Commodity momentum and reversal: Do they exist, and if so, why? ⋆

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Abstract

Whether momentum and reversal patterns on commodity markets are sensitive to formation periods, why differences in these patterns seem to emerge for commodity futures versus spot markets, and how these patterns can be explained, remain unanswered questions. Investigating 23 commodities for a period of fifty years, I take a comprehensive look at the momentum and reversal patterns on commodity markets. I first show that the inclusion of the net convenience yield in the commodity spot return definition reconciles the differences in the results for commodity spot and futures markets. Quantitively consistent momentum and reversal effects exists on both commodity futures and spot markets: An initial momentum effect is followed by a reversal effect and then a momentum effect again, which are robust to the choice of formation period. The observed momentum and reversal patterns for commodities are different from those on stock markets, but these patterns can be jointly explained by a combination of traditional asset pricing factors and a yield factor related to the net convenience yield.

Keywords: Commodity markets, Momentum, Reversal, Convenience yield, Asset pricing factors

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1. Introduction

The cross-sectional momentum effect (also regularly called momentum effect) is one of the most pervasive "anomalies" in financial literature (see Conrad and Kaul, 1998; Jegadeesh and Titman, 2001; Booth et al., 2016; Koziol and Proelss, 2021).[1] Assets with relatively better past performance (winners) continue to perform relatively better afterwards. In contrast, a reversal effect occurs when the past winners turn into losers and vice versa. A widely documented momentum and reversal pattern in equity markets is that a momentum effect occurs first, followed by a reversal effect (e.g., Jegadeesh and Titman, 2001; Cooper et al., 2004). However, the momentum and reversal patterns are not so clear for commodity markets. Bianchi et al. (2015) suggest that in commodity futures markets an initial momentum effect is followed by a reversal effect and then a momentum effect again, while only a reversal effect is found in commodity spot markets (see Chaves and Viswanathan, 2016). Both accurately documenting and understanding the momentum and reversal patterns in commodity markets is relevant for academics as well as investors. Commodities have become an important alternative investment class next to stocks and bonds, especially since investment strategies in commodity futures can currently be flexibly implemented, without short-selling restrictions (e.g., Shen et al., 2007; Miffre and Rallis, 2007; Fuertes et al., 2010; Cheng and Xiong, 2014; Bianchi et al., 2015). Therefore, I take a comprehensive look at the momentum and reversal patterns in commodity markets and try to explain these patterns.

Though there is increased attention directed to research on commodity momentum, it is still rather limited in comparison with research on momentum on equity markets. Momentum and reversal effects seem to be present in commodity markets, however, these may be sensitive to formation periods over which the past performance is estimated to

[1] Cross-sectional momentum is different from time-series momentum. Time-series momentum focuses on a single asset and decide whether to take a long or short position of that asset based on past performance. For instance, a positive past performance indicates a long position of that asset. This paper reserves the term "momentum" to cross-sectional momentum.

determine winners and losers portfolios. Bianchi et al. (2015) studies momentum and reversal patterns in commodity futures markets considering formation periods within fifteen months. In light of robustness of these results, the role of the formation period requires additional investigation. For instance, do the identified momentum and reversal effects still appear for longer formation periods, e.g., two to five years? Does the formation period affect the magnitudes of momentum and reversal effects?

In addition, differences in results seem to emerge for commodity futures versus spot markets. However, I argue that such differences might stem from the fact that the commodity spot returns are often proxied by pure capital gains. An appropriate definition of a commodity spot return should include the net convenience yield in addition to the capital gain, as argued by Pindyck (1993) and Tsvetanov et al. (2016). The net convenience yield is the latent payoff of holding a commodity in excess of storage cost, such as e.g. the ability to meet unexpected demand of the physical commodity because of urgent production (e.g., Fama and French, 1987; Pindyck, 1993).[2] As such, the net convenience yield can be interpreted as a future payoff of a physical commodity, similar to a dividend of a stock. Ignoring the role of the net convenience yield in commodity spot returns might have an impact on the observed momentum and reversal patterns. Hence, the consideration of the net convenience yield in assessing momentum and reversal effects on commodity spot markets requires additional investigation.

For the documented momentum and reversal patterns in equity markets, a behavioral explanation is commonly offered. In Particular, it is argued that investors might be overconfident in their private skills and such overconfidence is slowly corrected, which leads to a momentum effect followed by a reversal effect (e.g., Daniel et al., 1998; Jegadeesh and Titman, 2001). However, such an explanation seems incompatible for the momentum and reversal patterns observed on commodity markets, because this explanation

[2]Although this economic benefit is latent, the owner of a commodity can actually collect it through, e.g., renting out the commodity or engaging in a corresponding futures contract. I explain this in more detail later in the paper.

leaves the second momentum effect after the reversal effect in commodity futures markets unexplained. Even though some papers suggest a risk-return tradeoff to explain the momentum and reversal patterns on commodity markets, they conclude that the risk-return tradeoff framework seems unable to explain these patterns (see de Groot et al., 2014; Bianchi et al., 2016; Kang and Kwon, 2017). However, this preliminary evidence does not necessarily suggest the failure of the risk-return relationship. I instead argue that this failure might be because risk premiums are time-varying while they are assumed to be constant in the aforementioned studies, or because some relevant risk factors are not considered in these studies, warranting an additional asset pricing tests to explain the momentum and reversal patterns.

This paper first comprehensively analyzes the momentum and reversal effects in both commodity futures and spot markets and in turn investigates the source of these effects within a risk-return framework. The implied profit of the momentum effect can be achieved by a zero-cost long-short strategy engaging in a long position in the past winners and a short position in the past losers, the so-called momentum strategy. Similarly, the implied profit of the reversal effect can be achieved by a constrained (or mean-reversion) strategy, taking opposite positions of a momentum strategy. Regarding momentum or constrained strategies, two key elements of such strategies are the particular formation period and the holding period over which a winners-losers (long-short) portfolio is held without rebalancing. In this paper, I consider momentum strategies with a broad range of formation and holding periods up to sixty months. The momentum strategies are categorized into three groups with short, middle, and long formation periods. The momentum returns of strategies in these three groups are then compared to check the robustness of the momentum and reversal patterns. Particular attention is also devoted to the effects of formation periods on the magnitudes and durations of the momentum and reversal effects.

In order to explain the momentum and reversal patterns in commodity futures and spot markets, this paper studies the cross-sectional returns of different momentum strategies from the perspective of a risk-return relationship in a multifactor asset pricing model. In addition to a commodity-specific factor suggested by previous literature, I also consider conventional asset pricing factors. The risk premiums of these factors are assumed to be constant as well as allowed to be time-varying in the empirical analyses.

As to the commodity-specific risk factors, this paper considers a yield factor related to the percentage (net convenience) yield, defined as the net convenience yield to spot price ratio. The theory of storage relates the percentage yield to a risk-free interest foregone in holding a physical commodity and a basis, the difference between the current futures and spot price to spot price ratio (see Fama and French, 1987). Therefore, the percentage yield and basis incorporate similar cross-sectional information among commodities. The commodity with a higher percentage yield or lower basis is more backwardated.[3] Implied by the hedging pressure hypothesis (Keynes, 1930) and the theory of storage (Kaldor, 1939; Working, 1949; Brennan, 1958), it is profitable to take a long position in backwardated futures or a short position in contangoed futures.[4][5] The theory of storage in particular implies a negative relationship between inventory and net convenience yield (e.g., Fama and French, 1987; Miffre, 2016). A commodity is usually in backwardation when the corresponding inventory is low and the percentage yield is high. This market condition usually changes slowly because it takes time to produce a commodity (Daskalaki et al., 2014).

[3] One has to be cautious when determining backwardation and contango markets with the sign of basis. Some papers define basis as the difference between current spot and futures prices to spot price ratio (see Chaves and Viswanathan, 2016; Miffre, 2016). In this case, positive basis refers to backwardation market, while negative basis refers to contango market.

[4] According to the hedging pressure hypothesis (Keynes, 1930), if hedgers are net short, hedgers have to set a futures price below the expected spot price (backwardated market) to provide a positive risk premium to speculators, who is willing to take a long position in the futures contract. If hedgers are net long, the futures price has to be higher than expected spot price (contangoed market) to attract speculators to have short position in the futures contract.

[5] The theory of storage (Kaldor, 1939; Working, 1949; Brennan, 1958) suggests that a commodity is in a backwardated market if the inventory is low. If the spot price is constant, the futures price of a backwardated contract tends to increase as maturity getting closer, suggesting a long position in a backwardated contract. When the inventory is high, the commodity market is in contango. If the spot price is constant, the futures price of a contangoed contract tends to decrease as expiring, suggesting a short position in a contangoed contract.

As such, momentum strategies tend to buy backwardated commodities (with high percentage yields) and sell contangoed commodities (with low percentage yields). The yield factor, a mimicking risk factor related to percentage yield, might thus potentially explain the momentum and reversal patterns in commodity markets.

As to conventional asset pricing factors, I consider the risk factors of the Capital Asset Pricing model ($CAPM$), Fama and French (1993) three-factor model, Carhart (1997) four-factor model and Fama and French (2015) five-factor model. The intuition is that commodities are a distinct yet integrated asset class. The risk factors that successfully explain the cross-section of one asset should help explain the cross-section of other assets if the market is integrated (e.g., Fama and French, 1993; Campbell, 2000; Cochrane, 2009). One has to be wary of the fact that the risk factors that explain the cross-section of momentum strategies might be different from those that do so for the cross-section of common stock. I first test the performance of the widely used common risk factors in explaining the cross-section of commodity momentum strategies. Subsequently, the combined role of the yield factor and the common risk factors is studied. If the conjecture that the cross-section of commodity momentum strategies can be explained within a risk-return framework is supported, the commodity momentum and/or reversal effects are, at minimum, consistent with a market without arbitrage opportunities.

This paper relies on a sample of 23 commodities whose futures contracts are actively traded, with the sample ranging from September 1960 to September 2020. The findings first suggest that the inclusion of the net convenience yield in the commodity spot return definition reconciles the differences in results for commodity spot and futures markets. The momentum and reversal effects coexist and are quantitively consistent on both commodity futures and spot markets. The momentum effect emerges first, followed by a reversal effect and then a momentum effect again. Moreover, these momentum and reversal patterns are robust to the choice of formation period but the durations and magnitudes of the momentum and reversal effects vary somewhat with the formation periods. Furthermore, the momentum and reversal profits can be explained with risk factors when accounting for time-varying risk premiums. The yield factor alone cannot fully explain the variation in expected returns of momentum strategies, yet the model combining the Carhart (1997) four-factor model with the proposed yield factor performs best among all studied models in explaining the cross-section of momentum strategies and leaves no pricing errors. These findings are robust to the particular selection of momentum strategies and estimation methods with or without rolling window betas.

The main contribution of this paper is twofold. First, this paper extends the literature by arriving at a comprehensive understanding of the momentum and reversal patterns in commodity futures and spot markets. On the one hand, this paper digs deeper into the role of formation periods and the magnitudes and durations of momentum and reversal effects. In addition, this paper extends the discussion of momentum and reversal effects to spot markets, which are important but unexplored. In particular, novel evidence is presented for spot markets by including the net convenience yield into the definition of a spot return. Second, this paper provides a novel perspective to explore the sources of the momentum and reversal effects by studying the cross-sectional variation of different momentum strategies. The evidence that the commodity momentum and reversal profits are compensations for risks also offers some insight into the understanding of momentum and/or reversal effects present in other assets, e.g., stocks and bonds.

The rest of this paper is organized as follows. Section 2 explains the adopted commodity return definitions, commodity momentum strategies, and asset pricing tests. Section 3 describes the commodity data and risk factor proxies. Section 4 presents and discusses the results about commodity momentum strategies performance, the relationship between momentum strategy performance and corresponding percentage yield, the risk-return explanation for momentum and reversal patterns with constant and time-varying risk premiums, and reports the robustness and sensitivity checks. Section 5 concludes.

2. Methodology

2.1. *Defining commodity returns*

This paper assumes investors in futures markets earn fully collateralized futures returns, consistent with e.g., Bianchi et al. (2016), de Groot et al. (2014), Fuertes et al. (2010), Miffre and Rallis (2007), and Paschke et al. (2020). Since no payment is made when investors open a long position in a futures contract, the monetary amount equal to the value of the traded futures contract is assumed to be invested in a "safe" asset, e.g., a treasury bill or a margin account. That is, investors are assumed to engage in an unleveraged position in futures.[6] As such, the fully collateralized futures return is comparable to a stock return or a commodity spot return. Consider a futures strategy for which at time t an investor opens a long position of a second-nearby futures contract maturing at time $t+2$. This investor ends the position at time $t+1$, when this futures contract becomes the first-nearby contract, and rolls over to the next futures contract maturing at $t+3$. The fully collateralized futures return by engaging in this strategy from time t to $t+1$ ($r_{fu,t\rightarrow t+1}$ or $r_{fu,t+1}$) is defined as:

$$r_{fu,t\rightarrow t+1} = \frac{F_{t+1,t+2}}{F_{t,t+2}} + rf_{t\rightarrow t+1} - 1 \tag{1}$$

where $F_{t,t+2}$ and $F_{t+1,t+2}$ are futures prices at time t and $t+1$ of futures contract maturing at time $t+2$. $rf_{t\rightarrow t+1}$ (rf_t) refers to the net collateral return on the risk-free asset. This paper calculates futures return with prices of the same futures contract and thus it is replicable for investors, which is a common practice in the commodity literature (e.g., Shen et al., 2007; Chaves and Viswanathan, 2016; Kang and Kwon, 2017; Paschke et al., 2020).

As regards to spot return, this paper considers the net convenience yield rather than only looking into spot price changes since this makes more economic sense, as argued

[6] In practice, investors usually engage in leveraged position in futures, which achieves higher returns. Therefore, the futures return on fully-collateral basis used in this paper is more conservative.

by Pindyck (1993). An owner of a physical commodity is (implicitly) compensated by the net convenience yield and the owner could actually collect this latent payoff through e.g., leasing the physic commodity out or in particular by engaging in a futures contract written on this commodity. According to storage theory, the net convenience yield of a commodity from time t to $t+1$ and collected at time $t+1$ is defined as:

$$D_{t \to t+1}^{t+1} = S_t \left(1 + rf_{t \to t+1}\right) - F_{t,t+1} \tag{2}$$

where S_t is spot price at time t. $F_{t,t+1}$ refers to futures price at time t of futures contract maturing at time $t+1$. As mentioned, the net convenience yield, $D_{t \to t+1}^{t+1}$, can be collected by the owner of the physical commodity at time $t+1$ with a strategy engaging in a futures contract. Assume a holding of a commodity with value S_t at time t. The investor sells this commodity on the spot market and invests the nominal amount, S_t, into a bank account. Simultaneously, the investor engages in a futures contract maturing at time $t+1$, promising to purchase the commodity back at time $t+1$ at price $F_{t,t+1}$. Therefore, at time $t+1$, this investor has a risk-free net cash inflow $S_t \left(1 + rf_{t \to t+1}\right) - F_{t,t+1}$, which equals the net convenience yield, $D_{t \to t+1}^{t+1}$. Note that the net convenience yield might be positive or negative, depending on the relative size of the convenience yield to the storage costs. A positive net convenience yield is the money that the counterparty on the spot market (the owner of a commodity from time t to $t+1$) is willing to pay to the investor (the holder of a futures contract from time t to $t+1$) to enjoy the relatively large latent benefit of holding the physical commodity. Contrarily, a negative net convenience yield suggests the money that the investor on the futures markets is willing to pay to the counterpart on spot markets to compensate for the relatively large storage costs.

Subsequently, the investor owns the commodity again at time $t+1$, which now values S_{t+1}. The total value of the assets of this investor at time $t+1$ is $S_{t+1} + S_t \left(1 + rf_{t \to t+1}\right) -$

$F_{t,t+1}$. Accordingly, the return of holding a commodity from time t to $t+1$ is defined as:

$$r_{s,t\to t+1} = \frac{S_{t+1} + D^{t+1}_{t\to t+1}}{S_t} - 1 \tag{3}$$

Note that the strategy discussed above might not necessarily be attractive to the owner of a commodity. The aim here is merely to explain that the latent benefit can in principle be collected as cash and thus should be included into the definition of a spot return. Once the spot return includes the net convenience yield, it also has practical implications for investors on futures markets. Define the percentage yield as $y_{t\to t+1} = D^{t+1}_{t\to t+1}/S_t = 1 + rf_{t\to t+1} - F_{t,t+1}/S_t$. So $rf_{t\to t+1} - y_{t\to t+1} = F_{t,t+1}/S_t - 1 \approx \ln(F_{t,t+1}/S_t)$, where the approximation is justified because $F_{t,t+1}/S_t$ is close to one. Therefore $rf_{t\to t+1} - y_{t\to t+1}$ is close to zero and $F_{t,t+1}/S_t \approx e^{rf_{t\to t+1} - y_{t\to t+1}}$. Equation (3) can then be rewritten as:[7]

$$r_{s,t\to t+1} = \frac{S_{t+1} + D^{t+1}_{t\to t+1}}{S_t} - 1 \approx \frac{F_{t+1,t+2}}{F_{t,t+2}} + rf_{t\to t+1} - 1 \tag{4}$$

Equation (4) shows that the net convenience yield is implicitly already included in the definition of the futures return, which makes sense because it can be collected by engaging in a long position in a futures contract as explained above. In sum, the spot return that includes the net convenience yield is quantitively similar to the futures return. As such, it highlights that the spot return should also be of interest to financial investors on futures markets. Continuing with equation (4) the spot return can also be written to:[8]

$$\begin{aligned} r_{s,t\to t+1} &= \frac{S_{t+1} + D^{t+1}_{t\to t+1}}{S_t} - 1 = \frac{S_{t+1} + S_t(1 + rf_{t\to t+1}) - F_{t,t+1}}{S_t} - 1 \\ &\approx \frac{F_{t+1,t+2} + F_{t,t+1}(1 + rf_{t\to t+1}) - F_{t,t+2}}{F_{t,t+1}} - 1 \end{aligned} \tag{5}$$

Justified by equation (5), this paper approximates the spot price S_t with a nearby

[7]For a derivation of equation (4), see equation (A.1) in Appendix A.
[8]For a derivation of equation (5), see equation (A.2) in Appendix A.

futures price $F_{t,t+1}$ and approximates the nearby futures price $F_{t,t+1}$ with the second-nearby futures price $F_{t,t+2}$, which is common practice in the commodity literature (e.g., Fama and French, 1987; Szymanowska et al., 2014; Chaves and Viswanathan, 2016). The amount $F_{t+1,t+2}/F_{t,t+1} - 1$ is quite a precise proxy of the net capital gain, $S_{t+1}/S_t - 1$, which has also been shown empirically by Chaves and Viswanathan (2016). Moreover, $1 + rf_{t\to t+1} - F_{t,t+2}/F_{t,t+1}$ is a precise proxy of percentage yield, $1 + rf_{t\to t+1} - F_{t,t+1}/S_t$, from both mathematical and economic perspectives. The intuition is that there exists a term structure of futures prices, and the slope between the two consecutive futures at the most front-end of the term structure is approximated with the slope between the next two consecutive futures. These two slopes are not expected to differ too much, since the expected inventory and storage cost will not change substantially in few months (Paschke et al., 2020). The advantages of these approximations are twofold. First, using the nearest futures price to proxy spot prices ensures that the spot and futures prices are on the same commodity with the same detailed contract specifications. Second, the futures contract might not expire at the end of a month, yet using the approximations allows for calculating the net convenience yield and spot return from the end of month t to the end of month $t + 1$, which helps to align the sampling intervals of futures returns and risk factors.

2.2. Commodity momentum strategies

This section introduces the momentum strategies considered in this paper. I consider momentum strategies with formation and holding periods up to sixty months. In addition to the commodity futures and spot returns' definitions discussed in section 2.1, this paper also constructs momentum strategies based on capital gains in order to check the influence of the net convenience yield on the profitability of momentum strategies in spot markets and for comparison with the findings of Chaves and Viswanathan (2016), who study momentum strategies on spot markets but only with capital gains.

At the end of every period, I rank commodities according to their past performance over the formation period (J) based on futures returns, spot returns, and capital gains separately. Since the number of commodity futures is rather small compared to the number of assets on the equity market, this paper selects 30 percent as breakpoint to make sure there are enough commodities in each portfolio, which is also a commonly used breakpoint to construct stock portfolios (see Moskowitz and Grinblatt, 1999; Fama and French, 1993, 1996, 2015). The top 30 percent of commodities with higher past performance are labeled as winners and the bottom 30 percent of commodities with lower past performance are labeled as losers. The winners and losers commodities are then equally weighted to construct winners and losers portfolios respectively. The momentum strategy is to take a long position in the winners portfolio and a short position in the losers portfolio and to hold this winners-minus-losers portfolio in the following holding period (H) without rebalancing. Different from the momentum strategies in equities, this paper considers no skip between formation and holding periods for the commodity momentum strategies, because the short-term reversal does not seem to exist in commodity markets (Bianchi et al., 2015).

However, overlapping portfolios exist in each period in the case of holding periods longer than one. In order to avoid the overlapping issues, this paper calculates non-overlapping returns for each momentum strategy, following Jegadeesh and Titman (1993, 2001). To be precise, take the momentum strategy with a formation period of six ($J = 6$) and a holding period of two ($K = 2$), for example. During the period from time t to $t + 1$, there exists two winners-minus-losers portfolios, one constructed at time $t - 1$ and one at time t, respectively. The non-overlapping return from time t to $t + 1$ is then defined as the equally-weighted return of the two overlapping portfolios. Generally, a positive return suggests the profitability of the corresponding momentum strategy and a momentum effect, while a negative return suggests the profitability of the constrain strategy and a reversal effect.

In order to clearly show the momentum and reversal patterns, this paper focuses on the cumulative return for the holding period, following the method designed to study stock momentum and reversal (e.g., Jegadeesh and Titman, 2001; Cooper et al., 2004). The intuition is that once the winners and losers portfolios are selected, there is a momentum effect from the end of e.g., the first period to the end of e.g., the second period if the average cumulative return of the momentum strategy with a holding period of two ($K = 2$) is higher than that of the momentum strategy with a holding period of one ($K = 1$). Otherwise, there is a reversal effect. The cumulative return of a momentum strategy is calculated as the cumulative return of winners- minus-losers portfolio, which are compounded from the non-overlapping returns.

2.3. Asset pricing tests

In order to study the cross-sectional variation in expected returns among momentum strategies, this paper applies the Fama and MacBeth (1973) two-step procedure, which is a common method to study the cross-section of asset returns, mostly for common stock and commodities (see Chang et al., 2013; Daskalaki et al., 2014; Lübbers and Posch, 2016).

In the first step, the risk loadings or exposure of each momentum return on risk factors are estimated separately with time-series regressions:

$$WML_{J-K,t} = \alpha_{J-K} + f_t'\beta_{J-K,f} + \epsilon_{J-K,t} \qquad t = 1, \cdots, T \tag{6}$$

where $WML_{J-K,t}$ refers to the non-overlapping return at time t of the momentum strategies with a formation period of J and a holding period of K, where J and K range from one to sixty months. Since $WML_{J-K,t}$ is simply the return difference between the winners and the losers portfolios, it is an excess return. Denote the $\beta_{J-K,f}$ as loadings on the risk factors in f_t. The risk loadings suggest how sensitive the momentum return is to the risk factors. The constant and error term are represented as α_{J-K} and $\epsilon_{J-K,t}$. When all the risk factors are excess returns on traded assets, these time-series regressions provide a time-series test about the performance of those risk factors in explaining the cross-section of momentum returns with the restriction that the risk premiums are equal to the averages of risk factors. Under this restriction, if these risk factors perform well, the intercepts (pricing errors) α_{J-K} for all momentum strategies should be (jointly) zero, implied by asset pricing theory.

However, the risk premiums might be time-varying and/or different from the simple averages of risk factors. To account for this requires explicitly running cross-sectional regressions in a second step to estimate risk premiums based on the returns and betas of all momentum strategies. That is, for each time t, run the cross-sectional regression:

$$WML_{J-K,t} = \lambda_{0,t} + \hat{\beta}'_{J-K,f}\lambda_{f,t} + \epsilon_{J-K,t} \tag{7}$$

where $\hat{\beta}'_{J-K,f}$ are the estimated risk loadings from the first-step time-series regressions (equation (6)), $\lambda_{f,t}$ are the estimated risk premiums at time t, $\lambda_{0,t}$ represents an intercept, and $\epsilon_{J-K,t}$ refers to an error term. By running T cross-sectional regression (7), we obtain a time-series of intercepts $\lambda_{0,t}$ and risk premiums $\lambda_{f,t}$. . The final estimates of the intercept and risk premium are equal to the time-series average, i.e., $\hat{\lambda}_0 = \left(\sum_{t=1}^{T} \hat{\lambda}_{0,t}\right)/T$ and $\hat{\lambda}_f = \left(\sum_{t=1}^{T} \hat{\lambda}_{f,t}\right)/T$.

Asset pricing theory suggests that the risk premium of a risk factor should be significant if it is to explain the cross-section of momentum returns. If a model captures all the risk factors and performs well in explaining the variation across momentum returns, the intercept $\hat{\lambda}_0$ should be zero, which captures the unexplained common return among momentum strategies. Therefore, this paper tests the performance of a model in explaining the momentum returns by the significance of risk premiums $\hat{\lambda}_f$ and intercept $\hat{\lambda}_0$. The t-statistics are calculated with the Newey and West (1987) procedure with one lag to correct for autocorrelation, consistent with Szymanowska et al. (2014) and Bakshi et al. (2019).

3. Data

3.1. Commodities-specific factors

This paper collects the end-of-month closing futures prices from the Commodity Research Bureau (CRB). Since financial investors, especially speculators, are not willing to deliver the physical commodity when futures contract matures, they usually close the position of a futures contract four to six weeks before the maturity of the futures contract (e.g., Brunetti and Reiffen, 2014; Szymanowska et al., 2014). As such, a futures contract might have ”erratic” price behavior during the last two months before maturity. In order to avoid such erratic price behavior, this paper assumes that investors roll over to the next futures contract two months before maturity, consistent with Boons and Prado (2019), He et al. (2019), and Szymanowska et al. (2014). Furthermore, the number of distinct futures contracts varies among commodities. For instance, crude oil has twelve distinct futures contracts a year, while soybean has seven distinct futures contracts a year. In order to minimize the problem arising from irregular maturities, this paper constructs *bimonthly* price data and assumes investors hold the position of a futures contract for two months, following He et al. (2019), and Szymanowska et al. (2014). For instance, in January the investor ends the position of the futures contract maturing in March. In the meantime, this investor opens a position of the futures contract maturing in May and ends this position in March. That is, the futures contract maturing in two months is used as spot contract and the futures contract expiring two months later than the spot contract is used as nearby futures contract. Therefore, one period refers to two months.

The sample consists of 23 commodities, most of them have at least six distinct futures contracts maturing in January, March, May, July, September, and November.[9] Natural gas and gas oil are considered in this paper in addition to the 21 commodities studied in Szymanowska et al. (2014). The sample is comprised of unbalanced price data for the 23 commodities ranging from September 1960, when at least 9 commodities are available to

[9]Some commodities do not have futures contract maturing in two months or four months, the spot and nearby contracts are then the nearest futures contracts maturing after two and four months. For instance, soybean oil does not have futures contract maturing in November. Therefore, the nearby futures contract in July and the spot contract in September are futures contract maturing in December instead of November. Some commodities, e.g., gold, have futures contracts maturing in February, April, June, August, October and December. This paper rolls over to the next futures contract three months rather than two months before the maturity. For instance, in January, the spot and nearby futures contracts are the ones maturing in April and June.

ensure that at least 3 commodities in the winners and losers portfolios, in line with Bianchi et al. (2015). The sample ends in September 2020. The sample in this paper starts earlier than most commodity momentum literature, which commonly starts after 1977 (Miffre and Rallis, 2007; Fuertes et al., 2010, 2015; de Groot et al., 2014; Bianchi et al., 2015, 2016). Detailed information about the 23 commodities is shown in Table B.1 in Appendix B. The risk-free interest rate is represented with the one-month Treasury bill rate. The monthly risk-free interest rate since September 1960 is available from Kenneth French's website and is compounded into bimonthly frequency. [10]

Regarding the commodity-specific risk factor, this paper considers a yield factor to explain the momentum and reversal patterns in commodity markets because the yield factor contains information about the particular commodity market condition, e.g., is the market in backwardation or in contango. Although the percentage yield is not a perfect determinant for whether a commodity market is in backwardation or contango, it works well for the cross-sectional comparison among commodities, which is of main relevance for this paper. A commodity with a higher percentage yield than other commodities is in a more backwardated or less contangoed market. In order to construct the yield factor, this paper ranks the commodities at the end of every second month according to the percentage yield in the previous two months. In line with the breakpoint used to construct the winners-losers portfolio, the top 30 percent of the commodities with higher percentage yields are equally weighted to construct the most backwardated portfolio, while the bottom 30 percent of the commodities with lower percentage yields are equally weighted to construct the most contangoed portfolio. The yield factor is then defined as the return difference between the most backwardated portfolio and the most contangoed portfolio in the following two months.[11] Since the spot return is quantitively similar to the futures return as suggested in equation (4) in section 2.1, this paper uses the spot returns to cal-

[10] The Kenneth French's website is http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

[11] The yield factor is similar to basis factor, term structure or carry factor regularly mentioned in commodity papers.

culated the yield factor, which should not differ too much from the yield factor calculated with futures returns.

3.2. *Common asset pricing factors*

In additional to the yield factor, this paper considers the commonly used asset pricing factors as well. Four commonly used asset pricing models are considered in this paper. Specifically, this paper considers the Capital Asset Pricing Model ($CAPM$) by adopting a market excess return factor (MKT), the Fama and French (1993) three-factor model by adopting MKT, a size factor (SMB) and a value factor (HML), the Carhart (1997) four-factor model by adopting an equity momentum factor (MOM) in addition to the MKT, SMB and HML factors, and the Fama and French (2015) five-factor model by adopting a profitability factor (RMW) and an investment factor (CMA) in addition to the MKT, SMB and HML factors.

These asset pricing factors are available from Kenneth French's website since September 1963. MKT refers to the value-weighted return on equity market in excess of risk-free interest rate. The monthly equity return is compounded into bimonthly returns. The size, value, profitability, and investment factors are constructed with eighteen value-weighted portfolios with bivariate sorts, including six portfolios formed on size and value, six portfolios sorted on size and profitability and six portfolios sorted on size and investment. For detailed descriptions of these portfolios, see Kenneth French's website. The monthly returns of these portfolios are compounded into bimonthly returns. The size factor is defined as the average return of the nine portfolios with small stocks minus the average return of the nine portfolios with big stocks. The value factor is the difference between the average return of the two portfolios with value stocks (high book-to-market ratio) and the average return of the two portfolios with growth stocks (low book-to-market ratio). The profitability factor refers to the difference between the average return of the two portfolios with robust profitability and the average return of the two portfolios with week profitability. The investment factor is the difference between the average return of the two portfolios with conservative investment and the average return of the two portfolios with aggressive investment. Similarly, the equity momentum factor is formed with the six value-weighted portfolios sorted on size and previous twelve-month returns skipping the most recent month. The portfolio returns are compounded into bimonthly returns as well. The equity momentum factor is then defined as the difference between the average return of the two portfolios with high prior returns and the average return of the two portfolios with low prior returns.

As discussed in section 2.2, this paper considers momentum strategies with formation and holding periods up to sixty months ($J, K = 1, \cdots, 30$). In total, there are 900 distinct momentum strategies respectively for futures returns, spot returns, and capital gains. In the following analysis, this paper uses balanced momentum returns starting from September 1970, as the return on the momentum strategies with formation and holding periods of sixty months ($J = K = 30$) is available from that point on.

3.3. Data description

Table 1 displays the summary statistics of futures returns, spot returns, capital gains, and percentage yields of the 23 commodities. The table highlights that the average returns of individual commodities vary substantially. As to futures returns, Gasoline has the highest average futures return equal to 16.77% on an annual basis, while natural gas has the lowest average futures return equal to -5.95% annually. Since this paper calculates the futures return on a fully collateralized basis as discussed in section 2.1, the futures return is comparable to a spot return. The spot returns of the 23 commodities are quantitively similar to the futures returns and the corresponding standard deviations are quantitively similar as well, as they should be according to the implication of equation (4) in section 2.1. The capital gains exhibit different features compared to futures and spot returns. The cross-sectional differences in average capital gains are much smaller than those of futures and spot returns, ranging from 4.04% annually for feeder cattle to 13.37% annually for natural gas. The percentage yields also vary a lot, ranging from -19.66% annually for natural gas to 7.63% annually for gasoline. This variation mainly drives the cross-sectional difference of the futures and spot returns among individual commodities. As such, the percentage net convenience yields are not negligible and should be included into the spot returns.

Table 1: Annualized summary statistics of returns and percentage yield and correlations among returns.

Panel A: Annualized summary statistics and correlations among time-series returns											
Commodity	Futures market		Spot market				Yield		Correlation		
	$r_{fu}(\%)$		$r_s(\%)$		$cg(\%)$		$y(\%)$		ρ_{r_{fu},r_s}	$\rho_{r_{fu},cg}$	$\rho_{r_s,cg}$
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.			
Soybean oil	9.43	27.74	9.07	27.27	5.66	26.78	3.41	6.89	1.00	0.96	0.97
Soybean meal	13.81	31.99	13.89	31.65	7.87	32.96	6.02	7.59	1.00	0.97	0.97
Soybean	9.92	26.82	10.02	26.38	6.18	27.77	3.85	7.28	1.00	0.97	0.97
Copper	14.87	27.52	14.53	27.24	7.52	26.9	7.02	6.04	1.00	0.97	0.98
Cocoa	7.88	31.25	7.61	31.07	7.02	30.92	0.59	6.96	1.00	0.97	0.97
Cotton	6.53	23.72	6.66	23.61	4.74	25.94	1.92	10.13	1.00	0.93	0.92
Oats	3.86	26.34	3.58	26.61	5.98	27.33	-2.4	9.29	1.00	0.94	0.94
Corn	1.96	23.97	1.92	23.92	5.08	24.87	-3.16	7.41	1.00	0.96	0.95
Wheat	2.29	24.67	2.17	24.99	4.98	25.81	-2.81	8.27	1.00	0.95	0.95
Live cattle	9.71	16.69	9.79	16.63	4.58	18.78	5.21	7.84	1.00	0.91	0.91
Orange juice	8.8	31.54	8.64	31.69	6.95	32.07	1.69	8.05	1.00	0.97	0.97
Silver	8.4	32.61	8.34	32.95	9.74	32.83	-1.4	1.66	1.00	1.00	1.00
Lean hogs	10.2	26.11	10.13	26.21	7.5	32.49	2.63	19.85	1.00	0.79	0.79
Lumber	3.22	29.86	2.86	30.4	8.93	31.54	-6.07	11.49	1.00	0.93	0.93
Coffee	7.35	35.62	7.07	35.64	7.18	35.62	-0.11	8.58	1.00	0.97	0.97
Gold	6.53	19.85	6.51	20.14	7.08	20.17	-0.57	0.55	1.00	1.00	1.00
Feeder cattle	7.69	14.63	7.66	14.67	4.04	15.22	3.63	5.07	1.00	0.94	0.94
Heating oil	10.71	33.69	10.64	33.85	7.72	34.67	2.92	9.11	1.00	0.96	0.96
Crude oil	11.14	36.1	11.4	36.63	8.27	38.74	3.13	9.96	1.00	0.96	0.97
Gasoline	16.77	35.29	17.14	35.83	9.5	40.04	7.63	14.55	1.00	0.92	0.93
Gas oil	11.5	33.5	11.66	33.76	9.36	34.8	2.3	7.43	1.00	0.98	0.98
Rough rice	-3.15	25.13	-2.95	25.63	5.02	28.1	-7.97	8.95	1.00	0.96	0.95
Natural gas	-5.95	43.18	-6.29	44.69	13.38	50.14	-19.66	23.7	1.00	0.89	0.88

Panel B: Correlations among the three return series consisting of average individual returns			
	r_{fu}	r_s	cg
r_{fu}	1.00		
r_s	1.00	1.00	
cg	-0.02	-0.02	1.00

Note: This table reports the annualized summary statistics of individual commodity returns and the percentage yield. Futures return is defined as $r_{fu} = F_{t+1,t+2}/F_{t,t+2} + rf_{t\to t+1} - 1$. Spot return is calculated as $r_s = (F_{t+1,t+2} + F_{t,t+1}(1 + rf_{t\to t+1}) - F_{t,t+2})/F_{t,t+1} - 1$. Capital gain is calculated as $cg = F_{t+1,t+2}/F_{t,t+1} - 1$. Here one period refers to two months. The initial dates of individual commodities are shown in Table B.1 in Appendix B. Sample ranges from September 1960 to September 2020.

Panel A in Table 1 also shows the correlations among the three time-series of futures returns, spot returns, and capital gains for each commodity. The futures and spot returns are perfectly correlated for all commodities. The correlations between futures or spot returns and capital gains for individual commodities are also quite large. Accordingly, the time-series features of the futures returns, spot returns and capital gains are quite similar. Panel B in Table 1 displays the correlation among the three cross-sectional series respectively consisting of average futures returns, spot returns, and capital gains of individual commodities (columns 2, 4, and 6 in panel A in Table 1). The cross-sectional futures and spot returns are still perfectly correlated. Strikingly, the correlation between cross-sectional futures or spot returns and capital gains is quite low, which is only -0.02. As such, the cross-sectional features of capital gains differ, to a large extent, from that of futures and spot returns, although the time-series characteristics do not differ that much. These findings confirm that the performance of momentum strategies for spot prices should be revisited by taking the role of the net convenience yield into consideration.

Figure 1 visually illustrates the cross-sectional return-yield relationships among individual commodities. The left two scatters suggest that the futures and spot returns are positively related to percentage yields. The commodity with a higher percentage yield also has higher futures and spot returns. This positive cross-sectional relationship suggests to buy backwardated futures contracts or underlying physical commodities and to sell those in contangoed markets, consistent with the implications of the theory of storage (Kaldor, 1939; Working, 1949; Brennan, 1958) and the hedging pressure hypothesis (Keynes, 1930). Furthermore, this clearly positive cross-sectional relationship also provides evidence to support the conjecture in this paper that the past winners might be the futures or commodities with higher percentage yields and the past losers might be the futures or commodities with lower percentage yields. The percentage yield is therefore likely to represent a risk factor that the futures contracts and physical commodities are exposed to. The third scatter in Figure 1 demonstrates the cross-sectional relationship between capital gains and percentage yields. Except for the somewhat extreme values observed for natural gas (seemingly an outlier), there is no clear pattern that emerges.

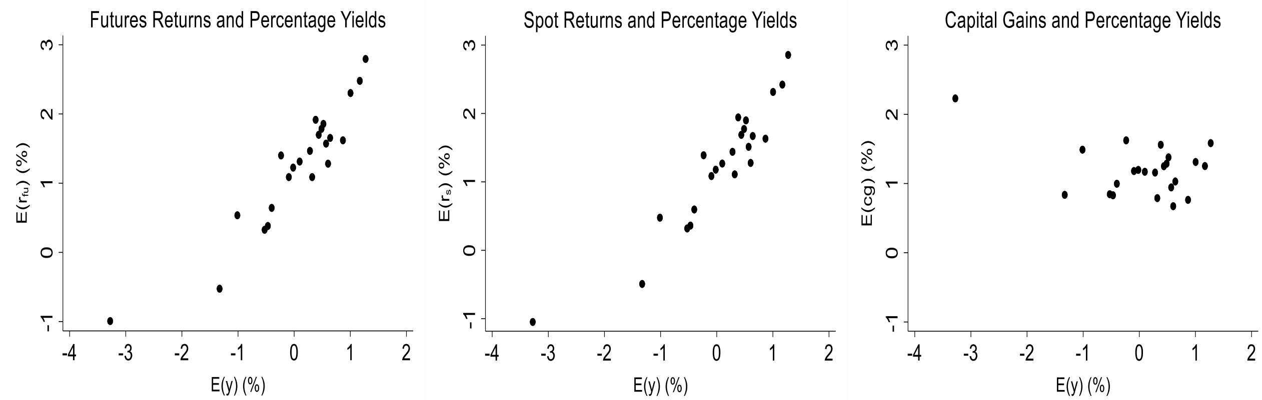


Figure 1: Return-yield relationships across individual commodities. *Note:* This Figure shows the relationships between bimonthly average futures returns and percentage yields, between bimonthly average spot returns and percentage yields and between bimonthly average capital gains and percentage yields among individuals. $E\left(r_{fu}\right)$, $E\left(r_{s}\right)$, and $E\left(r_{cg}\right)$ refers to bimonthly average futures returns, spot returns, and capital gains. Sample ranges from September 1960 to September 2020.

The annualized summary statistics of the yield factor and the common asset pricing factors and their correlations are shown in Table 2. Noteworthy, the yield factor is constructed with spot returns, which should not make much difference compared to the one constructed with futures returns, as discussed in section 2.1. As shown in panel A, all the risk factors have positive average returns, where the yield factor (HML_y) has the highest annual return of 11.40% and largest standard deviation of 19.49% as well. The positive return of the yield factor suggests the profitability of the yield strategy with a long position in backwardated commodities and a short position in contangoed ones, which is well documented in the existing literature (see Fuertes et al., 2010, 2015). In regard to the common asset pricing factors, the equity market has the highest average return of 7.55% annually, followed by the equity momentum factor with an average return of 7.52% annually. Panel B displays the correlation matrix among those risk factors. The correlations between the yield factor and the common asset pricing factors are quite low, suggesting that the risk related to percentage yield (mimicked by the yield factor) might be independent of the risks represented by the common asset pricing factors.

Table 2: Annualized summary statistics and correlations for risk factors.

	HML_y	MKT	SMB	HML	MOM	RMW	CMA
Panel A: Annualized summary statistics							
Mean(%)	11.40	7.55	2.07	2.54	7.52	3.42	3.01
Std. (%)	19.49	16.68	10.07	10.92	16.38	8.06	7.26
Panel B: Correlation							
HML_y	1						
MKT	-0.10	1					
SMB	-0.02	0.35	1				
HML	0.18	-0.27	-0.01	1			
MOM	0.00	-0.22	-0.12	-0.14	1		
RMW	0.14	-0.29	-0.24	0.09	0.18	1	
CMA	0.06	-0.38	-0.10	0.69	0.00	0.01	1

Note: This table reports the annualized summary statistics and correlations for risk factors. HML_y is the yield factor with spot returns. MKT is the equity market excess return factor. SMB is the size factor. HML is the value factor. MOM is the equity momentum factor. RMW is the profitability factor. CMA is the investment factor. The sample starts from September 1970 and ends in September 2020.

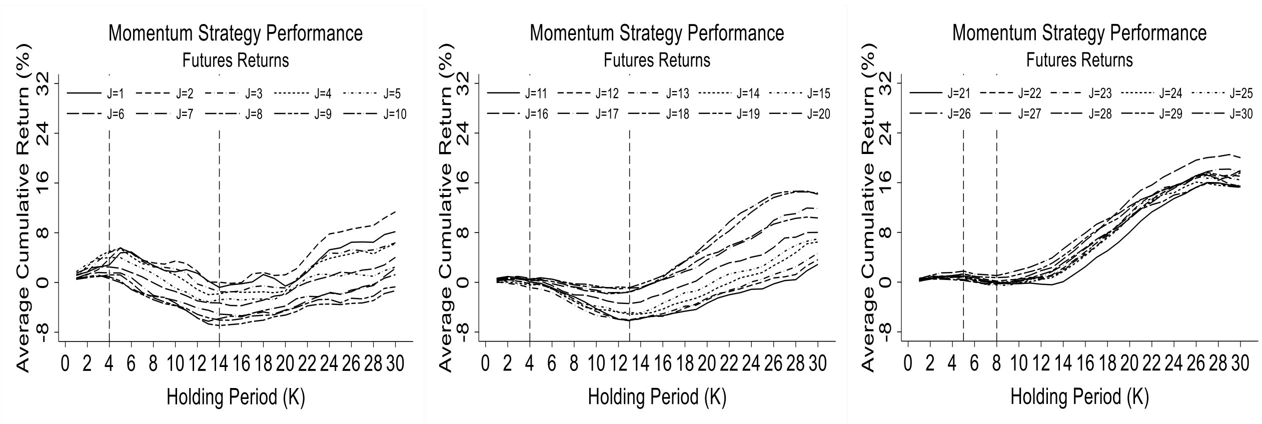
4. Results

4.1. Commodity momentum strategy performance

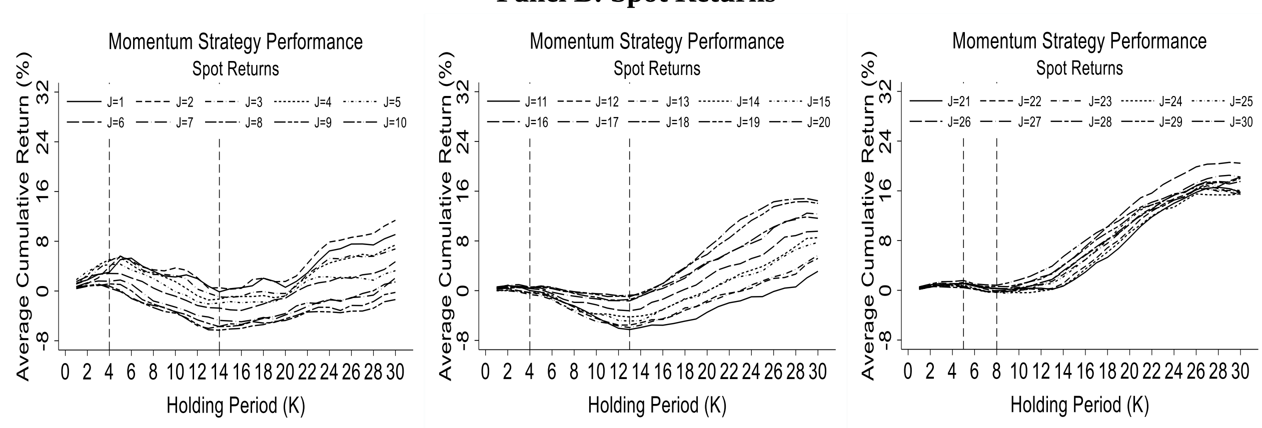
In order to comprehensively study the commodity momentum and reversal patterns, this section analyzes the performance of momentum strategies with formation and holding periods up to sixty months for futures returns, spot returns and capital gains. The average cumulative returns of all momentum strategies are illustrated in Figure 2. For the purpose of clarity in exposition, this paper categorizes the momentum strategies into three groups according to the length of the formation periods - groups with short, middle and long formation periods. It is also convenient to do so to be able to make a comparison with existing studies, which usually focus on strategies with shorter formation periods, e.g., two months to fifteen months.

Panel A shows the average cumulative returns of momentum strategies with futures returns. In general, the average cumulative returns move upwards first, then downwards, and upwards again, suggesting a momentum effect first, followed by a reversal effect and then a momentum effect in commodity futures markets. These momentum-reversal patterns hold in all cases irrespective of the different formation periods. Notably, the for-

Panel A: Futures Returns



Panel B: Spot Returns



Panel C: Capital Gains

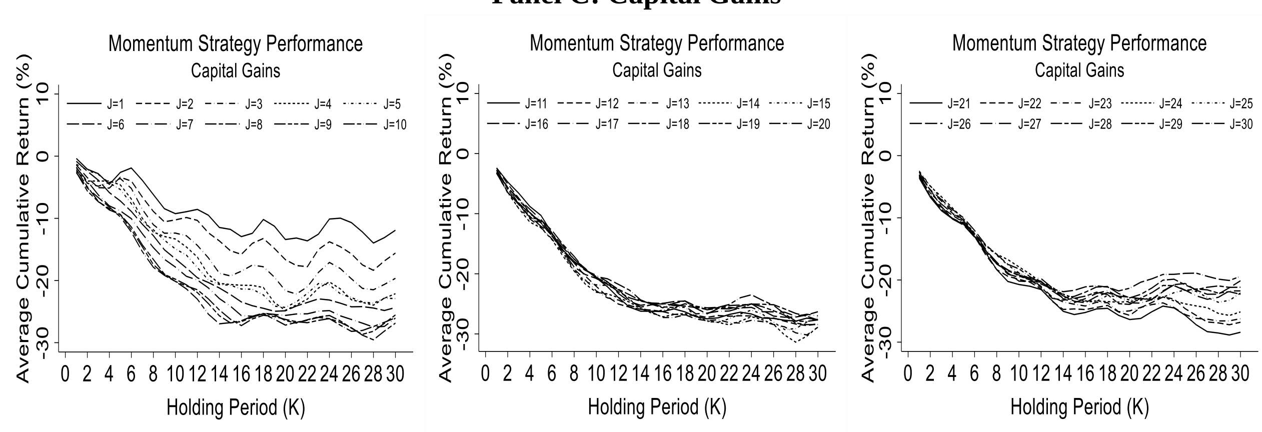


Figure 2: Average cumulative returns of commodity momentum strategies. *Note:* The cumulative (excess) returns of commodity strategies are calculated as the difference between cumulative returns on relevant winners and losers portfolios. The cumulative returns of winners and losers portfolios are compounded from the non-overlapping bimonthly returns, which range from November 1970 to September 2020. J is the formation period to rank commodities. K is the holding period for the winners and losers portfolios. One period refers to two months.

mation period does affect the durations and magnitudes of the momentum and reversal effects. As shown in the upper left figure in panel A for the momentum strategies with short formation periods ($J < 10$, recall that I use bimonthly data), the average cumulative returns monotonously increase when the holding period is shorter than eight months ($K < 4$), suggesting a momentum effect in the first eight months once the winners-losers portfolio is formed. Then the cumulative returns tend to collapse until the twenty-eighth month ($4 < K < 14$). As such, a reversal effect exists and lasts around twenty months. This reversal loss finally offsets the momentum profit in the first eight months. These findings are consistent with those of Shen et al. (2007), which studies the momentum strategies with a formation period of two months and a holding period ranging from one to thirty months. The cumulative profits climb up again after the twenty-eighth month ($K > 14$). This upward trend continues until the sixtieth month. These momentum and reversal patterns are in line with the findings of Bianchi et al. (2015), which analyzes the momentum strategies with holding periods up to sixty months but only consider formation periods up to fifteen months.

As an extension of the previous literature (e.g., Shen et al., 2007; Bianchi et al., 2015), this paper also considers the momentum strategies with longer formation periods, which gives insights into the impact of the choice of length of the formation periods on the momentum profits. Compared to momentum strategies with short formation periods, shown in the upper left figure in panel A, the durations of the momentum and reversal effects are similar but the magnitudes of the first momentum and reversal effects are smaller, while the second momentum effect is stronger for the strategies with middle formation periods, as shown in the middle figure in panel A. With regard to the momentum strategies with long formation periods, shown in the bottom left figure in panel A, the durations of the first momentum effects are similar to those with short and middle formation periods, while the magnitudes are similar to those with middle formation periods and thus are much smaller than those with short formation periods. The reversal effects last shorter and are much weaker than those with short and middle formation periods. Accordingly, the second momentum effects last longer and are stronger for the momentum strategies with long formation period. In general, the longer the formation period, the weaker the first momentum and reversal effects, and the reversal effect lasts shorter, while the second momentum effect is stronger and lasts longer.

The average cumulative profits of momentum strategies with spot returns are displayed in Panel B. As expected, the momentum and reversal patterns are almost identical to those with futures returns. This is because the futures and spot returns are quantitively similar, conform the discussion in section 2.1 and 3.3. Panel C illustrates the cumulative profits of momentum strategies with capital gains. Interestingly, there is a clear downward trend in the cumulative profits of all momentum strategies, suggesting a consistent reversal effect in capital gains. These findings explain why Chaves and Viswanathan (2016) suggest that constrain strategies works in ”spot return”, because they only focus on capital gains - without including the yield. As such, the profitability of momentum strategies for spot returns and capital gains differs substantially, because the percentage yield drives cross-sectional characteristics of spot returns, which in turn affects the profitability of momentum strategies. These findings also support my argument that the net convenience yield should be considered when studying momentum and reversal effects in spot markets.

In all, the momentum and reversal effects are consistent when investigating either commodity futures or spot markets. Noteworthy, these patterns are quite different from those in equity markets. According to Jegadeesh and Titman (2001); Cooper et al. (2004), the momentum effect in equity markets occurs in the first twelve months once the portfolios are formed, followed by a reversal effect from the thirteenth month to sixtieth month. There is no momentum effect again following the reversal effect for equities. Therefore, the well-studied constrain strategies with formation and holding periods of three to five years that are profitable for equities are less applicable for commodities, which explains the poor performance of those constrain strategies for commodities in Miffre and Rallis (2007) and Bianchi et al. (2015). Furthermore, the widely adopted explanation that the equity momentum and reversal effects arise from the initial overreaction and subsequent correction of investors might not be able to jointly explain the momentum and reversal effects in commodity markets. In particular, this behavioral explanation leaves the second continuing momentum effect in commodity markets unexplained.

4.2. Commodity momentum strategy performance and percentage yield

This section assesses the cross-sectional relationship between the momentum profits and corresponding percentage yields by selecting thirty momentum strategies for futures returns. The results should have the same implications to the momentum strategies for spot returns because the momentum and reversal patterns for futures and spot returns are quantitively similar, as discussed and shown in section 4.1. Thirty momentum strategies are selected with formation periods of one year, two years, three years, four years, and five years ($J = 6, 12, 18, 24, 30$) and holding periods of two months, one year, two years, three years, four years, and five years ($K = 1, 6, 12, 18, 24, 30$), which are commonly used strategies in momentum studies. The percentage yields of momentum strategies are calculated in the same way with the non-overlapping momentum return, as discussed in section 2.2.

Table 3 reports the annualized average bimonthly returns and percentage yields for the thirty momentum strategies and corresponding winners and losers portfolios. Panel A and Panel B separately present the average returns and percentage yields for the winners and losers portfolios. Some interesting patterns for winners and losers returns can be observed. Specifically, for each formation group (each row), that is, the momentum strategies with the same formation period, the winners returns are U-shaped, while the losers returns are inverted-U-shaped. For each holding group (each column), that is, the momentum strategies with the same holding period, the winners returns increase but the losers returns decrease with growing formation periods longer than two years, except for the first holding group with a two-month holding period - which does not seem to exhibit clear patterns for winners and losers returns. Furthermore, the percentage yields of winners portfolios are all positive, while the percentage yields of loser portfolios are all

Table 3: Annualized returns and percentage yields for winners, losers and winners-losers portfolios with futures returns.

	K=1	K=6	K=12	K=18	K=24	K=30	K=1	K=6	K=12	K=18	K=24	K=30
Panel A: Winners portfolio												
	Annualized average returns (%)						*Annualized Standard deviation for returns (%)*					
J=6	13.95	9.76	8.20	8.65	8.83	8.97	8.45	7.91	7.29	7.03	6.84	6.68
J=12	9.65	7.98	7.33	8.26	8.55	9.02	8.31	7.97	7.60	7.34	7.04	6.87
J=18	9.52	8.48	8.39	9.19	9.32	9.72	8.42	8.34	7.92	7.66	7.34	7.24
J=24	10.92	8.99	8.98	10.05	10.48	10.61	9.38	8.39	8.16	7.97	7.85	7.79
J=30	9.65	9.47	9.87	10.85	10.99	10.90	9.17	8.49	8.31	8.14	8.06	8.01
	Annualized average yields (%)						*Annualized Standard deviation for yields(%)*					
J=6	10.82	8.27	5.63	4.30	3.69	3.31	2.25	2.07	1.83	1.71	1.68	1.62
J=12	10.82	7.51	5.10	4.05	3.55	3.30	2.23	1.97	1.77	1.68	1.61	1.60
J=18	9.91	6.92	4.94	4.14	3.74	3.57	2.23	1.94	1.78	1.70	1.68	1.67
J=24	8.94	6.46	4.76	4.22	4.01	3.86	2.19	1.96	1.74	1.77	1.78	1.79
J=30	8.64	6.45	5.02	4.52	4.28	4.00	2.11	1.91	1.83	1.86	1.86	1.86
Panel B: Losers portfolios												
	Annualized average returns (%)						*Annualized Standard deviation for returns (%)*					
J=6	5.00	8.15	9.14	9.05	8.35	7.89	7.05	6.23	5.96	5.82	5.74	5.81
J=12	7.72	8.47	9.12	8.46	7.69	7.31	6.64	6.18	6.12	5.99	5.91	5.97
J=18	6.26	8.13	8.14	7.41	6.78	6.62	6.75	6.34	6.11	6.11	6.08	6.14
J=24	7.21	7.93	7.46	6.67	6.31	6.39	6.29	6.19	6.17	6.22	6.20	6.26
J=30	6.36	7.31	7.33	6.52	6.31	6.37	6.48	6.51	6.60	6.60	6.58	6.60
	Annualized average yields (%)						*Annualized Standard deviation for yields(%)*					
J=6	-9.25	-6.53	-3.84	-2.45	-1.90	-1.69	2.00	1.77	1.80	1.80	1.74	1.73
J=12	-9.22	-5.97	-3.56	-2.37	-2.01	-1.95	2.02	1.91	1.91	1.85	1.80	1.81
J=18	-8.01	-5.37	-3.34	-2.49	-2.28	-2.16	2.06	1.95	1.93	1.89	1.86	1.84
J=24	-7.30	-4.75	-3.15	-2.53	-2.34	-2.18	2.10	1.98	1.99	2.00	1.95	1.93
J=30	-6.76	-4.83	-3.33	-2.62	-2.35	-2.14	2.04	2.05	2.07	2.07	2.03	1.98
Panel C: Winners-losers portfolios												
	Annualized average returns (%)						*Annualized Standard deviation for returns (%)*					
J=6	8.96	1.61	-0.94	-0.40	0.48	1.09	20.38	16.15	11.90	10.10	8.56	7.82
J=12	1.93	-0.49	-1.80	-0.21	0.86	1.71	19.46	17.05	14.86	12.91	11.33	10.27
J=18	3.26	0.35	0.24	1.78	2.54	3.10	19.26	18.09	16.27	14.97	13.53	12.44
J=24	3.71	1.06	1.52	3.38	4.17	4.22	20.52	18.52	17.55	16.58	15.33	14.54
J=30	3.29	2.16	2.54	4.33	4.68	4.53	19.37	18.20	17.37	16.41	15.83	15.38
	Annualized average yields (%)						*Annualized Standard deviation for yields(%)*					
J=6	20.07	14.80	9.47	6.75	5.59	5.00	5.90	4.51	3.41	2.89	2.51	2.21
J=12	20.05	13.48	8.66	6.42	5.57	5.24	5.63	4.70	4.17	3.62	3.16	2.93
J=18	17.92	12.28	8.28	6.63	6.02	5.72	5.73	4.87	4.34	3.90	3.61	3.32
J=24	16.24	11.22	7.92	6.74	6.35	6.04	5.77	5.02	4.47	4.33	4.07	3.88
J=30	15.40	11.28	8.35	7.14	6.63	6.14	5.70	5.01	4.76	4.56	4.44	4.30

Note: This table reports the annualized returns and percentage yields for winners, losers and winners-losers portfolios. The percentage yield of winners, losers and winners-losers portfolios are constructed in the same way of the construction of portfolios. J is the formation period to rank commodities. K is the holding period for the winners and losers portfolios. One period refers to two months. The sample starts from September 1970 in order to use balanced bimonthly portfolio returns. The sample ends in September 2020.

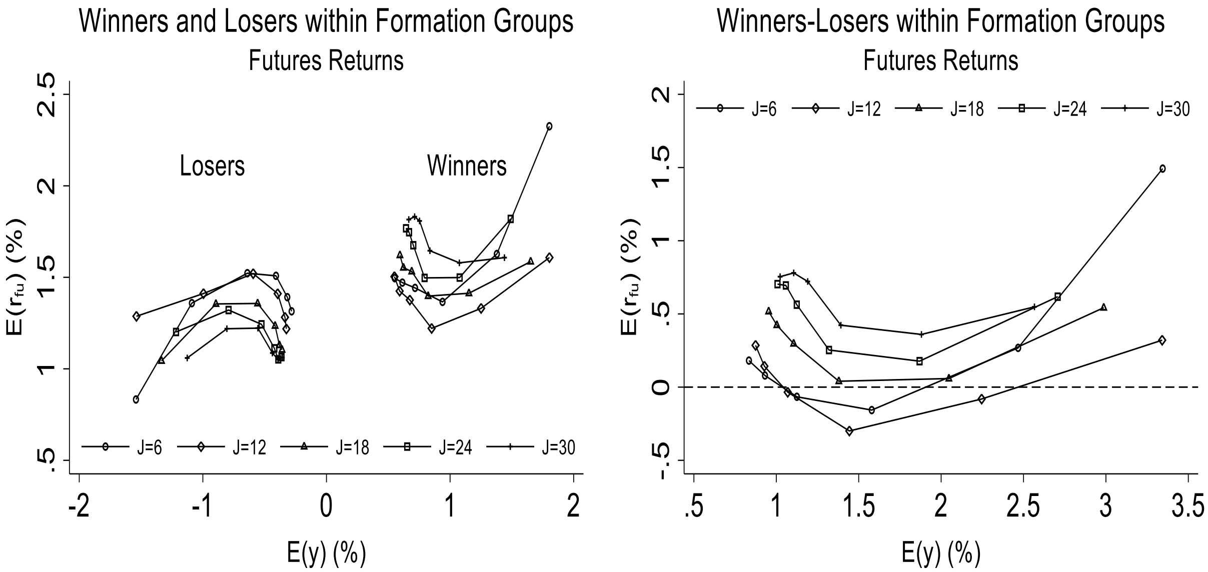
negative. The futures contracts in winner portfolios are more backwardated than those in loser portfolios, as implied by the theory of storage (Kaldor, 1939; Working, 1949; Brennan,

1958) and the hedging pressure hypothesis (Keynes, 1930). However, the positive percentage yields of winners decline and the negative percentage yields of losers increase with holding periods in each formation groups, suggesting that the backwardated portfolios tend to be less backwardated while the contangoed portfolios tend to be less contangoed with increasing holding periods.

Panel C presents some additional results of interest for the winners-losers portfolios. Generally, there is a wide range of average returns of momentum strategies, ranging from -1.80% to 8.96% annually among the thirty strategies. For each formation group, the winners-losers returns (momentum profits) are U-shaped. The momentum profits are negative with holding period of around one to three years in the first two formation groups with one- and two-year formation period, suggesting a reversal effect. In the other three groups with longer formation periods, all the momentum profits are positive, suggesting a momentum effect. These patterns are consistent with the findings with cumulative momentum profits discussed in section 4.1. Noteworthy, the momentum returns in each holding groups vary a lot, which provides evidence of some effect of the formation period on momentum profits. Specifically, there is a clear increasing pattern in the profits of the holding groups with three- to five-year holding period. It seems that the formation period affects the risk loadings that the momentum strategies are exposed to, as well as they do for the holding periods, and the role of the formation period thus requires more attention. The percentage yields of the winners-losers portfolios have a decreasing pattern in each formation groups, while the patterns in each holding groups are not fully consistent. The annualized returns and percentage yields of the momentum strategies and corresponding winners and losers portfolios for spot returns are shown in Table B.2 in Appendix B, which provides similar evidence.

Figure 3 visualizes the cross-sectional relationship between the average returns and the percentage yields among the thirty momentum strategies. As shown in Panel A, within each formation group, there is a consistent U-shaped relationship for the winners and

Panel A: Formation Groups



Panel B: Holding Groups

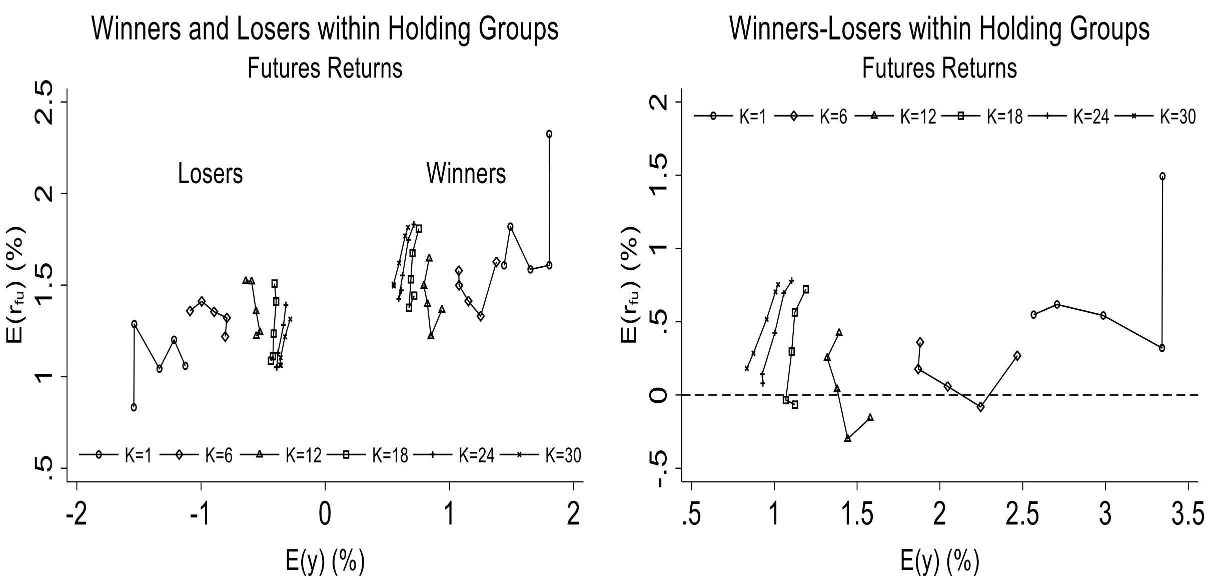


Figure 3: Return-yield relationship across different momentum strategies. *Note:* This Figure shows the cross-sectional relationships between bimonthly percentage yields and average futures returns of winners, losers, winners-losers portfolios within formation and holding groups. The percentage yield of winners, losers and winners-losers portfolios are constructed in the same way of the construction of portfolios. $E\left(r_{fu}\right)$ refers to bimonthly average futures returns. Sample ranges from November 1970 to September 2020. J is the formation period to rank commodities. K is the holding period for the winners and losers portfolios. One period refers to two months. Panel A connects the portfolios with different holding periods within formation groups. Panel B connects the portfolios with different formation periods within holding groups.

winners-losers portfolios, while an inverted U-shaped relationship exists for the losers portfolios. Panel B displays the cases within each holding group. There is a slightly positive cross-sectional relationship for the winners, losers, or winners-losers portfolios with four- and five-year holding period. However, there are no clear cross-sectional patterns for other holding groups. Similar results are found for the thirty spot momentum strategies, as shown in Figure C.1 in Appendix C.

Different from the findings discussed in section 3.3 that the futures returns are positively related to the percentage yields across individual commodities, there is no monotonous cross-sectional relationship between the percentage yields and the returns of winners, losers and winners-losers portfolios. These findings suggest that the cross-section of momentum returns indicate different risk exposures compared to the cross-section of individual commodity returns. Therefore, it is not clear whether the yield factor can explain the cross-section of momentum returns, although again, it is strongly implied by the theory of storage (Kaldor, 1939; Working, 1949; Brennan, 1958) and the hedging pressure hypothesis (Keynes, 1930). As shown in Figure 3, the conjecture that the portfolios with higher percentage yields have a higher return holds for some winners, losers and winners-losers portfolios in each formation group. The percentage yield, at minimum, seems to represent a risk factor, although it might not be able to represent all relevant risks that the momentum strategies are exposed to. In this regard, the momentum risk and yield risk do not totally overlap. This might explain the benefits to combine momentum and term-structure signals in Fuertes et al. (2010), which suggests the outperformance of the double-sort strategies over the pure momentum and term-structure strategies.

4.3. Risk-return explanation for momentum and reversal patterns with constant risk premiums

Next, I aim to jointly explain the observed momentum and reversal patterns with the assumption that the momentum profits are compensations for bearing systematic risks. The intuition is that the risk sensitivities of the winners-losers portfolios with different formation and holding periods might be different. It is rather obvious that the momentum portfolios selected with different formation periods might have different risk sensitivities because the corresponding winners and losers portfolios might consist of different commodity sets. Similarly, once the winners and losers portfolios are selected, the risk sensitivities might change over holding periods, resulting from the time-varying risk sensitivity of individual commodities and the corresponding futures. To put it differently, the risks loadings of the strategy to hold the portfolio for e.g., two months are different from those of the strategy to hold the portfolio for e.g., four months.

This section first studies the cross-section of momentum strategies with the assumption of constant risk premiums. As discussed in section 2.3, the intercepts of the time-series regressions in the first step of Fama and MacBeth (1973) two-step procedure provide an asset pricing test of whether the risk factors can explain the momentum and reversal effects. Under the adopted assumption, the risk premiums are restricted to the average returns of risk factors. Moreover, constant risk loadings of momentum strategies are assumed as well.[12] In order to be able to make a comparison with existing work, this section studies whether the yield factor, a mimicking risk factor related to the percentage yield, can explain the momentum and reversal effects discussed above. The time-series regression results of the thirty futures momentum strategies discussed in section 4.2 are shown in Table 4. Generally, the risk loadings of different momentum strategies are significant and vary from 0.11 to 0.42, which provides evidence to support the conjecture that risk compensation might explain variation in the momentum profits. These positive risk loadings are consistent with the findings of the specific momentum strategies with a formation

[12]The constant risk loadings of momentum strategies do not contradict to the time-varying risk loadings of individual commodities if they are. Assume that the momentum portfolios are selected at the end of January according to the performance in past two months, the momentum strategy to hold the portfolio to the end of March has different risk loadings to the strategy to hold the portfolio to the end of May, which might because the time-varying risk loadings of individual commodities from March to May. But the momentum portfolio selected at the end of January and held to the end of Mach might has the same risk loadings with the momentum portfolio selected at the end of March according to the performance in past two months and held to the end of May. That is the momentum strategy with formation period with two months and holding period of two months have the same risk loadings from March to May. The risk loadings of momentum strategies, of course, might also be time-varying. This paper tests the robustness in section 4.5.

period of twelve months and a holding period of one month reported in de Groot et al. (2014) and Bianchi et al. (2016). Moreover, the risk loadings are larger but fluctuate less for the holding groups with shorter holding periods. The R^2 of the time-series regressions are also shown in Table 4, which highlights the fraction of time-series variation of momentum returns that the yield factor can explain. The yield factor captures more of the time-series variation in returns in the holding group with a two-month holding period, consistent with the larger risk loadings in this holding group.

Table 4: Pricing errors and GRS tests for futures momentum strategies with one-factor model with yield factor.

	K=1	K=6	K=12	K=18	K=24	K=30	K=1	K=6	K=12	K=18	K=24	K=30
Futures returns (*GRS: F=1.70***)												
	β_{HML_y}						$t(\beta_{HML_y})$					
J=6	0.42	0.31	0.21	0.19	0.12	0.11	4.48	3.43	3.33	3.51	2.67	3.18
J=12	0.40	0.30	0.26	0.20	0.15	0.15	3.65	3.12	3.32	2.73	2.76	3.75
J=18	0.43	0.33	0.23	0.19	0.15	0.18	4.86	3.37	2.59	2.61	2.76	4.24
J=24	0.41	0.26	0.18	0.16	0.18	0.21	3.08	2.43	2.01	2.05	2.88	3.85
J=30	0.40	0.28	0.21	0.21	0.21	0.21	4.07	4.13	3.26	3.47	3.69	3.76
	$\alpha(\%)$						$t(\alpha)$					
J=6	0.69	-0.32	-0.56	-0.42	-0.15	-0.03	1.39	-0.66	-1.66	-1.75	-0.72	-0.14
J=12	-0.44	-0.65	-0.79	-0.41	-0.15	0.00	-0.82	-1.33	-2.22	-1.38	-0.54	0.02
J=18	-0.28	-0.57	-0.39	-0.06	0.13	0.17	-0.63	-1.24	-1.00	-0.16	0.39	0.56
J=24	-0.17	-0.31	-0.08	0.26	0.35	0.30	-0.30	-0.67	-0.20	0.63	0.91	0.84
J=30	-0.21	-0.18	0.02	0.32	0.38	0.36	-0.48	-0.39	0.04	0.80	0.96	0.94
	$R^2(\%)$											
J=6	16.15	13.78	11.92	13.19	7.78	7.55						
J=12	16.22	11.84	11.36	8.93	6.87	7.88						
J=18	19.06	12.80	7.46	5.85	4.95	8.24						
J=24	15.38	7.25	3.89	3.58	5.47	8.01						
J=30	16.05	9.18	5.70	6.24	6.75	6.99						

Note: This table reports the risk loadings and pricing errors (α) for momentum strategies with constant risk premium. The t-statistic is corrected with Newey and West (1978) procedure with one lag. The GRS F-statistics are also shown in the table. The null hypothesis of GRS test is that the pricing errors are jointly zero. *, ** and *** denotes 10%, 5% and 1% significance respectively. J is the formation period to rank commodities. K is the holding period for the winners-losers portfolios. One period refers to two months. The sample starts from September 1970 in order to use balanced bimonthly portfolio returns. The sample ends in September 2020.

The intercepts, denoted with α, of the time-series regressions are shown in Table 4 as well. As discussed in section 2.3, the intercepts represent pricing errors when the risk factors are excess returns and hint at the performance of risk factors in explaining the cross-section of momentum returns. If a model works well, the pricing errors should be insignificantly different from zero. Only three of the thirty intercepts are slightly significantly different from zero. Elven of the thirty intercepts are smaller than 0.2% bimonthly (implying around 1.2% yearly) at the absolute level, which is quite small in both statistical and economic terms. There is a clear pattern though, all alphas to the upper left are negative and vice versa. In order to statistically test the hypothesis that the thirty intercepts are jointly zero, this paper applies the Gibbons et al. (1989) test (GRS) as in Fama and French (1993, 1996). However, the F-statistic of the GRS test suggests that the thirty intercepts are not jointly zero. As such, the GRS test implies that the yield factor alone cannot fully explain the variation in expected returns of the thirty momentum strategies, which is not surprising because of the U-shaped cross-sectional relationship between momentum returns and percentage yields. But the results do hint that the yield factor can explain part of the cross-sectional variation in expected momentum returns, suggested by the economically small intercepts. The regression results of spot momentum returns on the yield factor are shown in Table B.3 in Appendix B, which demonstrates similar results.

Figure 4 displays the explanatory power of the yield factor for the momentum returns. The predicted average returns are calculated by multiplying the risk loadings with the average return of the yield factor. The distance of each scatter, representing each momentum portfolio, to the 45-degree line is the pricing error, that is the difference between the realized and predicted momentum returns. As shown in Figure 4, the yield factor explains some variation across the expected momentum returns within each formation group. The scatters of the formation groups with longer formation periods are closer to the 45-degree lines, suggesting better explanatory performance of the yield factor for these strategies. Yet, the yield factor only explains little variation across expected momentum returns within each holding groups. The yield factor performs better for the two holding groups with four- and five-year holding periods compared to other holding groups, where the scatters almost line up vertically. This is might be because of the small variation of the risk loadings in the holding groups with shorter holding periods, which prevents the yield factor from explaining much variation across the momentum returns within these holding groups. The R^2 of the cross-sectional regression of average momentum returns on their risk loadings is also shown in the figures. The yield factor only explains 8.45% of the cross-sectional variation among expected momentum returns when the risk premium is restricted to be constant, among which the variation within formation groups contributes more than that within holding groups. Similar explanatory power of the yield factor to the spot momentum returns is suggested in Figure C.2 in Appendix C.

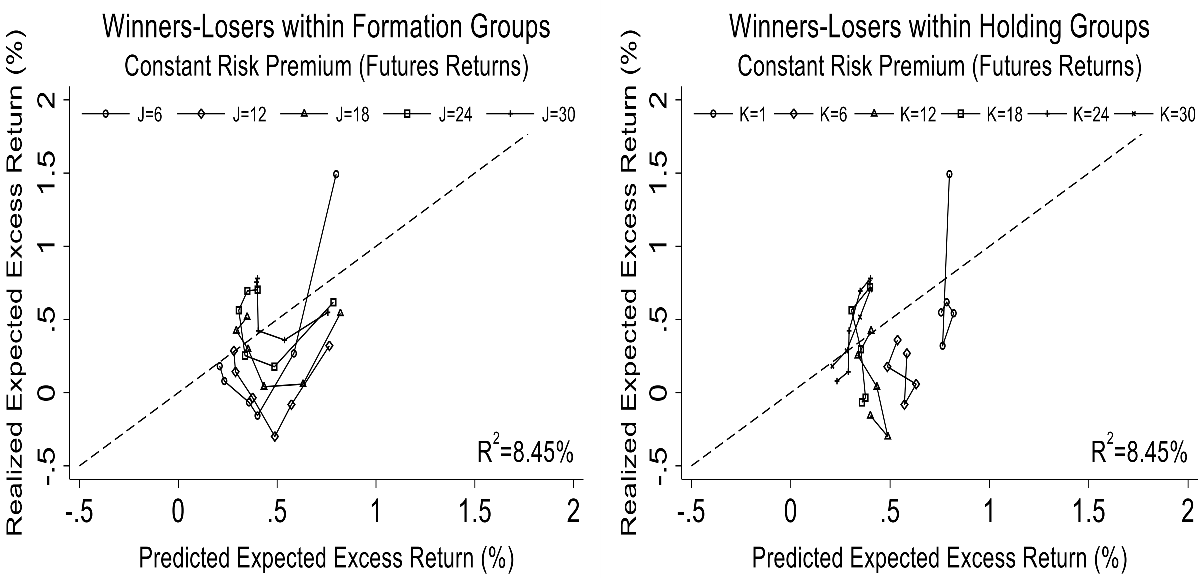


Figure 4: Realized and predicted average returns of one-factor model with yield factor with constant risk premiums. *Note:* The predicted expected returns are calculated with $E\left(WML_{J-K}\right) = \hat{\beta}_{i,f}\hat{\lambda}_f$, where $\hat{\beta}_{i,f}$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). $\hat{\lambda}_f$ is the average return of risk factors. The realized expected returns are the average return in the sample from November 1970 to September 2020. The R^2 is calculated with the cross-sectional regression of the realized expected returns of the thirty winners-losers portfolios on the estimated risk loadings $\hat{\beta}_{i,f}$. J is the formation period to rank commodities. K is the holding period for the winners and losers portfolios. One period refers to two months.

In addition to the yield factor, this section also studies the performance of the common asset pricing factors and their performance combined with the yield factor, again with the restriction of constant risk premiums in explaining the cross-section of momentum returns. The intercepts of the time-series regressions are shown in Table 5.[13] When the four asset pricing models, including the Capital Asset Pricing Model ($CAPM$), the Fama and

[13]The risk loadings of the asset pricing models and the ones including yield factor are not reported in this paper but are available upon request.

Table 5: Pricing errors and GRS tests for futures momentum strategies with constant risk premium.

	K=1	K=6	K=12	K=18	K=24	K=30	K=1	K=6	K=12	K=18	K=24	K=30
Panel A: $CAPM$ model (*GRS: F=1.81****)												
	$\alpha(\%)$						$t\,(\alpha)$					
J=6	1.55	0.34	-0.08	-0.03	0.13	0.23	3.00	0.76	-0.27	-0.12	0.57	1.11
J=12	0.46	0.02	-0.23	0.04	0.21	0.33	0.91	0.05	-0.63	0.11	0.71	1.24
J=18	0.71	0.19	0.17	0.40	0.51	0.57	1.50	0.41	0.42	1.06	1.45	1.78
J=24	0.81	0.34	0.40	0.68	0.78	0.76	1.43	0.70	0.90	1.58	1.94	2.00
J=30	0.73	0.53	0.55	0.80	0.84	0.79	1.44	1.15	1.26	1.92	2.05	2.00
Panel B: $FF3$ model (*GRS: F= 1.75***)												
	$\alpha(\%)$						$t\,(\alpha)$					
J=6	1.44	0.21	-0.20	-0.14	0.03	0.15	2.82	0.47	-0.65	-0.52	0.14	0.74
J=12	0.34	-0.14	-0.37	-0.08	0.11	0.25	0.67	-0.31	-0.99	-0.26	0.37	0.94
J=18	0.59	0.01	0.00	0.26	0.39	0.48	1.26	0.03	-0.01	0.69	1.12	1.50
J=24	0.61	0.12	0.23	0.53	0.66	0.66	1.04	0.25	0.51	1.25	1.65	1.74
J=30	0.50	0.36	0.40	0.67	0.74	0.71	1.01	0.78	0.90	1.61	1.81	1.80
Panel C: $FF4$ model (*GRS: F=1.59***)												
	$\alpha(\%)$						$t\,(\alpha)$					
J=6	0.97	-0.04	-0.36	-0.22	-0.01	0.11	1.82	-0.08	-1.08	-0.82	-0.03	0.52
J=12	0.06	-0.34	-0.47	-0.14	0.05	0.18	0.12	-0.71	-1.16	-0.40	0.15	0.63
J=18	0.23	-0.16	-0.09	0.20	0.31	0.40	0.46	-0.34	-0.20	0.50	0.85	1.18
J=24	0.34	0.00	0.13	0.45	0.58	0.58	0.58	-0.01	0.28	0.99	1.37	1.45
J=30	0.19	0.19	0.27	0.58	0.65	0.63	0.39	0.40	0.58	1.31	1.51	1.51
Panel D: $FF5$ model (*GRS:F=2.21****)												
	$\alpha(\%)$						$t\,(\alpha)$					
J=6	1.38	0.08	-0.26	-0.09	0.13	0.25	2.52	0.17	-0.81	-0.32	0.57	1.17
J=12	0.24	-0.26	-0.36	0.03	0.23	0.38	0.44	-0.55	-0.89	0.08	0.79	1.37
J=18	0.44	0.01	0.09	0.43	0.57	0.68	0.86	0.02	0.22	1.10	1.59	2.02
J=24	0.77	0.29	0.44	0.81	0.95	0.92	1.22	0.59	0.97	1.84	2.30	2.30
J=30	0.76	0.49	0.63	0.97	1.01	0.99	1.43	1.00	1.36	2.19	2.34	2.34
Panel E: $YCAPM$ model (*GRS:F=1.67***)												
	$\alpha(\%)$						$t\,(\alpha)$					
J=6	0.70	-0.29	-0.51	-0.42	-0.12	0.01	1.24	-0.51	-1.30	-1.53	-0.48	0.05
J=12	-0.35	-0.58	-0.75	-0.36	-0.10	0.03	-0.55	-1.00	-1.88	-1.14	-0.34	0.11
J=18	-0.15	-0.47	-0.28	0.04	0.20	0.20	-0.32	-0.88	-0.64	0.09	0.57	0.61
J=24	-0.02	-0.17	0.06	0.37	0.42	0.33	-0.03	-0.32	0.13	0.84	1.01	0.86
J=30	-0.07	-0.02	0.13	0.38	0.41	0.36	-0.14	-0.05	0.29	0.88	0.97	0.90
Panel F: $YFF3$ model (*GRS:F=1.64***)												
	$\alpha(\%)$						$t\,(\alpha)$					
J=6	0.67	-0.34	-0.57	-0.47	-0.17	-0.03	1.19	-0.60	-1.47	-1.73	-0.73	-0.15
J=12	-0.38	-0.67	-0.82	-0.42	-0.15	-0.01	-0.61	-1.15	-2.06	-1.34	-0.53	-0.03
J=18	-0.19	-0.56	-0.38	-0.05	0.13	0.16	-0.39	-1.06	-0.89	-0.12	0.38	0.48
J=24	-0.11	-0.29	-0.05	0.28	0.35	0.29	-0.17	-0.58	-0.11	0.64	0.84	0.73
J=30	-0.19	-0.12	0.05	0.31	0.37	0.34	-0.40	-0.24	0.10	0.72	0.86	0.82

Table 5: Pricing errors and GRS tests for futures momentum strategies with constant risk premium (continued).

	K=1	K=6	K=12	K=18	K=24	K=30	K=1	K=6	K=12	K=18	K=24	K=30
Panel G: $YFF4$ model (*GRS: F=1.62***)												
	$\alpha(\%)$						$t(\alpha)$					
J=6	0.22	-0.57	-0.71	-0.55	-0.21	-0.07	0.38	-1.02	-1.81	-1.94	-0.85	-0.31
J=12	-0.64	-0.85	-0.91	-0.47	-0.21	-0.07	-1.02	-1.46	-2.13	-1.38	-0.68	-0.25
J=18	-0.53	-0.72	-0.46	-0.10	0.06	0.08	-1.06	-1.34	-1.01	-0.26	0.17	0.24
J=24	-0.36	-0.41	-0.14	0.20	0.28	0.21	-0.53	-0.78	-0.29	0.43	0.62	0.51
J=30	-0.48	-0.27	-0.07	0.23	0.29	0.26	-0.98	-0.54	-0.15	0.49	0.62	0.59
Panel H: $YFF5$ model (*GRS: F=2.02****)												
	$\alpha(\%)$						$t(\alpha)$					
J=6	0.65	-0.47	-0.62	-0.41	-0.06	0.07	1.13	-0.85	-1.60	-1.47	-0.28	0.31
J=12	-0.46	-0.77	-0.79	-0.30	-0.01	0.13	-0.73	-1.34	-1.91	-0.92	-0.05	0.48
J=18	-0.30	-0.55	-0.27	0.14	0.33	0.37	-0.62	-1.03	-0.62	0.37	0.91	1.10
J=24	0.06	-0.12	0.17	0.57	0.65	0.57	0.09	-0.24	0.37	1.28	1.55	1.41
J=30	0.11	0.03	0.29	0.63	0.66	0.63	0.23	0.06	0.61	1.38	1.48	1.47

Note: This table reports the pricing errors (α) for the thirty momentum strategies with constant risk premium. $t(\alpha)$ is corrected with Newey and West (1978) procedure with one lag. The GRS F-statistics are also shown in the table. The null hypothesis of GRS test is that the pricing errors are jointly zero. *, ** and *** denotes 10%, 5% and 1% significance respectively. J is the formation period to rank commodities. K is the holding period for the winners and losers portfolios. One period refers to two months. The sample starts from September 1970 in order to use balanced bimonthly portfolio returns. The sample ends in September 2020. $CAPM$ refers to the model only including MKT factor. $FF3$ refers to the model including MKT, SMB, and HML factors. $FF4$ refers to the model including MKT, SMB, HML, and MOM factors. $FF5$ refers to the model including MKT, SMB, HML, RMW and CMA factors. $YCAPM$, $YFF3$, $YFF4$, and $YFF5$ respectively refer to the models including HML_y factor in addition to the factors in $CAPM$, $FF3$, $FF4$, and $FF5$.

French (1993) three-factor model, the Carhart (1997) four-factor model, and the Fama and French (2015) five-factor model, are used without the addition of the yield factor, the GRS test suggests to reject these four asset pricing models in explaining the cross-section of momentum returns. This finding is consistent with the findings in Kang and Kwon (2017) although their analysis differs in that they consider momentum strategies with formation periods up to one year for an international commodity markets. Table 5 also shows the intercepts of the four combined models incorporating the yield factor into the four asset pricing models. Compared with the intercepts of the common asset pricing models, augmenting them with the yield factor helps to decrease the large positive intercepts, though it renders the negative intercepts even more negative. However, the GRS test still rejects those combined asset pricing models. The regression results of the four asset pricing models and the four combined models for the spot momentum returns are shown in Table B.4 in Appendix B. The intercepts are quantitively similar to those discussed in Table 5. Notably, the GRS test marginally accepts the Carhart (1997) four-factor model and the two combined models adding the yield factor in the Fama and French (1993) three-factor model and Carhart (1997) four-factor model for spot momentum returns. But recall that the intercepts were already rather small and therefore any minor difference might lead to the GRS test accepting the models.

The realized and predicted average futures momentum returns of the models discussed in Table 5 are shown in Figure 5 and Figure 6. As shown in Figure 5, which displays the performance of those models within each formation groups, the Carhart (1997) four-factor model performs better than the other three common asset pricing models, suggested by the distance of the scatters to the 45-degree line. This might be driven by the high average return of the equity momentum factor, which enhances the ability of the Carhart (1997) four-factor model to explain the cross-section of expected momentum returns. The Carhart (1997) four-factor model explains 73.69% of the variation across expected momentum returns, suggested by the R^2 of the cross-sectional regression of expected momentum returns on the risk factors. By incorporating the yield factor into the four asset pricing models, the performance is improved especially for the Capital Asset Pricing Model ($CAPM$) and the Fama and French (1993) three-factor model, which does not explain the cross-section among momentum returns well within formation groups when used without the addition of the yield factor. The four combined asset pricing models consistently perform better for the formation groups with longer formation periods. Figure 6 shows the model performance for the momentum returns within holding groups. Again, the models combined with the yield factor perform better than the four common asset pricing models and do a better job for the two holding groups with four- and five-year holding periods. Similar patterns are found in the spot momentum returns with the assumption of constant risk premiums, as shown in Figure C.3 and Figure C.4 in Appendix C.

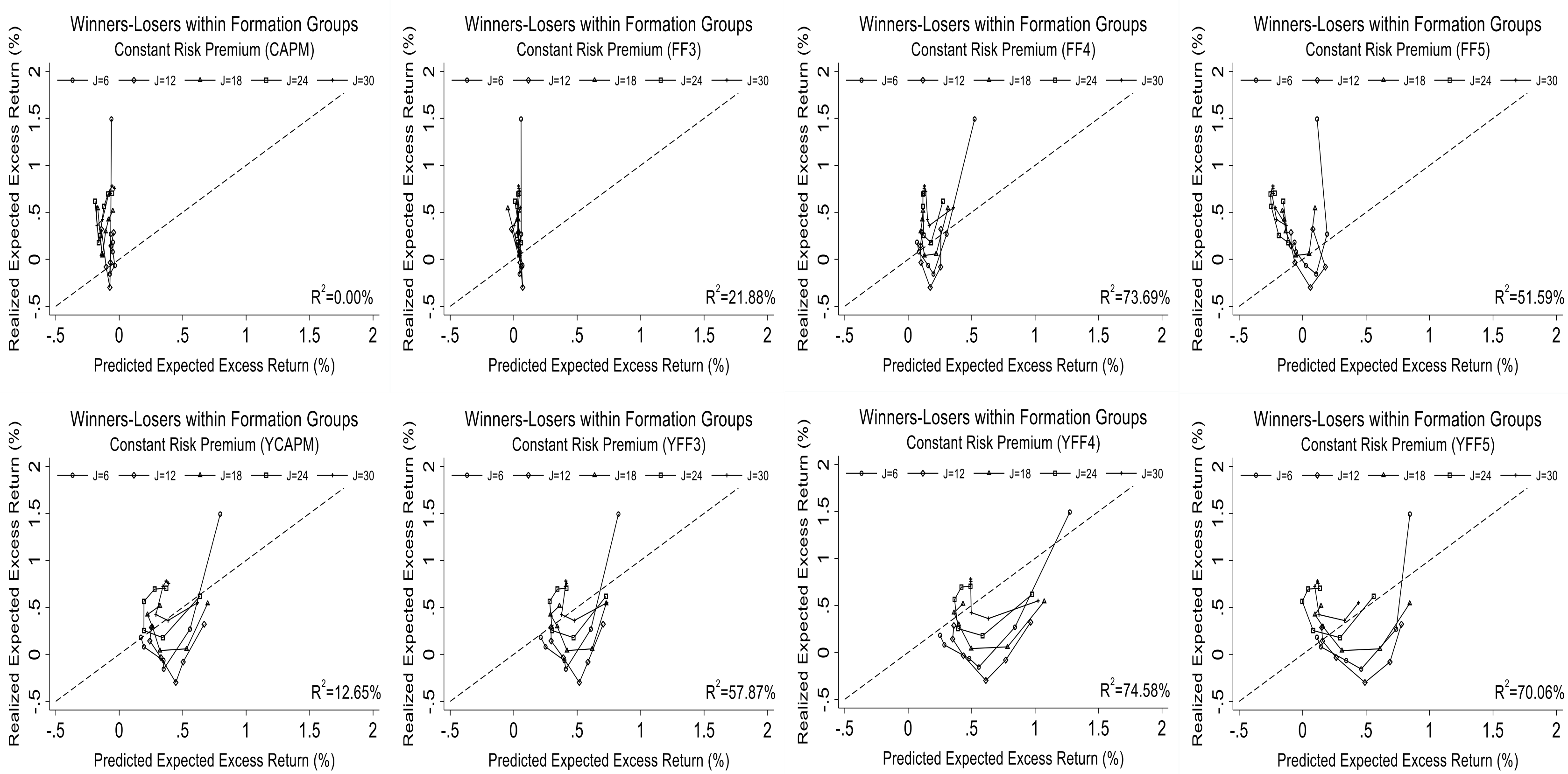


Figure 5: Realized and predicted average returns with constant risk premiums within formation groups. *Note:* The predicted expected returns are calculated with $E\left(WML_{J-K}\right) = \hat{\beta}_{i,f}\hat{\lambda}_f$, where $\hat{\beta}_{i,f}$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). $\hat{\lambda}_f$ is the average return of risk factors. The realized expected returns are the average return in the sample from November 1970 to September 2020. The R^2 is calculated with the cross-sectional regression of the realized expected returns of the winners-losers portfolios on the estimated risk loadings $\hat{\beta}_{i,f}$. J is the formation period to rank commodities. K is the holding period for the winners and losers portfolios. One period refers to two months. $CAPM$ refers to the model only including MKT factor. $FF3$ refers to the model including MKT, SMB, and HML factors. $FF4$ refers to the model including MKT, SMB, HML, and MOM factors. $FF5$ refers to the model including MKT, SMB, HML, RMW and CMA factors. $YCAPM$, $YFF3$, $YFF4$, and $YFF5$ respectively refer to the models including HML_y factor in addition to the factors in $CAPM$, $FF3$, $FF4$, and $FF5$.

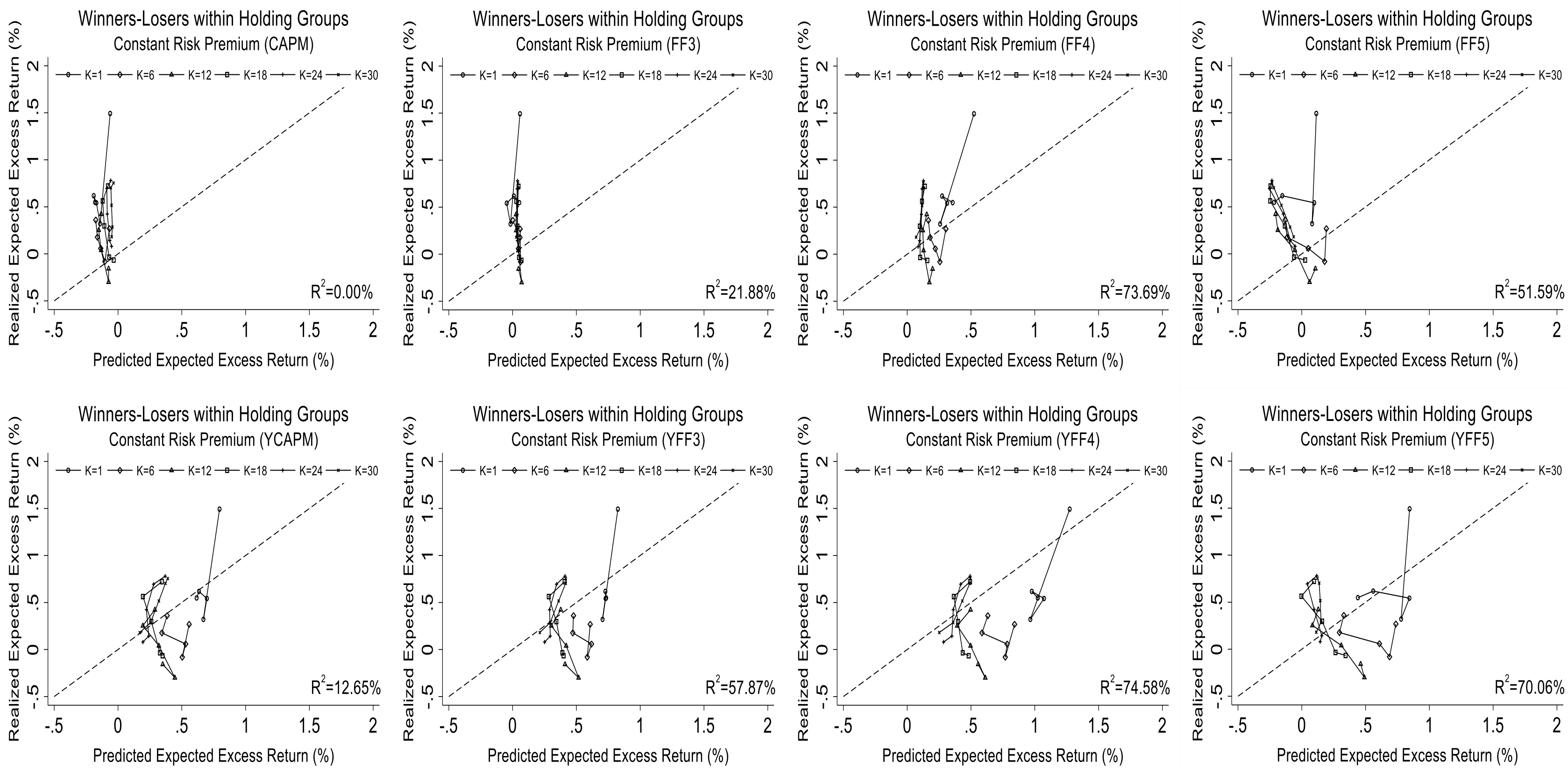


Figure 6: Realized and predicted average returns with constant risk premiums within holding groups. *Note:* The predicted expected returns are calculated with $E\left(WML_{J-K}\right) = \hat{\beta}_{i,f}\hat{\lambda}_f$, where $\hat{\beta}_{i,f}$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). $\hat{\lambda}_f$ is the average return of risk factors. The realized expected returns are the average return in the sample from November 1970 to September 2020. The R^2 is calculated with the cross-sectional regression of the realized expected returns of the winners-losers portfolios on the estimated risk loadings $\hat{\beta}_{i,f}$. J is the formation period to rank commodities. K is the holding period for the winners and losers portfolios. One period refers to two months. $CAPM$ refers to the model only including MKT factor. $FF3$ refers to the model including MKT, SMB, and HML factors. $FF4$ refers to the model including MKT, SMB, HML, and MOM factors. $FF5$ refers to the model including MKT, SMB, HML, RMW and CMA factors. $YCAPM$, $YFF3$, $YFF4$, and $YFF5$ respectively refer to the models including HML_y factor in addition to the factors in $CAPM$, $FF3$, $FF4$, and $FF5$.

To sum up, although the models considered in this section are rejected by the GRS test with the restriction of constant risk premiums, the yield factor and the combined models do have some ability to explain the cross-section of momentum returns. The combined models perform better than the common asset pricing models but exhibit similar performance patterns related to the yield factor, that is, a better performance for the formation groups with longer formation periods as well as for the holding groups with longer holding periods. Therefore, it appears that the yield factor contains important risk information for commodities that cannot be replaced with the common asset pricing factors.

4.4. *Risk-return explanation for momentum and reversal patterns with time-varying risk premiums*

The relatively poor performance of the models discussed in section 4.3 might be due to the assumption of constant risk premiums. Restricting the risk premiums to be equal to the average returns of the risk factors might be subject to some sample bias, because only the information contained in the risk factors matters to the level of risk premiums. This section estimates the risk premiums based on all the thirty futures momentum assets and also allows the risk premiums to change over time. The time-varying risk premiums are estimated with the second-step of the Fama and MacBeth (1973) two-step procedure based on the estimated risk loadings in the first step, as discussed in section 2.3.

The cross-sectional regression results with the thirty futures momentum returns of the second step of the Fama and MacBeth (1973) two-step procedure are reported in Table 6. In addition to the risk premiums and intercepts of the cross-sectional regressions, Table 6 also reports the average R^2 of the cross-sectional regressions over time. The average R^2 suggests a measure of fit of how much of the average cross-sectional variation among the expected momentum returns can be explained by a model, which is similar but different from the R^2 of the cross-sectional regression of the average momentum returns on the risk loadings discussed in section 4.3, which ignores the time dimension of the data and provides more an "intuitive" measure of fit.

Table 6: Fama-Macbeth cross-sectional regressions for futures momentum strategies.

Model	λ_{MKT} (%)	λ_{SMB} (%)	λ_{HML} (%)	λ_{MOM} (%)	λ_{RMW} (%)	λ_{CMA} (%)	λ_{HML_y} (%)	λ_0 (%)	Avg. R^2 (%)
YF							1.13	0.08	22.77
							(0.89)	(0.20)	
$CAPM$	-0.04							0.35	14.09
	(-0.02)							(1.61)	
$FF3$	-4.59**	-3.62*	-1.86					0.44*	42.86
	(-2.14)	(-1.77)	(-1.55)					(1.93)	
$FF4$	0.09	-4.74**	-1.61	6.22***				0.03	60.27
	(0.04)	(-2.48)	(-1.39)	(3.04)				(0.12)	
$FF5$	-2.73	-0.34	-1.32		1.73	-2.40***		-0.04	61.23
	(-1.38)	(-0.30)	(-1.19)		(1.60)	(-2.88)		(-0.20)	
$YCAPM$	2.28						1.44	0.13	38.02
	(0.79)						(0.99)	(0.36)	
$YFF3$	0.07	-4.45**	-1.86				2.61**	-0.17	56.54
	(0.03)	(-2.33)	(-1.55)				(2.28)	(-0.74)	
$YFF4$	-0.33	-4.74**	-1.54	7.72***			-1.42	0.13	64.76
	(-0.16)	(-2.48)	(-1.32)	(3.04)			(-1.06)	(0.69)	
$YFF5$	0.32	-1.87*	-2.80**		-0.98	-2.03**	2.98**	-0.20	67.54
	(0.15)	(-1.66)	(-2.28)		(-1.14)	(-2.47)	(2.55)	(-0.84)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for the thirty momentum strategies: $WML_{J-K,t} = \lambda_{0,t} + \hat{\beta}'_{J-K,f}\lambda_{f,t} + \epsilon_{J-K,t}$, where $WML_{J-K,t}$ refers to the excess return at time t of the winners-losers portfolios with formation period of J and holding period of K. $\hat{\beta}'_{J-K,f}$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). $\lambda_{f,t}$ is the risk premia of risk factor f. $\lambda_{0,t}$ and $\epsilon_{J-K,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of $\lambda_{f,t}$ and $\lambda_{0,t}$ are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with one lag. *, ** and *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R_t^2 of the T cross-sectional regressions. The sample ranges from September 1970 to September 2020. YF refers to the model only including HML_y factor. $CAPM$ refers to the model only including MKT factor. $FF3$ refers to the model including MKT, SMB, and HML factors. $FF4$ refers to the model including MKT, SMB, HML, and MOM factors. $FF5$ refers to the model including MKT, SMB, HML, RMW and CMA factors. $YCAPM$, $YFF3$, $YFF4$, and $YFF5$ respectively refer to the models including HML_y factor in addition to the factors in $CAPM$, $FF3$, $FF4$, and $FF5$.

As shown in Table 6, the commodity-specific one-factor model with the yield factor, YF, still cannot explain the cross-section of momentum returns, and the risk premium of the yield factor is estimated at 1.13% bimonthly (around 6.78% annually) but it is not significant. Among the four common asset pricing models, the Carhart (1997) four-factor model and the Fama and French (2015) five-factor model do a good job in explaining the cross-section of momentum returns, and explain on average around 60% of the cross-sectional variation. Particularly, the equity market excess factor in the Capital Asset Pricing Model ($CAPM$) is not significantly priced, implying the poor performance of the

$CAPM$ model. Although the equity market excess factor and the size factor are significantly priced (-4.95% bimonthly for the equity market excess factor and -3.62% bimonthly for the size factor) in the Fama and French (1993) three-factor model specification, the significant intercept suggests that on average a common return of around 0.44% bimonthly across momentum strategies is left unexplained by the Fama and French (1993) three-factor model, which might be due to an omitted risk factor. Considering the risk related to equity momentum, the Carhart (1997) four-factor model performs well with a significant risk premium for the size factor of -4.74% bimonthly and significant risk premium for the equity momentum factor of 6.22% bimonthly. Similarly, the Fama and French (2015) five-factor model does a good job with a significant risk premium for the investment risk factor of -2.4% bimonthly. Except for the equity momentum factor, the significant risk premiums for other risk factors, e.g., the size and investment factors, are negative. This is because the momentum returns have negative risk loadings on these risk factors in the unreported results. This implies that investors are willing to pay the risk premiums to get rid of the exposure to those risks.

Table 6 also reports the performance of the four combined models. The three combined models incorporating the yield factor into the Fama and French (1993) three-factor model, the Carhart (1997) four-factor model, and the Fama and French (2015) five-factor model ($YFF3$, $YFF4$, and $YFF5$ models) perform reasonably well. The yield factor has a positive and significant risk premium of 2.61% bimonthly in the $YFF3$ model, which is similar to the estimate for the $YFF5$ model (2.98% bimonthly). These results provide additional evidence that the yield factor contains important risk information that helps to explain the expected momentum returns, in line with the findings with constant risk premiums in section 4.3. The value factor is significantly and negatively priced in the $YFF5$ specifictation (-2.80% bimonthly). The negative risk premium of the value factor is found in the other models as well, although it is not significant. However, the risk loadings related to the value factor are consistently positive in all models (results not reported here). The momentum strategies that behave like value stock portfolios have negative risk premium. The value factor seems like a hedging instrument for the momentum strategies. Additionally, the yield factor is not significantly priced and the corresponding risk premium is even negative in $YFF4$ model, which might result from the large positive risk premium for the equity momentum factor, suggesting the strong ability of the equity momentum factor to explain the cross-section of commodity momentum returns. Finally, the estimated risk premiums for the risk factors are quite different from their average values, which I interpret as evidence in support of time-varying risk premiums. The cross-sectional regression results with time-varying risk premiums for spot momentum strategies suggest similar evidence, as shown in Table B.5 in Appendix B.

In order to visually compare the performance of those models discussed in Table 6, the realized and predicted momentum returns with time-varying risk premiums within each formation and holding groups are plotted in Figure 7 and Figure 8. The predicted momentum returns are calculated by multiplying the risk loading with the estimated risk premiums displayed in Table 6. Generally, the performance of all models are improved significantly with time-varying risk premiums compared to those under the assumption of constant risk premiums as shown in Figure 5 and Figure 6, except for the $CAPM$ model, which performs poorly in both cases. Specifically, as shown in Figure 7 and Figure 8, the Carhart (1997) four-factor model performs better than the other three common asset pricing models for the momentum returns within each formation and holding group, followed by the Fama and French (2015) five-factor model. With regard to the combined asset pricing models, the $YFF3$ and $YFF5$ perform much better than the Fama and French (1993) three-factor model and the Fama and French (2015) five-factor model. The performance of $YFF4$ model is only slightly improved compared to the Carhart (1997) four-factor model. Generally, the $YFF4$ model performs best among all the considered models, followed by the Carhart (1997) four-factor model. Different from the patterns shown in Figure 5 and Figure 6 that the combined models perform better for the groups with longer formation and holding periods, the scatters for the $YFF3$, $YFF4$, and $YFF5$ models with time-varying risk premiums scatter more closely to the 45-degree line as shown in Figure 7 and Figure 8, suggesting that these models perform quite well in explaining the cross-section of momentum returns within different formation and holding groups. The performance of these models for the spot momentum returns are shown in Figure C.5 and Figure C.6 in Appendix C, which provide similar evidence.

This section also provides evidence about whether the yield factor is redundant in the four combined models. As in Fama and French (2015) and Zaremba et al. (2019), this paper applies time-series spanning tests by regressing the yield factor on the common asset pricing factors for the Capital Asset Pricing Model ($CAPM$), Fama and French (1993) three-factor model, Carhart (1997) four-factor model, and Fama and French (2015) five-factor model. The aim of the time-series spanning test is to check whether the yield factor can be explained by those asset pricing factors, and as such, is a redundant risk factor. The regression results are shown in Table 7. The intercepts of the four time-series regressions are all around 2% bimonthly and significant at the 1% level, implying unexplained abnormal returns for the yield factor. Therefore, the yield factor is not redundant in the four combined models. Especially for the $YFF4$ model, the yield factor still seems to be required, although the performance is only slightly improved compared to the Carhart (1997) four-factor model.

In addition, this section checks whether the percentage yield of the corresponding momentum strategy directly helps to explain the cross-section of momentum returns. This is motivated by the ability of firms' characteristics, e.g., book equity to market equity ratio (BE/ME) and market equity (ME), to capture the cross-section of average stock returns, as evidenced in Fama and French (1992). In order to study whether the percentage yield, as a commodity *characteristic*, matters to momentum returns, the percentage yield of each momentum strategy is added to the cross-sectional regression in the second step of the Fama and MacBeth (1973) two-step procedure, besides the risk loadings discussed above. Sim-

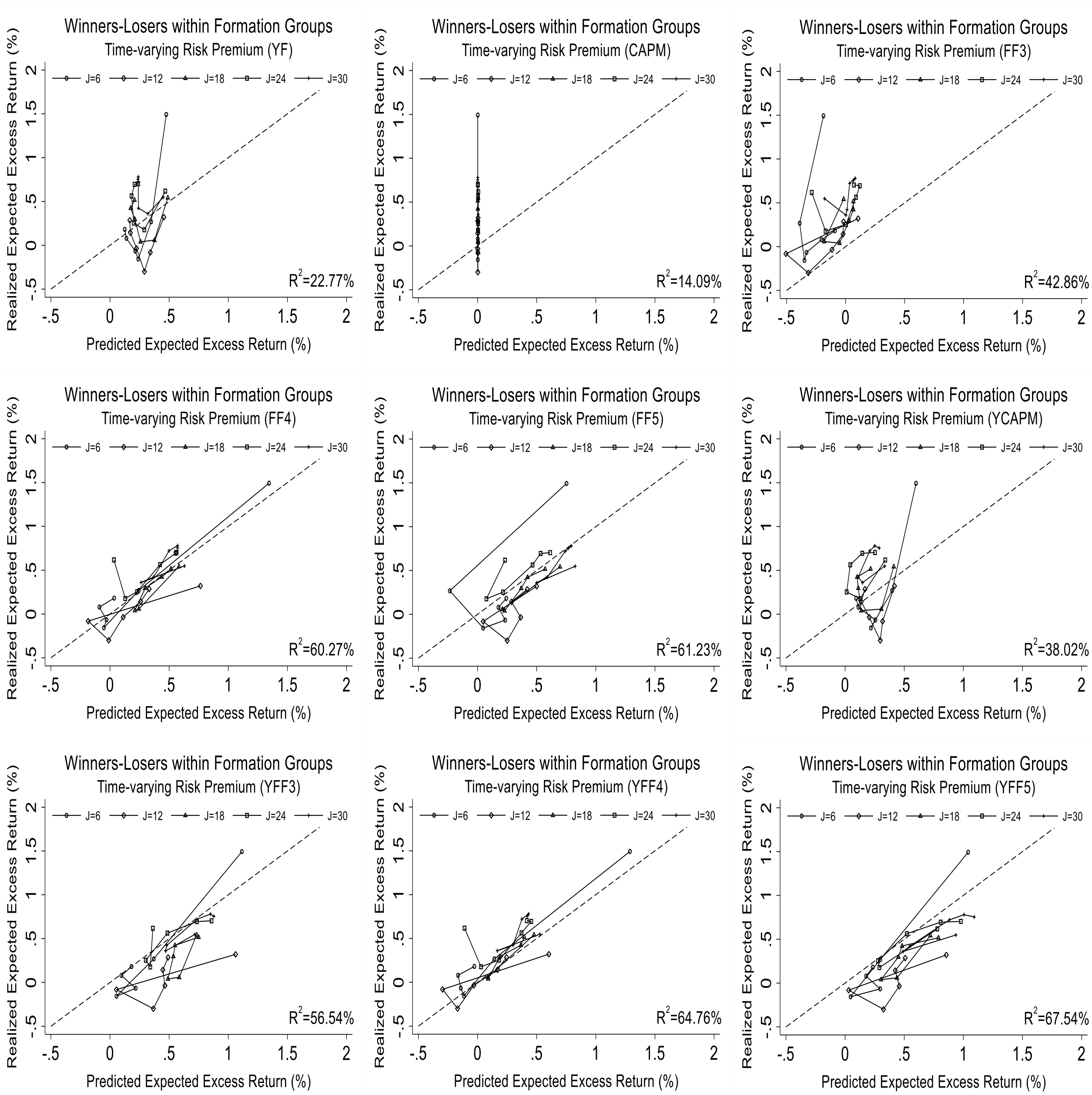


Figure 7: Realized and predicted average returns with time-varying risk premiums within formation groups. *Note:* The predicted expected returns are calculated with $E\left(WML_{J-K}\right) = \hat{\beta}_{i,f}\hat{\lambda}_f$, where $\hat{\beta}_{i,f}$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). $\hat{\lambda}_f$ is the estimated risk premia of risk factors with the cross-sectional regressions (the second step) of Fama and MacBeth (1973). The realized expected returns are the average return in the sample from November 1970 to September 2020. The R^2 is the average value of the R_t^2 of the T cross-sectional regressions. That is $R^2 = \sum_{t=1}^{T} R_t^2/T$. J is the formation period to rank commodities. K is the holding period for the winners and losers portfolios. One period refers to two months. YF refers to the model only including HML_y factor. $CAPM$ refers to the model only including MKT factor. $FF3$ refers to the model including MKT, SMB, and HML factors. $FF4$ refers to the model including MKT, SMB, HML, and MOM factors. $FF5$ refers to the model including MKT, SMB, HML, RMW and CMA factors. $YCAPM$, $YFF3$, $YFF4$, and $YFF5$ respectively refer to the models including HML_y factor in addition to the factors in $CAPM$, $FF3$, $FF4$, and $FF5$.

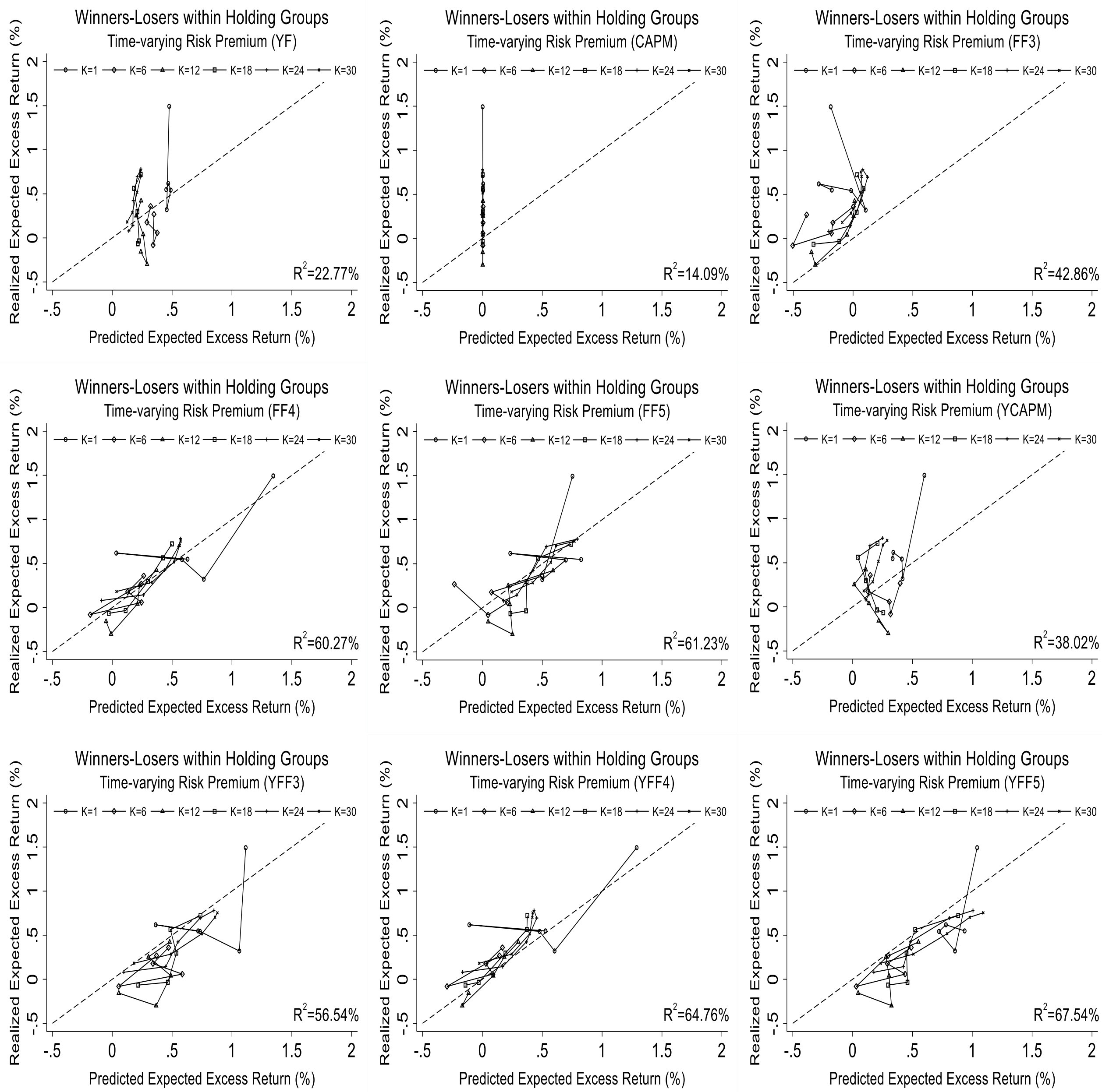


Figure 8: Realized and predicted average returns with time-varying risk premiums within holding groups.
Note: The predicted expected returns are calculated with $E\left(WML_{J-K}\right) = \hat{\beta}_{i,f}\hat{\lambda}_f$, where $\hat{\beta}_{i,f}$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). $\hat{\lambda}_f$ is the estimated risk premia of risk factors with the cross-sectional regressions (the second step) of Fama and MacBeth (1973). The realized expected returns are the average return in the sample from November 1970 to September 2020. The R^2 is the average value of the R_t^2 of the T cross-sectional regressions. That is $R^2 = \sum_{t=1}^{T} R_t^2/T$. J is the formation period to rank commodities. K is the holding period for the winners and losers portfolios. One period refers to two months. YF refers to the model only including HML_y factor. $CAPM$ refers to the model only including MKT factor. $FF3$ refers to the model including MKT, SMB, and HML factors. $FF4$ refers to the model including MKT, SMB, HML, and MOM factors. $FF5$ refers to the model including MKT, SMB, HML, RMW and CMA factors. $YCAPM$, $YFF3$, $YFF4$, and $YFF5$ respectively refer to the models including HML_y factor in addition to the factors in $CAPM$, $FF3$, $FF4$, and $FF5$.

ilar to the risk premiums, a time-series of the slope of the percentage yield characteristic is obtained from the bimonthly cross-sectional regressions. The average of the time-series slope is the final estimation of the slope of the percentage yield, which provides a test of whether the percentage yield is on average priced.

Table 7: Time-series spanning test of the yield factor.

Factors	HML_y	HML_y	HML_y	HML_y
MKT	-0.11*	-0.06	-0.06	-0.06
	(-1.66)	(-0.81)	(-0.73)	(-0.80)
SMB		0.00	0.00	0.03
		(0.00)	(0.01)	(0.22)
HML		0.30***	0.30***	0.43***
		(2.78)	(2.77)	(3.02)
MOM			0.02	
			(0.23)	
RMW				0.25*
				(1.67)
CMA				-0.33
				(-1.47)
$Cons.$	0.02***	0.02***	0.02***	0.02***
	(4.39)	(3.98)	(3.78)	(3.71)
R^2(%)	0.92	3.46	3.48	5.39

Note: This table reports the time-series regressions of yield factor HML_y on the factors in $CAPM$, $FF3$, $FF4$, and $FF5$. MKT is the equity market excess return factor. SMB is the size factor. HML is the value factor. MOM is the equity momentum factor. RMW is the profitability factor. CMA is the investment factor. The sample starts from September 1970 and ends in September 2020. *, ** and *** denote the significance at the 10%, 5% and 1% levels respectively.

The cross-sectional regression results including the percentage yield characteristic of the thirty futures momentum returns are shown in Table 8. Strikingly, the percentage yields are not significantly priced in all the considered models. The significant risk premium for the yield factor in $YFF3$ and $YFF5$ disappears after including the percentage yield. This might be because the percentage yield crowds out some of the significance of the yield factor due to the close relation between the percentage yield as a characteristic and the yield factor. These results suggest that the percentage yield as a characteristic adds little information about the cross-section of expected commodity momentum returns. As such, comovement of the momentum returns with the mimicking yield factor is a better proxy of the risk related to the percentage yield than the (idiosyncratic) percentage yield

Table 8: Fama-Macbeth cross-sectional regressions of futures momentum strategy returns on percentage yield and risk loadings on factors.

Model	λ_{MKT} (%)	λ_{SMB} (%)	λ_{HML} (%)	λ_{MOM} (%)	λ_{RMW} (%)	λ_{CMA} (%)	λ_{HML_y} (%)	λ_{Yield} (%)	λ_0 (%)	Avg. R^2 (%)
$Yield$								10.40	-0.01	27.56
								(0.76)	(-0.04)	
$YF + Yield$							0.45	5.74	0.11	41.33
							(0.32)	(0.39)	(0.36)	
$CAPM + Yield$	1.71							14.10	0.14	40.24
	(0.69)							(0.93)	(0.56)	
$FF3 + Yield$	-0.89	-3.83**	-1.69					17.70	0.05	59.34
	(-0.38)	(-2.05)	(-1.55)					(1.36)	(0.23)	
$FF4 + Yield$	-1.10	-4.46***	-1.60	4.60**				11.30	0.03	69.21
	(-0.47)	(-2.68)	(-1.39)	(2.29)				(0.88)	(0.14)	
$FF5 + Yield$	-1.32	-0.29	-2.51**		-0.69	-2.50***		16.30	-0.03	72.17
	(-0.58)	(-0.25)	(-2.17)		(-0.70)	(-3.04)		(1.24)	(-0.15)	
$YCAPM + Yield$	1.39						0.90	6.82	0.15	53.07
	(0.51)						(0.62)	(0.45)	(0.50)	
$YFF3 + Yield$	-0.90	-4.57***	-1.69				1.22	9.82	-0.04	66.71
	(-0.40)	(-2.77)	(-1.46)				(1.07)	(0.75)	(-0.19)	
$YFF4 + Yield$	-1.57	-4.61***	-1.63	5.69**			-1.03	7.50	0.20	73.10
	(-0.70)	(-2.84)	(-1.42)	(2.34)			(-0.75)	(0.56)	(0.94)	
$YFF5 + Yield$	-0.95	-1.44	-3.23***		-1.46	-2.33***	0.79	11.70	0.00	76.41
	(-0.40)	(-1.26)	(-2.69)		(-1.55)	(-2.79)	(0.74)	(0.87)	(-0.01)	

Note: This table reports the cross-sectional regression of the thirty momentum strategy returns on $\hat{\beta}'_{J-K,f}$ f risk factors and the percentage yield. $\hat{\beta}'_{J-K,f}$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). $\lambda_{f,t}$ is the risk premia of risk factor f and percentage yield. $\lambda_{0,t}$ and is the intercept of the cross-sectional regressions. The final estimates of $\lambda_{f,t}$ and $\lambda_{0,t}$ are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with one lag. *, ** and *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R_t^2 of the T cross-sectional regressions. The sample ranges from September 1970 to September 2020. *Yield* model refers to the one only including the percentage yield. YF refers to the model only including HML_y factor. $CAPM$ refers to the model only including MKT factor. $FF3$ refers to the model including MKT, SMB, and HML factors. $FF4$ refers to the model including MKT, SMB, HML, and MOM factors. $FF5$ refers to the model including MKT, SMB, HML, RMW and CMA factors. $YCAPM$, $YFF3$, $YFF4$, and $YFF5$ respectively refer to the models including HML_y factor in addition to the factors in $CAPM$, $FF3$, $FF4$, and $FF5$.

itself. The regression results with spot momentum returns provide similar evidence, as shown in Table B.6 in Appendix B.

In sum, the yield factor together with the common asset pricing factors suffice to capture the cross-sectional variation in expected momentum returns, and thus in particular the momentum and reversal effects in commodity markets. Among all the considered models, the combined model, $YFF4$, performs best in explaining the cross-section of commodity momentum returns within all formation and holding groups, followed by the Carhart (1997) four-factor model. As such, the momentum and reversal patterns can be explained with risk compensations, consistent with a market without arbitrage opportunities. These results add to the literature that attempts to explain momentum returns within a risk-return framework. For instance, Booth et al. (2016) argue that the momentum and reversal patterns in stock returns can be explained with the size effect of stocks.

4.5. Robustness and sensitivity checks

This section conducts a number of robustness and sensitivity checks in particular, the role of the selection of the momentum strategies and the estimation method.

First, the regression results are based on the selected thirty futures momentum strategies with different formation and holding periods. The particular selection of the momentum strategies might affect the results. In order to deal with this concern, 900 futures momentum strategies are adopted to test the performance of the various models in explaining the cross-sectional variation of momentum returns. The model performance is shown for the case of constant risk premiums in Figure C.7 in Appendix C.[14] With the restriction of constant risk premiums, the combined models have better performance than those common asset pricing models in explaining the cross-section of the 900 momentum strategies. In the case of time-varying risk premiums, the cross-sectional regression results of the second step of Fama and MacBeth (1973) two-step procedure with the 900 futures momentum strategies are shown in Table B.7 in Appendix B. The Carhart (1997) four-factor model and Fama and French (2015) five-factor model do a good job when used alone. The three combined models, $YFF3$, $YFF4$, and $YFF5$, also perform well. The model performance with time-varying risk premiums are displayed in Figure C.8 in Appendix C, which are better than the performance in the case of constant risk premiums. The $YFF3$ and $YFF5$ exhibit better performance than the Fama and French (1993) three-factor model and Fama and French (2015) five-factor model. The $YFF4$ and Carhart (1997) four-factor model perform better than the other models. These findings are similar to those discussed in section 4.3 and 4.4. As such, the results do not appear to be sensitive to the particular

[14] Since the number of momentum strategies is larger than the sample size, it is difficult to conduct the GRS test.

selection of momentum strategies.

Another concern arises related to the risk loadings of the momentum strategies. This paper assumes that the risk loadings of momentum strategies are constant in section 4.3 and 4.4, while it is possible that the risk loadings are time-varying. Therefore, this section estimates risk loadings with rolling windows for the time-series regressions of the first step of the Fama and MacBeth (1973) two-step procedure. These time-varying risk loadings are then used to estimate the risk premiums in the second step. A long window to estimate the time-varying loadings means a shorter sample to estimate the risk premiums. In order to ensure enough observations to estimate the risk loadings as well as the risk premiums, this paper selects two rolling windows of six years and ten years (recall that we use bimonthly data). The regression results with a rolling window of six years are shown in Table B.8 in Appendix B. The Fama and French (1993) three-factor model, Carhart (1997) four-factor model and Fama and French (2015) five-factor model perform well in explaining the cross-section of commodity momentum returns when they are used alone or combined with the yield factor. Table B.9 shows the regression results with a rolling window of ten years. The Fama and French (1993) three-factor model and Fama and French (2015) five-factor model perform well, while again the Carhart (1997) four-factor model does a good job when combined with the yield factor. Additionally, the risk premium of the yield factor is consistently positive for both the rolling window of six and ten years. As such, the findings that the momentum returns can be explained with risk compensations and that the yield factor contains helpful information about the momentum returns is not sensitive to the estimation method.

5. Conclusion

This paper studies what the momentum and reversal patterns are in commodity markets and tries to explain these patterns.

To do so, this paper considers momentum strategies with formation and holding periods up to sixty months. These momentum strategies are studied in both commodity futures and spot markets. When it comes to commodity spot returns, this paper argues that the net convenience yield should be included into the spot returns rather than only looking into capital gains. The net convenience yield represents the economic benefit to the owner of a physical commodity and can be interpreted as latent payoff of holding the commodity. As such, it makes economic sense to include the payoff into the spot return, analogues to the role of dividends in stock returns. With this spot return definition, this paper finds that the momentum and reversal patterns are quantitively similar in futures and spot markets. Generally, a momentum effect happens first, followed by a reversal effect and then a momentum effect again. Although these momentum and reversal patterns are consistent for all considered formation periods, the formation period does affect the magnitudes and durations of the momentum and reversal effects. Especially, the magnitudes of the first momentum and reversal effects are larger for the strategies with shorter formation periods, while the second momentum effects are stronger for the strategies with longer formation periods. The durations of the first momentum effects are similar for the strategies with different formation periods, while the reversal effects last shorter and thus the second momentum effects remain longer for the strategies with longer formation periods.

This paper tries to explains the momentum and reversal patterns from the perspective of a risk-return tradeoff. I argue that the momentum and reversal patterns might derive from the different risk exposures of the momentum strategies. In order to test this explanation, this paper considers a commodity-specific one-factor model with a yield factor, the Capital Asset Pricing Model ($CAPM$), Fama and French (1993) three-factor model, Carhart (1997) four-factor model and Fama and French (2015) five-factor model. The results suggest that the cross-section of momentum returns can be explained as compensations for bearing risks with time-varying risk premiums. When the yield factor and common asset pricing models are used in isolation, the Carhart (1997) four-factor model performs best in explaining the cross-section of momentum returns, followed by the Fama and French (2015) five-factor model. Although the yield factor alone cannot fully explain the average returns of momentum strategies, it contains important risk information and is not redundant in the combined models that incorporate the yield factor into the common asset pricing models. The model combining the Carhart (1997) four-factor model and the yield factor performs best among all the considered models, followed by the Carhart (1997) four-factor model. As such, the momentum returns can be explained by a risk-return relation. These findings are robust to the selection of the momentum strategies and the estimation with rolling windows.

Appendix

Please download appendix here: `https://www.financemeng.com/en/Appendix.html`

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