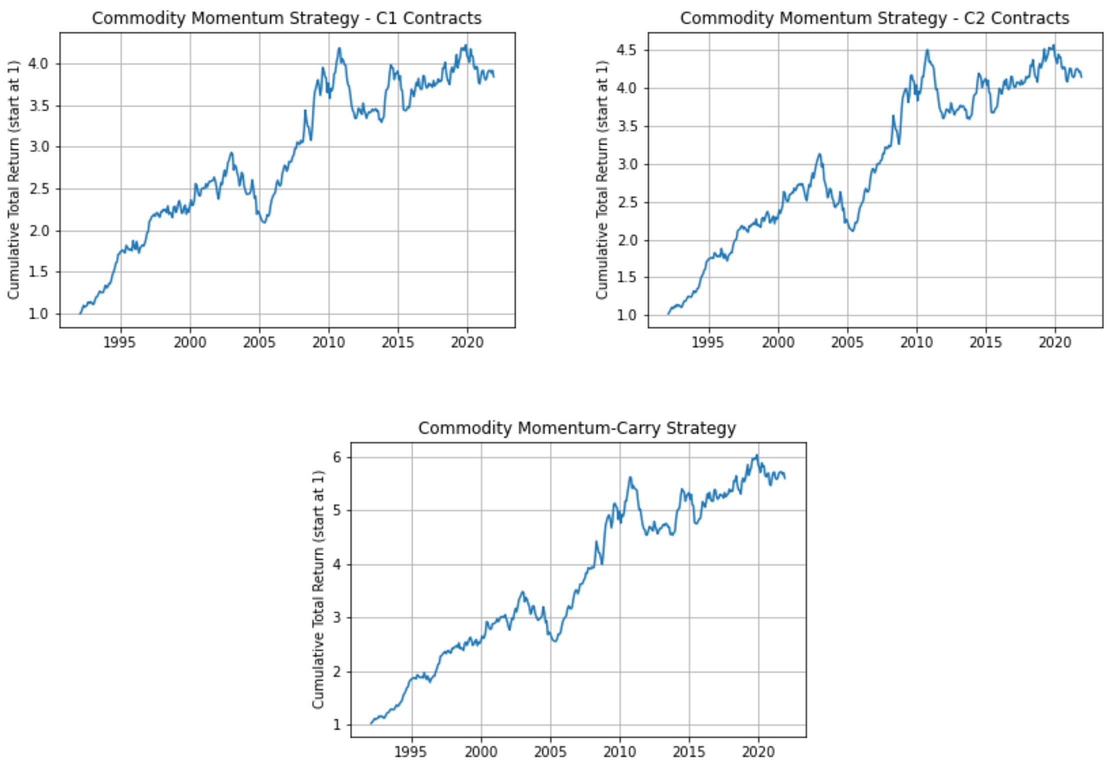


Table 2: Risk-return comparison of the Momentum-Carry strategy to its respective benchmarks. All figures in the table are calculated for the period 1992 to 2021. The Momentum-Carry strategy outperforms all four of the benchmarks on returns and lies in the middle regarding volatility. Furthermore, it outperforms all four benchmarks on Sharpe Ratio and only the Carry strategy has a smaller maximum drawdown.

	Equal Weighted	Carry	Momentum C1	Momentum C2	Momentum-Carry
Mean Monthly Return	0.41%	0.34%	0.41%	0.43%	0.51%
Geometric Mean Monthly Return	0.36%	0.32%	0.38%	0.40%	0.48%
Monthly Volatility	3.14%	2.08%	2.48%	2.38%	2.38%
Monthly Sharpe Ratio	0.06	0.06	0.08	0.09	0.13
Annualized Sharpe Ratio	0.22	0.22	0.27	0.31	0.44
Maximum Drawdown	42.90%	15.27%	28.68%	32.63%	26.63%

5.2.2. Basis-Momentum-Carry

The second implementation of Algorithm 2 is the Basis-Momentum-Carry strategy. Since the Basis-Momentum score already incorporates information on both first and second maturity contracts, the score can be used directly in Algorithm 2 rather than taking the average score of both contracts. For this implementation, Carry is calculated as the percentage difference in price between the first and second maturity futures contracts of a commodity. The Basis-Momentum score is calculated as outlined in Section 2.1.1 with a lookback period of 12 months and a lag of 1 trading day to the day in which the strategy invests. This lookback period is in line with the strategy used by Boons & Prado (Boons & Prado, 2019). Due to this lookback period, the backtesting period can only start in 1993 for this strategy

Figure 4 shows the cumulative total return of the Basis-Momentum-Carry strategy from 1993 to 2021. It also shows the cumulative total return of the Basis-Momentum strategy as a comparison, where the Basis-Momentum strategy is defined to be exactly the same as Basis-Momentum-Carry strategy, with the exception that Carry is not taken into account. The Basis-Momentum strategy is shown both for first maturity (C1) and second maturity (C2) contracts. In addition, Table 3 shows a comparison of the risk-return tradeoff of the Basis-Momentum-Carry strategy to its benchmarks.

Figure 4: **Cumulative total return of the Basis-Momentum (top) versus Basis-Momentum-Carry (bottom) strategies. The total return is calculated by simulating the performance of a portfolio where any gains or losses from the previous period are re-invested into the next period. From these charts, the Basis-Momentum-Carry appears as a less volatile version of the Basis-Momentum strategy.**

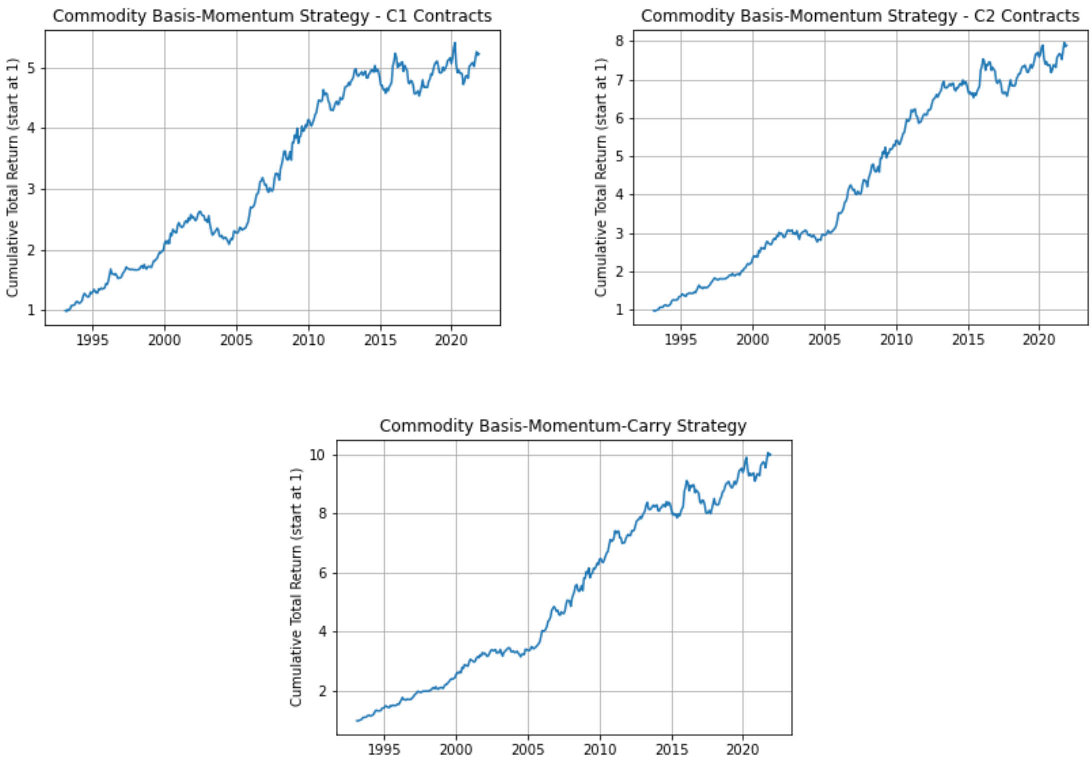


Table 3: **Risk-return comparison of the Basis-Momentum-Carry strategy to its respective benchmarks. All figures in the table are calculated for the period 1993 to 2021. The Momentum-Carry strategy outperforms all four of the benchmarks on returns and only fails to outperform the Basis-Momentum C2 strategy on volatility. Furthermore, it outperforms all four benchmarks on Sharpe Ratio and has the smallest maximum drawdown.**

	Equal Weighted	**Carry**	**Basis-Momentum C1**	**Basis-Momentum C2**	**Basis-Momentum-Carry**
Mean Monthly Return	0.42%	0.34%	0.50%	0.62%	0.69%
Geometric Mean Monthly Return	0.37%	0.32%	0.48%	0.60%	0.67%
Monthly Volatility	3.19%	2.10%	2.22%	2.00%	2.05%
Monthly Sharpe Ratio	0.07	0.06	0.13	0.21	0.24
Annualized Sharpe Ratio	0.23	0.22	0.46	0.72	0.82
Maximum Drawdown	42.90%	15.27%	20.61%	12.79%	12.24%

5.2.3. Value-Carry

The third, and final, implementation of Algorithm 2 is the Value-Carry strategy. For this implementation, Carry is calculated as the percentage difference in price between the first and second maturity futures contracts of a commodity. The Value score is calculated as outlined in Section 2.1.1 where the long term average price is the average price between 4.5 and 5.5 years ago and the recent price is 1 trading day before the day in which the strategy invests. This configuration is in line with the strategy used by Asness et al. (Asness, Moskowitz & Pedersen, 2013). Due to this long term average price, the backtesting period can only start in 1997 for this strategy.

Figure 5 shows the cumulative total return of the Value-Carry strategy from 1997 to 2021. It also shows the cumulative total return of the Value strategy as a comparison, where the Value strategy is defined to be exactly the same as Value-Carry strategy, with the exception that Carry is not taken into account. The Value strategy is shown both for first maturity (C1) and second maturity (C2) contracts. In addition, Table 4 shows a comparison of the risk-return tradeoff of the Value-Carry strategy to its benchmarks.

Figure 5: **Cumulative total return of the Value (top) versus Value-Carry (bottom) strategies. The total return is calculated by simulating the performance of a portfolio where any gains or losses from the previous period are re-invested into the next period. From these charts, the Value-Carry appears as a less volatile version of the Value strategy.**

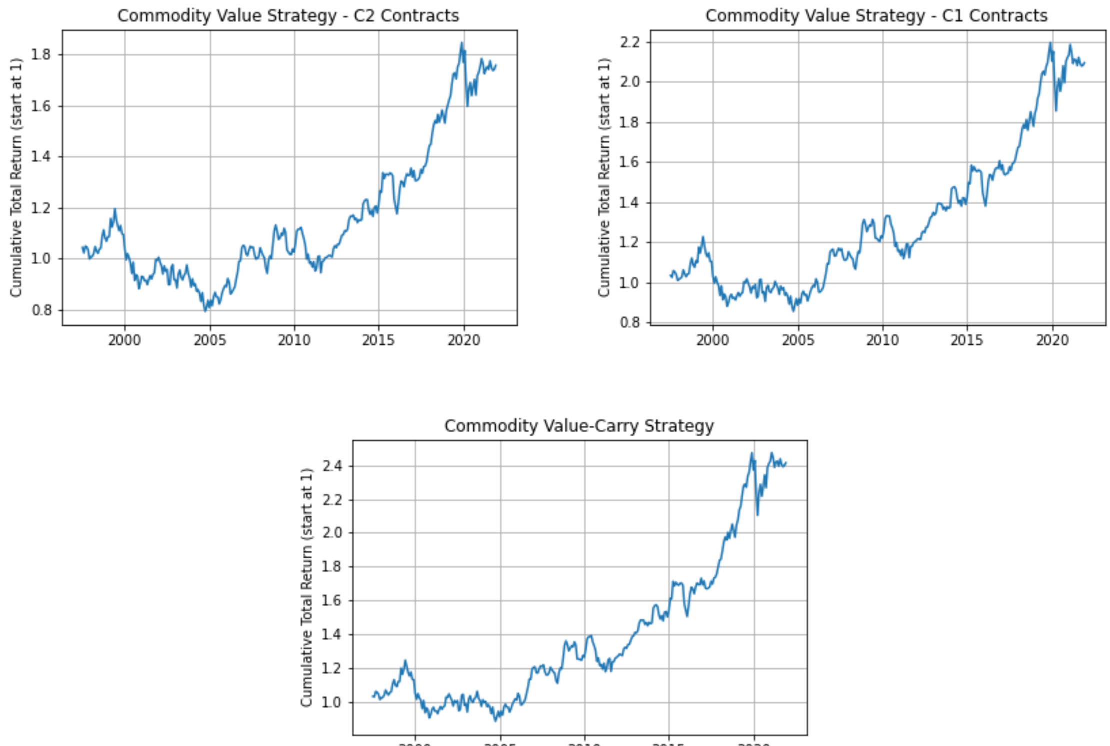


Table 4: **Risk-return comparison of the Value-Carry strategy to its respective benchmarks. All figures in the table are calculated for the period 1997 to 2021. The Value-Carry strategy outperforms the Equal Weighted and Value – C1 benchmarks on returns and volatility but fails to outperform the Value – C2 benchmark on volatility and the Carry benchmark overall. In line with this, it only outperforms the Equal Weighted and Value benchmarks on Sharpe Ratio and maximum drawdown.**

	Equal Weighted	Carry	Value – C1	Value – C2	Value-Carry
Mean Monthly Return	0.33%	0.34%	0.29%	0.23%	0.34%
Geometric Mean Monthly Return	0.27%	0.32%	0.25%	0.19%	0.30%
Monthly Volatility	3.37%	2.13%	2.84%	2.64%	2.77%
Monthly Sharpe Ratio	0.05	0.08	0.04	0.02	0.06
Annualized Sharpe Ratio	0.16	0.29	0.15	0.07	0.21
Maximum Drawdown	42.90%	15.27%	30.44%	33.57%	28.88%

5.3. Strategy analysis

Appendix 3 contains a side by side comparison of the three single-factor Carry strategies with all of their benchmarks and each other. In line with prior academic research (Boons & Prado, 2019; Sakkas & Tessaromatis, 2020), the Basis-Momentum strategy has the strongest risk-return metrics, followed by the Momentum strategy, while the Value strategy displays the weakest risk-return metrics. Overall, the Basis-Momentum-Carry strategy outperforms all other strategies and benchmarks on each of the risk-return metrics.

In addition, the single-factor Carry strategies presented above provide proof that hypothesis 1 and 2 from Section 2.4 hold true. For reference, hypothesis 1 and 2 are presented again below.

H1: Some single-factor Carry strategies have superior risk-return characteristics over their corresponding single-factor strategies

H2: Some single-factor Carry strategies have superior risk-return characteristics over the basic commodity Carry strategy

Regarding hypothesis 1, each of the three single-factor Carry strategies outperforms their corresponding single-factor strategy on Sharpe Ratio. Furthermore, incorporating Carry information increases absolute returns and lowers maximum drawdowns for all three strategies. Volatility is also lower for the Momentum-Carry and Value-Carry strategies than for their single-factor counterparts. For the Basis-Momentum-Carry strategy, the corresponding single-factor strategy applied to second maturity contracts (C2) has a slightly lower volatility.

This observations above suggest that incorporating Carry information along the futures curve potentially is a general improvement that can be applied to other factors and commodity strategies as well.

Regarding hypothesis 2, both Momentum-Carry and Basis-Momentum-Carry manage to outperform the basic Carry strategy on Sharpe Ratio. Only Basis-Momentum-Carry manages to also outperform the basic Carry strategy on volatility and maximum drawdown, whereas Value-Carry fails to outperform the basic Carry strategy on any of the risk-return metrics.

Unlike hypotheses 1 and 2, the risk-return comparison of the different strategies is not sufficient to draw conclusions on hypothesis 3. Instead an additional regression analysis is required. For reference, hypothesis 3 is presented again below.

H3: Some single-factor Carry strategies generate alpha that cannot be explained by the individual factors, the general commodity market, and commodity Carry

5.3.1. Testing for alpha

Abnormal returns, or alpha, are the returns of an investment strategy that cannot be explained by correlation to common risk-factors. For equities, a common model used to test for alpha is the so-called three-factor model from Fama & French. This model is based on the CAPM (Capital Asset Pricing Model) and adds two additional risk factors, namely Market Capitalization and Value (Fama & French, 1993).

There are other models as well, such as the five-factor model from Fama & French, but the main idea behind each model is that the returns of an asset or strategy can be decomposed into individual components. The main components are the risk-free return, the excess return[3] of the market, and the excess returns of a number of factor strategies.

In line with this idea, the benchmark and single-factor strategies constructed above are used to create a model to test for abnormal returns of the single-factor Carry strategies. Concretely, this model looks as follows:

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[3] Excess returns are the returns of an asset or strategy after deducting the risk-free rate or return

$$\mathrm{R} - \mathrm{RF} = \alpha + \beta_1 \cdot \mathrm{EW} + \beta_2 \cdot \mathrm{CAR} + \beta_3 \cdot \mathrm{MOM} + \beta_4 \cdot \mathrm{BMOM} + \beta_5 \cdot \mathrm{VAL}$$

In this model, $\mathrm{R} - \mathrm{RF}$ are the excess returns of the tested strategy, EW are the excess returns to the equal weighted long-commodity strategy, CAR are the excess returns to the basic Carry strategy, MOM are the excess returns to the Momentum strategy, BMOM are the excess returns to the Basis-Momentum strategy, and VAL are the excess returns to the Value strategy. The different betas within this model represent the exposure of the tested strategy to the different benchmark strategies, while the alpha of this model represents the abnormal returns of the tested strategy.

This model is implemented by running a series of OLS models for the different single-factor Carry strategies. Similar to the analysis from Section 5.2, the single-factor strategies can be constructed either with first maturity (C1) or second maturity (C2) contracts. Since these strategies are highly correlated, they cannot be used in a linear regression together. Therefore, two series of OLS models will be calculated: one where the single-factor strategies only use first maturity contracts and one where the single-factor strategies only use second maturity contracts.

If one or more of the single-factor Carry strategies display a positive, statistically significant alpha in both series of regressions, this provides proof that hypothesis 3 holds true. The output of these OLS regressions can be seen in Table 5 and Table 6.

As can be seen in Table 5, all three strategies display a positive alpha that is also significant at a 1% confidence level. According to this model, 0.1% of the monthly returns of the Momentum-Carry and Value-Carry strategy and 0.2% of the monthly returns of the Basis-Momentum-Carry are not explained by the commodity market or any of the individual factors. On an annualized basis, this corresponds to a little over 1% for Momentum-Carry and Value-Carry and a little over 2% for Basis-Momentum-Carry.

Table 5: **Abnormal return OLS regression output for each of the three single-factor Carry strategies on C1 benchmarks. The single-factor strategies are constructed using first maturity (C1) contracts. All regressions are performed on monthly returns. An intercept/beta of 0.01 corresponds to 1%. All three strategies have a positive, statistically significant alpha (represented by Intercept). All three strategies are closely linked to their respective single-factor strategies, but Basis-Momentum is the only single-factor strategy that has a statistically significant effect on the other two strategies as well.**

	Momentum-Carry	**Basis-Momentum-Carry**	**Value-Carry**
Intercept	0.001***	0.002***	0.001***
	(0.000)	(0.000)	(0.000)
Equal Weighted	0.004	0.007	-0.002
	(0.007)	(0.011)	(0.005)
Carry	0.012	0.071***	0.009
	(0.013)	(0.020)	(0.010)
Momentum – C1	0.958***	-0.016	-0.008
	(0.010)	(0.015)	(0.008)
Basis-Momentum – C1	-0.051***	0.857***	-0.022**
	(0.012)	(0.019)	(0.010)
Value – C1	0.000	0.016	0.967***
	(0.009)	(0.014)	(0.007)
Observations	294	294	294
R^2	0.974	0.903	0.987
Adjusted R^2	0.973	0.902	0.987
Residual Std. Error	0.004 (df=288)	0.006 (df=288)	0.003 (df=288)
F Statistic	2133.948*** (df=5; 288)	538.999*** (df=5; 288)	4514.664*** (df=5; 288)
Note:			**p<0.1; **p<0.05; ***p<0.01*

As can be seen in Table 6, all three strategies display a positive alpha as well when the second maturity contracts are used in the benchmark strategies. The alpha of the Basis-Momentum-Carry and Value strategies is again significant at a 1% confidence level, while the alpha of the Momentum-Carry strategy is only significant at a 5% confidence level. According to this model, 0.1% of the monthly returns of all strategies are not explained by the commodity market or any of the individual factors. On an annualized basis, this corresponds to a little over 1%.

Table 6: Abnormal return OLS regression output for each of the three single-factor Carry strategies on C2 benchmarks. The single-factor strategies are constructed using second maturity (C2) contracts. All regressions are performed on monthly returns. An intercept/beta of 0.01 corresponds to 1%. All three strategies have a positive, statistically significant alpha (represented by Intercept). All three strategies are closely linked to their respective single-factor strategies.

	Momentum-Carry	**Basis-Momentum-Carry**	**Value-Carry**
Intercept	0.001**	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Equal Weighted	0.006	0.001	0.011
	(0.008)	(0.005)	(0.008)
Carry	0.013	-0.013	-0.013
	(0.016)	(0.009)	(0.015)
Momentum – C2	0.967***	-0.009	-0.010
	(0.012)	(0.007)	(0.012)
Basis-Momentum – C2	0.010	1.004***	-0.033**
	(0.016)	(0.009)	(0.016)
Value – C2	-0.012	-0.021***	1.021***
	(0.011)	(0.006)	(0.011)
Observations	294	294	294
R^2	0.962	0.983	0.973
Adjusted R^2	0.961	0.982	0.973
Residual Std. Error	0.005 (df=288)	0.003 (df=288)	0.005 (df=288)
F Statistic	1441.003*** (df=5; 288)	3253.532*** (df=5; 288)	2109.989*** (df=5; 288)
Note:			**p<0.1; **p<0.05; ***p<0.01*

The fact that all three single-factor Carry strategies display a positive alpha that is significant at a 5% confidence level in both series of models provides proof that hypothesis 3 holds true.

5.4. Theoretical explanations behind the results

The largest shortcoming of this empirical analysis is that although all three single-factor Carry strategies have attractive risk-return characteristics and display statistically significant alpha, the intuition behind them is not entirely clear. Two potential explanations are presented below.

The idea behind the single-factor Carry strategies is to enhance single-factor returns by investing in maturities where the Carry is aligned with the factor signal. Concretely, on long positions, second maturity contracts are selected if their Carry is positive (downwards sloping curve) and on short positions, second maturity contracts are selected if their Carry is negative (upwards sloping curve). Otherwise, first maturity contracts are selected. However, the first maturity contract also has a Carry itself, namely the difference between its price and the local spot price. This is more commonly referred to as Basis (Chicago Board of Trade, 2013).

A first explanation makes the assumption that the Carry on second maturity contracts is always greater than the basis on first maturity contracts. In other words, it assumes that upwards sloping curves are concave up (convex) for near-term maturities and downwards sloping curves are concave down (concave) for near-term maturities. This is the situation shown in Figure 1. This explanation would contribute the improvements seen in the single-factor Carry strategies to the incorporation of Carry.

An alternative explanation makes the assumption that the improvements are not due to Carry, but rather due to changes in the shape of the futures curve. The positions taken by the single-factor Carry strategies would benefit from a flattening or reversal of the futures curve. To see why, consider the following example: a short position displays an upwards sloping curve. This would mean that the second maturity contract is selected. If the curve now starts to flatten, but the spot price remains the same, the second maturity contract would benefit more than the first maturity contract. This is because intuitively (and visually) the futures curve will act as a lever or seesaw if it flattens, but the spot price remains the same. Just like in a lever, points (maturities) further from the pivotal point (spot) will move more than points (maturities) closer to the pivotal point (spot).

This explanation would contribute the improvements seen in the single-factor Carry strategies to this “lever effect” described above. In this case, Carry would only be indirectly relevant as it is not the reason behind the improvements but just a way to see if the curve is upwards or downwards sloping. It would instead imply that there is a link between the directional movements of commodity prices suggested by factors and changes in the directions of the futures curves.

6. Beyond the empirical analysis

Although the empirical analysis has already provided proof that all three hypotheses hold true, it has not yet given many insights into the behavior of the single-factor strategies in relation to the broader markets. Therefore, two additional aspects of these strategies are investigated. First, these strategies are compared against two of the major financial asset classes, namely equities and bonds. Second, the behavior of these strategies during periods of high financial stress is investigated. Concretely, the dot-com bubble of the early 2000s, the financial crisis of 2008 and the Covid crisis of 2020 are considered.

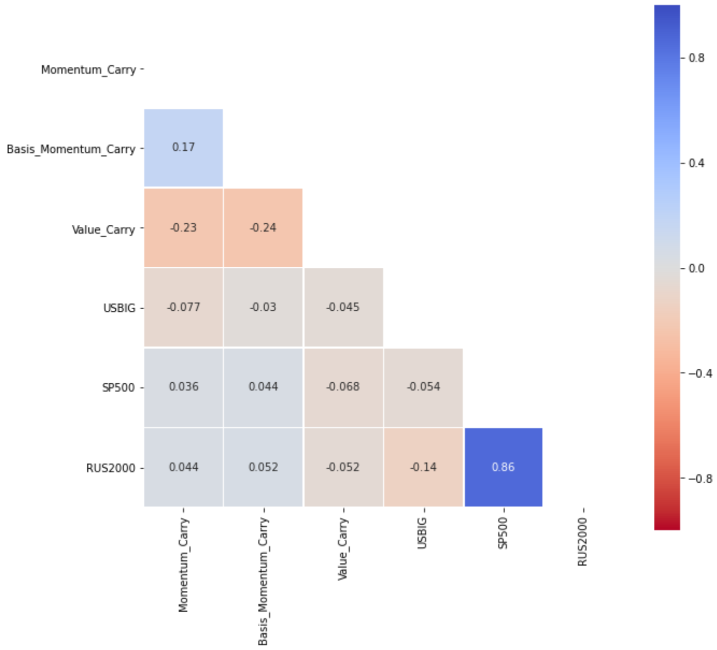
6.1. Relation to equities and bonds

Traditionally, a 60/40 portfolio is used as a baseline for a diversified portfolio for many investors. This portfolio consists of 60% equities and 40% bonds. One of the key reasons why this portfolio is so widespread is that there are almost no periods in history where both equities and bonds go down. In fact, between 1929 and 2022 there are only 4 years (including 2022 year-to-date) where both asset classes recorded negative returns (BlackRock, 2022). At the same time, large institutional investors, such as BlackRock and J.P. Morgan, both argue for the inclusion of alternative assets and/or strategies in such portfolios to further enhance the diversification (J.P. Morgan, 2021; BlackRock, 2022).

To see how the three single-factor Carry strategies relate to a traditional 60/40 portfolio, they are compared against three broad equity and bond indices. The first index is the S&P 500® Index (SP500), which is a market capitalization weighted index of the 500 largest companies listed on US stock exchanges (S&P Dow Jones Indices, 2022B). Next is the Russell 2000® Index (RUS2000), which is a market capitalization weighted index of the smallest companies listed on US stock exchanges (FTSE Russell, 2022B). Third and last is the FTSE US Broad Investment-Grade Bond Index (USBIG®), which "measures the performance of US Dollar-denominated bonds issued in the US investment-grade bond market. (…) the index covers US Treasury, government sponsored, collateralized, and corporate debt" (FTSE Russell, 2022A). Total return data for each of the three indices is retrieved from Refinitiv Eikon (Thomson Reuters Eikon, 2022B).

Figure 6 shows the correlations between the returns of the single-factor Carry strategies from this thesis and the bond and equity indices described above for the period 1997 to 2021. As can be seen, there is little to no correlation between the strategies developed within this thesis and the equity or bond indices. This suggests that these strategies can potentially enhance more traditional portfolios by adding a new source of uncorrelated returns.

Figure 6: **Correlation matrix of the three single-factor Carry strategies to the equity and bond markets. There is little to no correlation observable between the single-factor Carry strategies and the equity or bond indices. This suggests that these strategies could act as a good diversifier for a 60/40 portfolio.**



As can be seen in Table 7, the Basis-Momentum-Carry strategy is the best candidate to act as a diversifier within a traditional 60/40 portfolio. Overall, its risk-return metrics lie in between the equity and bond indices and notably it boasts a Sharpe ratio that is higher than both the S&P 500® and Russell 2000®. Given the low volatility and maximum drawdown of the Basis-Momentum-Carry strategy, the strategy also has potential to incorporate leverage to offer higher (average) returns while maintaining a relatively low volatility.

Table 7: **Risk-return comparison of the single-factor Carry strategies to the market benchmarks. All figures in the table are calculated for the period 1997 to 2021. The Basis-Momentum-Carry strategy seems to be the best candidate to diversify a 60/40 portfolio given that its risk-return metrics lie in between those of the equity and bond indices, while the Momentum-Carry and Value-Carry strategies underperform both the equity and bond indices on most risk-return metrics.**

	S&P 500®	**Russell 2000®**	**USBIG®**	**Momentum-Carry**	**Basis-Momentum-Carry**	**Value-Carry**
Mean Monthly Return	0.85%	0.91%	0.42%	0.32%	0.57%	0.34%
Geometric Mean Monthly Return	0.73%	0.70%	0.41%	0.29%	0.55%	0.30%
Monthly Volatility	4.79%	6.44%	0.99%	2.36%	1.97%	2.77%
Monthly Sharpe Ratio	0.14	0.12	0.25	0.06	0.21	0.06
Annualized Sharpe Ratio	0.49	0.40	0.86	0.22	0.72	0.21
Maximum Drawdown	53.11%	55.79%	4.15%	26.63%	12.24%	28.88%

6.2. Behavior during periods of financial stress

The analysis above suggests that there is little to no correlation between the single-factor Carry strategies and the bond or equity markets. In line with that observation, these strategies also do not seem to be influenced by episodes of high financial stress, unlike equity markets. As can be seen on Figure 7, Figure 8, and Figure 9 none of the three single-factor Carry strategies experience large drawdowns during the dot-com bubble, the 2008 financial crisis, or the Covid-19 crisis. Next to that, the three strategies book positive returns during each of those three periods, on average.

In line with the results from Section 5, the Basis-Momentum-Carry strategy shows the strongest returns during these periods, outperforming the other two single-factor Carry strategies. During the dot-com bubble, the strategy is almost tied with the bond index and widely outperforms the equity indices. During the financial crisis of 2008, the strategy widely outperforms both the bond and equity indices. Only during the Covid-19 crisis, the strategy fails to outperform the bond and equity indices.

The robust behavior of the single-factor Carry strategies during these three periods of high financial stress, and the strong results of the Basis-Momentum-Carry strategy during these periods, further suggest that these strategies can potentially enhance more traditional portfolios by adding a new source of returns that are less likely to be impacted by financial crises.

Figure 7: **Returns to the single-factor Carry strategies during the dot-com bubble versus the broader market. None of the single-factor Carry strategies are visibly influenced by the financial crisis. Nonetheless, all strategies get outperformed by the bond index and only the Momentum-Carry and Basis-Momentum-Carry strategy outperform the equity indices while the Value-Carry strategy even has negative returns during this period.**

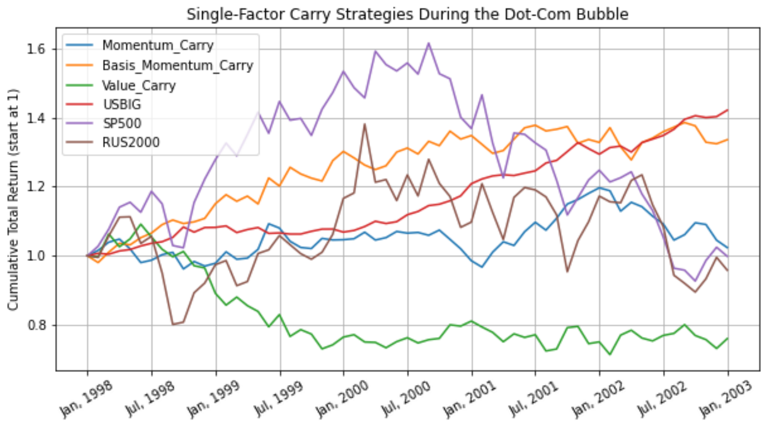


Figure 8: **Returns to the single-factor Carry strategies during the 2008 global financial crisis versus the broader market. None of the single-factor Carry strategies are visibly influenced by the financial crisis. This leads them to outperform the equity indices during this period. On top of that, both the Momentum-Carry and Basis-Momentum-Carry strategies continue to post strong positive results during this period, even outperforming bonds, while the Value-Carry strategy remains neutral over this period.**

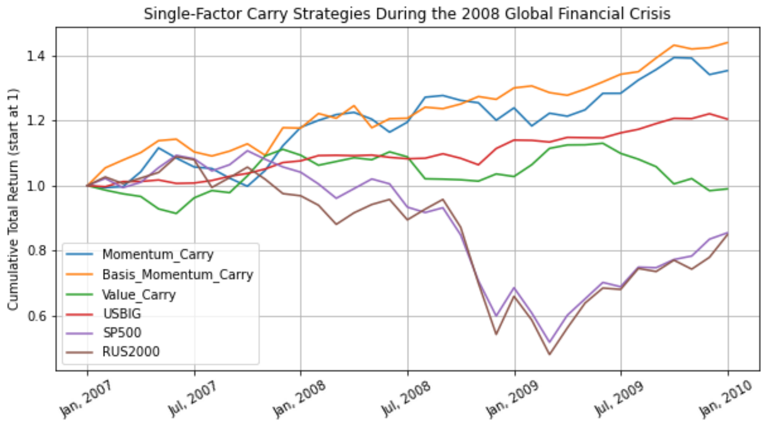
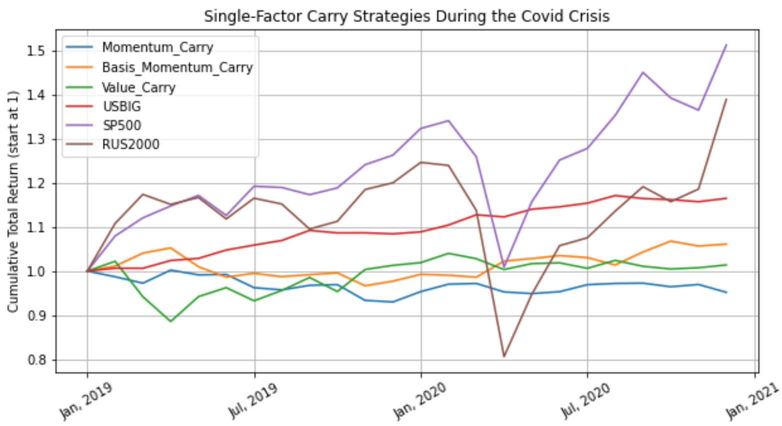


Figure 9: **Returns to the single-factor Carry strategies during the Covid-19 crisis versus the broader market. None of the single-factor Carry strategies are visibly influenced by the financial crisis. While these strategies do not see a large drawdown during this period, they still underperformed the equity indices as the equity markets had a fast, V-shaped recovery during this period. Furthermore, all of the single-factor Carry strategies also underperformed the bond index during this period.**



7. Conclusion

This thesis set out to investigate the following question: "Does information on roll-yields enhance commodity factor strategies over commodity factor strategies that exclusively invest in nearest maturity contracts?" This question was tested through three hypotheses:

H1: Some single-factor Carry strategies have superior risk-return characteristics over their corresponding single-factor strategies

H2: Some single-factor Carry strategies have superior risk-return characteristics over the basic commodity Carry strategy

H3: Some single-factor Carry strategies generate alpha that cannot be explained by the individual factors, the general commodity market, and commodity Carry

As outlined in Section 5, there is empirical evidence that all three of the hypotheses hold true. For hypothesis 1, all three single-factor Carry strategies have superior risk-return characteristics over their single-factor counterparts. For hypothesis 2, the Momentum-Carry and Basis-Momentum-Carry strategies have superior risk-return characteristics over the basic commodity Carry strategy. Finally, for hypothesis 3, all three single-factor Carry strategies have a positive alpha that is significant at a 5% confidence level when their excess returns are regressed against the excess returns of all the benchmarks.

As a result of the above, it can be concluded that the research question also holds true: this thesis presents empirical evidence that information on roll-yields enhances commodity factor strategies over commodity factor strategies that exclusively invest in nearest maturity contracts. This thesis also provides a blueprint algorithm that details how to achieve these enhancements.

Beyond the main research question of this thesis, there is also empirical evidence that the single-factor Carry strategies have the potential to enhance traditional (60/40) portfolios by adding a new source of uncorrelated returns. First, the single-factor Carry strategies show little to no correlation with equity and bond markets. Second, the single-factor Carry strategies are relatively unaffected by periods of high financial stress, unlike equity markets. Third, the Basis-Momentum-Carry strategy stands out as the best candidate out of the three single-factor Carry strategies with a Sharpe ratio higher than the S&P 500® and Russell 2000®. Lastly, given the low volatility and maximum drawdowns of the single-factor Carry strategies, leverage can be utilized as a cheap tool to offer higher returns to investors with a greater risk-appetite.

7.1. Limitations of the research

Although this thesis is able to provide empirical evidence for the research question, it fails to provide a clear, theoretical explanation behind the results. Therefore, the name "single-factor Carry" is somewhat of a misnomer for the strategies from this thesis as it is, as of yet, unproven that Carry is the cause behind the enhanced risk-return characteristics seen in these strategies.

Section 5.4 offers two potential explanations behind the results. First, the enhanced returns can be due to selecting the contracts with the highest Carry. This idea relies on the convexity/concavity of the futures curve in early maturities. Second, the enhanced returns can be due to a "lever" effect where later maturities are more sensitive to changes in the shape of futures curves than early maturities. This idea would imply that there is a link between the directional movements of a commodity suggested by the factors and changes in the direction, or shape, of the futures curve of that commodity. Further research is necessary to validate whether either of these explanations applies.

Next to this theoretical limitation, there is also an empirical limitation namely that this research only investigates one specific configuration of the single-factor Carry algorithm: trades take place on the first trading day of the month, 1/3 of the universe gets longed, 1/3 of the universe gets shorted, no leverage is applied, & the holding period is 1 month. Although the results are robust for this specific configuration, a Monte Carlo simulation that explores many different configurations could provide further robustness to the results.

7.2. Implications of the research

The results of this thesis are mainly relevant to two parties, namely commodity investors (such as hedge funds and CTAs) and corporate hedgers. For commodity investors, the results suggest that they should incorporate contracts along the entire futures curve into their commodity factor strategies.

For corporate hedgers, the results suggest that there is a potential opportunity cost when factors and Carry are not both taken into account when selecting the hedging contracts. This could potentially reduce the hedging cost for these corporate hedgers over hedging exclusively through nearest maturity contracts or contracts with delivery dates that match the physical needs of the corporation.

7.3. Future Research

There are a number of avenues for future research. First, since roll-yield is a characteristic of all futures, and not just commodities, the single-factor Carry algorithm could be modified for other asset classes, such as equity and FX futures. Although roll-yield does not have the same theoretical meaning across asset classes, this thesis presents no evidence that the enhancements are exclusive to commodities.

Second, in an attempt to extract the alpha from the single-factor Carry strategies, a new strategy could be developed that goes long on a single-factor Carry strategy and goes short on the corresponding single-factor strategy. This would essentially lead to a calendar spread strategy that simultaneously holds long and short positions on the same commodities, but with different maturities. What would be new about these strategies is that the selection of commodities to invest in would be driven not only by Carry, but also by factor scores.

Third and last, next to expanding on the research from this thesis, different data sources can also be used to verify the results presented here. While the Refinitiv Eikon dataset used in this thesis is of high-quality, its unique structure of continuous futures contracts means that some information is lost. As a result, workarounds need to be applied such as exiting positions around rebalancing dates. Next to this, the dataset also does not provide detailed information on margin requirements and bid-ask spreads. Depending on the dataset, trading cost information or returns to margin could be incorporated into the backtests which would expand on the robustness of the research from this thesis.

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Appendices

Appendix 1: Futures delivery months and expiration rules

Description	Last Trading Day	Delivery Months	Source
Sugar No. 11	“Last trading day of the month preceding the delivery month”	“March, May, July and October”	(ICE, 2022G)
Sugar White	“Sixteen calendar days preceding the first day of the delivery month at 17:55 (if not a business day then the first business day immediately preceding)”	“March, May, August, October, December”	(ICE, 2022H)
Coffee “C”	Eight “business days prior to the last business day of the delivery month”	“March, May, July, September, December”	(ICE, 2022C)
Arabica Coffee 4/5	“6th business day preceding the last trading day of the contract month”	“March, May, July, September, December”	(B3, 2022)
Cotton No. 2	“Seventeen business days from end of spot month”	“March, May, July, October, December”	(ICE, 2022D)
Chicago Wheat	“Trading terminates on the business day prior to the 15th day of the contract month”	March, May, July, September, December	(CME Group, 2022A)
Kansas Wheat	“Trading terminates on (sic) business day prior (sic) the 15th day of the contract month”	March, May, July, September, December	(CME Group, 2022G)
Corn	“Trading terminates on the business day prior to the 15th day of the contract month”	March, May, July, September, December	(CME Group, 2022C)
Soybeans	“Trading terminates on the business day prior to the 15th day of the contract month”	January, March, May, July, August, September, November	(CME Group 2022N)
Cocoa	Eleven “business days prior to (sic) last business day of (sic) delivery month”	“March, May, July, September, December”	(ICE, 2022B)
Live Cattle	“Trading terminates at 12:00 Noon CT on the last business day of the contract month”	February, April, June, August, October, December	(CME Group, 2022I)
Lean Hogs	“Trading terminates on the 10th business day of the contract month”	February, April, May, June, July, August, October, December	(CME Group, 2022H)
Feeder Cattle	“Trading terminates on the last Thursday of the contract month. If the last Thursday of the contract month is not a business day, trading terminates on the prior Thursday”	January, March, April, May, August, September, October, November	(CME Group, 2022E)
COMEX Copper	“Trading terminates at 12:00 Noon CT on the third last business day of the contract month”	March, May, July, September, December	(CME Group, 2022B)
SHFE Aluminum	“15th day of the delivery month (postponed in the event of statutory holidays)”	Each month	(SHFE, 2008A)
SHFE Zinc	“15th day of the delivery month (postponed in the event of statutory holidays)”	Each month	(SHFE, 2008B)
SHFE Nickel	“The 15th day of the delivery month (If it is a public holiday, the Last Trading Day shall be the 1st business day after the holiday)”	Each month	(SHFE, 2014)

Description	Last Trading Day	Delivery Months	Source
SHFE Lead	"The 15th day of the spot month (If it is a public holiday, the Last Trading Day shall be the 1st business day after the holiday)"	Each month	(SHFE, 2011)
COMEX Gold	"Trading terminates at 12:30 p.m. CT on the third last business day of the contract month"	Each month	(CME Group, 2022F)
COMEX Silver	"Trading terminates at 12:55 p.m. CT on the third last business day of the contract month"	Each month	(CME Group, 2022M)
WTI Crude Oil	"Trading terminates 3 business day before the 25th calendar day of the month prior to the contract month. If the 25th calendar day is not a business day, trading terminates 4 business days before the 25th calendar day of the month prior to the contract month."	Each month	(CME Group, 2022D)
Natural Gas	"Trading terminates on the 3rd last business day of the month prior to the contract month"	Each month	(CME Group, 2022J)
Brent Crude Oil	"Trading shall cease at the end of the designated settlement period on the last Business Day of the second month preceding the relevant contract month (e.g. the March contract month will expire on the last Business Day of January). If the day on which trading is due to cease would be either: (i) the Business Day preceding Christmas Day, or (ii) the Business Day preceding New Year's Day, then trading shall cease on the next preceding Business Day"	Each month	(ICE, 2022A)
Low Sulphur Gasoil	"Trading shall cease at 12:00 hours London Time, 2 business days prior to the 14th calendar day of the delivery month"	Each month	(ICE, 2022F)
RBOB Gasoline	"Trading terminates on the last business day of the month prior to the contract month"	Each month	(CME Group, 2022L)
ULS Diesel	"Trading terminates on the last business day of the month prior to the contract month"	Each month	(CME Group, 2022K)
Heating Oil - Low Sulphur	"Trading shall cease at the end of the designated settlement period on the penultimate US business day of the month preceding the delivery month where a US business day is a day on which NYMEX is opened for business"	Each month	(ICE, 2022E)

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Appendix 2: Example return calculation to commodity strategies

A detailed return calculation for a commodity Momentum strategy is outlined below. The return calculation for all other strategies is analogous to this example.

Step 0: Assume that there is $10 Million to invest, the strategy invests in 10 commodities (5 long & 5 short) and an equal exposure is given to each strategy.

Step 1: At time 0, the portfolio has not invested in any assets and consists just of cash. The portfolio looks as follows:

Time	Asset	Long/Short	Margin	Exposure/Notional Value	P&L
0	Cash	Long	NA	$ 10,000,000	$ -

Portfolio Market Value: $ 10,000,000

Net Exposure: $ 10,000,000

Gross Exposure: $ 10,000,000

P&L: $ -

Step 2: At time 1, the first cycle of the Momentum strategy is ran. It selects and invests in 10 commodities. The portfolio now looks as follows:

Time	Asset	Long/Short	Margin	Exposure/Notional Value	P&L
1	Oil	Long	$ 100,000	$ 1,000,000	$ -
1	Gas	Long	$ 100,000	$ 1,000,000	$ -
1	Coal	Long	$ 100,000	$ 1,000,000	$ -
1	Iron	Long	$ 100,000	$ 1,000,000	$ -
1	Gold	Long	$ 100,000	$ 1,000,000	$ -
1	Silver	Short	$ 100,000	$ -1,000,000	$ -
1	Lean Hog	Short	$ 100,000	$ -1,000,000	$ -
1	Soybeans	Short	$ 100,000	$ -1,000,000	$ -
1	Coffee	Short	$ 100,000	$ -1,000,000	$ -
1	Lumber	Short	$ 100,000	$ -1,000,000	$ -

Portfolio Market Value: $ 10,000,000

Net Exposure: $ -

Gross Exposure: $ 10,000,000

P&L: $ -

Step 3: At time 2, one month has passed and during that time the prices of the commodities have moved, creating a P&L on the different positions. The portfolio now looks as follows:

Time	Asset	Long/Short	Margin[4]		Exposure/Notional Value		P&L
2	Oil	Long	$	100,000	$	1,014,938	$ 14,938
2	Gas	Long	$	100,000	$	1,012,290	$ 12,290
2	Coal	Long	$	100,000	$	999,123	$ -877
2	Iron	Long	$	100,000	$	1,089,270	$ 89,270
2	Gold	Long	$	100,000	$	1,009,270	$ 9,270
2	Silver	Short	$	100,000	$	-1,089,370	$ -89,370
2	Lean Hog	Short	$	100,000	$	-1,000,291	$ -291
2	Soybeans	Short	$	100,000	$	-960,288	$ 39,712
2	Coffee	Short	$	100,000	$	-989,281	$ 10,719
2	Lumber	Short	$	100,000	$	-1,032,838	$ -32,838

Portfolio Market Value: $ 10,052,823

Net Exposure: $ 52,823

Gross Exposure: $ 10,196,959

P&L: $ 52,823

Step 4: Now that the cycle has ended, the return for the month can be calculated. The return is calculated by taking the portfolio market value at the end of the cycle (Time 2), dividing it by the portfolio market value at the beginning of the cycle (Time 1) and subtracting 1.

Return Time 1 – Time 2: ($ 10,052,823 / $ 10,000,000) – 1 = 0.53%

Note: There are other ways to calculate the returns, such as "return to margin", but since the dataset from Refinitiv Eikon does not include detailed margin data, this could not be calculated accurately. The above method of calculating returns shows the returns to a portfolio that exclusively invests in the Momentum strategy without applying any leverage.

Step 4: At the end of the cycle, all positions are closed. This results in an all-cash portfolio of $10,052,823. The next cycle works by simply going back to Step 1 but now $10,052,823 is divided equally across the 10 new commodities instead of $10,000,000.

[4] Margin is assumed constant in this example. However, movements of the underlying commodity prices could cause margin calls and therefore increase the amount of margin required.

Appendix 3: Comparison of all single-factor Carry strategies from 1997 to 2021

	Equal Weighted	**Carry**	**Momentum – C1**	**Basis-Momentum – C1**	**Value – C1**	**Momentum -Carry**	**Basis-Momentum-Carry**	**Value-Carry**
Mean Monthly Return	0.33%	0.34%	0.22%	0.41%	0.29%	0.32%	0.57%	0.34%
Geometric Mean Monthly Return	0.27%	0.32%	0.19%	0.39%	0.25%	0.29%	0.55%	0.30%
Monthly Volatility	3.37%	2.13%	2.45%	2.13%	2.84%	2.37%	1.97%	2.77%
Monthly Sharpe Ratio	0.05	0.08	0.02	0.11	0.04	0.06	0.21	0.06
Annualized Sharpe Ratio	0.16	0.29	0.07	0.39	0.15	0.22	0.72	0.21
Maximum Drawdown	42.90%	15.27%	28.68%	20.61%	30.44%	26.63%	12.24%	28.88%

	Equal Weighted	**Carry**	**Momentum – C2**	**Basis-Momentum – C2**	**Value – C2**	**Momentum -Carry**	**Basis-Momentum-Carry**	**Value-Carry**
Mean Monthly Return	0.33%	0.34%	0.25%	0.52%	0.23%	0.32%	0.57%	0.34%
Geometric Mean Monthly Return	0.27%	0.32%	0.22%	0.50%	0.19%	0.29%	0.55%	0.30%
Monthly Volatility	3.37%	2.13%	2.38%	1.96%	2.65%	2.37%	1.97%	2.77%
Monthly Sharpe Ratio	0.05	0.08	0.03	0.18	0.02	0.06	0.21	0.06
Annualized Sharpe Ratio	0.16	0.29	0.11	0.63	0.07	0.22	0.72	0.21
Maximum Drawdown	42.90%	15.27%	32.64%	12.79%	33.57%	26.63%	12.24%	28.88%

Appendix 4: Codebase

An overview of the notebooks used for this research can be found in the following repository:

https://github.com/yvesdhondt/commodity_futures_trading