The Net Convenience Yield and the Cross-section of Commodity Returns ⋆

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Abstract

We study which risk factors explain the cross-section of commodity returns and decompose commodity returns into capital gains and net convenience yields. The findings reveal that a commodity-specific three-factor model performs best in explaining the cross-section of commodity returns. As to individual commodity returns, the ability of risk factors to explain the cross-sectional variation mainly results from the yields. For commodity portfolios returns, the ability of risk factors derives from both capital gains and yields. Commodity-specific factors perform better in explaining the cross-section of portfolio capital gains, whereas asset pricing factors perform better in explaining the cross-section of portfolio yields.

Keywords: Cross-section of commodity returns, asset pricing factors, commodity-specific factors, convenience yield

JEL classification: G10, G11, G13, G17

1. Introduction

Commodities have gained increased attention from investors who seek to diversify their risks with more conventional assets like stocks and bonds (e.g., Basak and Pavlova, 2016; Brunetti and Reiffen, 2014; Hollstein et al., 2021b; van Huellen, 2019). However, it is

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important to realize that the returns of individual commodities vary a lot (e.g., Daskalaki et al., 2014; Shang et al., 2016). Understanding the cross-sectional variation in commodity returns is crucial for practitioners to make better use of the diversification properties of commodities. For academics, it is relevant to find out what drives the variation. The cross-section of returns of traditional assets is well understood: The asset pricing literature explains the cross-sectional variation in stock returns with a relatively small number of factors such as consumption growth, market excess return, size, value, momentum, profitability, and investment strategy (e.g., Breeden, 1979; Campbell and Cochrane, 2000; Carhart, 1997; Fama and French, 1993, 2015). Risk factors that successfully explain one asset class's returns also help explain other classes' returns in integrated markets (e.g., Campbell, 2000; Cochrane, 2009; Daskalaki et al., 2014). Our study fits in this tradition and focuses on commodities. Commodities relate to stocks in different ways. First, they are both substitutes and complements from the perspective of investors, as the inclusion of commodities in an equity portfolio will affect the risk-return profile. Further, commodities affect the inflation level and thus households' purchasing and investment power. At the same time, commodities are value drivers for the firm. This is because they not only are capital assets, but also consumable (transformable) assets. This motivates us to investigate whether well-documented risk factors explaining the cross-section of stock returns also have the ability to help explain the cross-section of commodity returns.

Surprisingly, there are only few studies regarding the cross-sectional variation in commodity returns with asset pricing risk factors that prove successful in stock markets as well. Among such studies, there is no consensus whether there are any common risk factors. Next to the standard asset pricing factors, some studies provide evidence that commodity-specific factors, in particular commodity momentum and basis risk (the difference between contemporaneous commodity futures and spot prices), play a role in explaining the cross-section of commodity returns. However, the source of this ability is not clear. We pick up this challenge by accounting for the role of net convenience yield. We argue that the commodity return need to be defined in the same way as a stock return, and hence should include both the relevant payoff (dividend) and the stock price change (e.g., Cochrane, 2008). We motivate this because of the analogy with the dividend on stock and regard the net convenience yield as the (latent) future payoff to commodities. The net convenience yield implicitly represents the economic benefits of holding a commodity net of storage costs (e.g., Pindyck, 1993; Szymanowska et al., 2014). For instance, the owner of a commodity has the ability to meet unexpected production rearrangements. As such, the owner is actually (implicitly) compensated with this net convenience yield because she can obtain the latent economic benefits by holding the commodity. The commodity owner is willing to pay a monetary sum that she values the net convenience yield to her counterpart on futures markets. Therefore, this latent payoff is the real money that can be collected by the counterpart on the futures markets and is already included in futures returns. [1] Accordingly, the commodity spot return should also include the net convenience yield to make economic sense (e.g., Pindyck, 1993; Tsvetanov et al., 2016).

We argue that the spot return that includes the net convenience yield is theoretically similar to the futures return within the same period. We decompose commodity (spot or futures) returns into capital gains (relative spot price changes) and (percentage) yields. With such decomposition, we revisit the question which risk factors explain the cross-sectional variation in commodity returns and study whether such explanatory ability of risk factors, if any, comes from capital gains or yields, or from both. We start by applying the widely used asset pricing models, such as Consumption-based Capital Asset Pricing model ($CCAPM$), 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. In case the commodity and stock markets are segmented, asset pricing risk factors are unlikely to play a role in explaining the cross-sectional variation in expected commod-

[1] Futures contracts on backwardation markets where the spot price are higher than futures prices (positive net convenience yield) have positive expected returns.

ity returns. Therefore, we also consider the ability of commodity-specific factors to explain the cross-sectional variation in commodity returns, namely the commodity market excess returns, the commodity momentum factor, and the commodity yield factor. We argue that these factors closely relate to the net convenience yield. Accounting for them adds value for the understanding and analysis of their financial performance.

With our test assets, we focus on the return variation across individual commodities, which allows us to test the heterogeneity among individual commodities (e.g., Daskalaki et al., 2014; Lübbers and Posch, 2016), [2] and the return variation of commodity portfolios (e.g., Dhume, 2010; Adrian et al., 2014; Petkova, 2006). We rely on a sample of 23 commodities for the period from September 1963 to September 2020 to study the cross-sectional variation in commodity returns.

We find that both asset pricing and commodity-specific factors explain the cross-section of commodity returns. In particular, we establish that a commodity-specific three-factor model with commodity market excess return, commodity yield factor and commodity momentum factor is highly informative regarding the returns' determinants. However, the more conventional asset pricing models, like Fama and French (1993), also perform satisfactory in explaining the cross-section of commodity returns. For individual commodities, there is no one risk factor which is significantly priced in the cross-section of capital gains. Asset pricing factors, e.g., the value factor, and commodity-specific factors are significantly priced in the cross-section of percentage yields. The ability of asset pricing and commodity-specific factors to explain the cross-section of individual returns stems from the return accrued to the percentage yield. For commodity portfolios, asset pricing and commodity-specific factors are significantly priced in the cross-section of capital gains and percentage yields. The ability of these risk factors to explain the cross-sectional port-

[2]Commodities are fully heterogenous if there is no risk factor to explain the cross-section of individual commodity returns (Daskalaki et al., 2014). When there are risk factors that help explain the cross-section of individual commodity returns, the commodities are said to be increasingly homogenous (Lübbers and Posch, 2016).

folio returns results from both capital gains and percentage yields. Commodity-specific models, e.g., a one-factor model with commodity momentum factor, perform better in explaining the cross-section of portfolios capital gains, while asset pricing models, e.g., Fama and French (1993) three-factor model, perform better in explaining the cross-section of portfolios percentage yields. As such, we provide a novel perspective regarding the understanding of commodity returns. Furthermore, we show that commodity and stock markets are somewhat integrated because asset pricing factors help explain the cross-section of commodity returns. This result provides further evidence for the literature that tries to link these markets (e.g., Alves and Szymanowska, 2019; Boons et al., 2014; Brooks et al., 2016; Hou and Szymanowska, 2013; Lutzenberger, 2014; Salisu et al., 2019).

As such, the main contribution of this paper is twofold. First, we provide a novel perspective on the cross-section of commodity returns by decomposing the return into capital gains and yields. With this decomposition, we not only study whether the well-documented asset pricing factors and the commodity-specific factors explain the cross-section of commodity returns, but also explore where such explanatory ability of risk factors comes from. By doing so, we extend the literature and arrive at a more detailed understanding of the risk factors investors are compensated for on commodity markets and of the heterogeneity among the various commodity assets. Second, we complement the literature regarding the use of asset pricing models for commodity markets by accounting for the key properties of commodities as an asset class.

The rest of this paper is organized as follows. Section 2 elaborates on the commodity return definition, the practical implication of return and the asset pricing and commodity-specific models used to explain the cross-section of commodity returns. Section 3 describes the data used in this study. Section 4 presents and discusses the results about the cross-section of individual commodities and commodity portfolios, study the source of explanatory ability of risk factors, and reports the sensitivity and robustness check. Section 5 concludes.

2. Methodology

2.1. Defining commodity returns

As in Pindyck (1993), we define commodity (spot) returns as a combination of the net convenience yields and relative spot price changes. The net convenience yield is the (latent) payoff of commodities similar to the dividends of stocks. It is the benefit associated with holding the underlying commodity, rather than the associated derivative security or contract. Although it is a *latent* payoff for the owner of a commodity, it can be collected by engaging in a long position in corresponding futures contract and it is the real monetary cash flow of the holder of a futures contract. This cash flow is already included in futures return (see details in section 2.2). It therefore makes economic sense to include the convenience yield in the definition of a spot return, just as dividends are included in the definition of a stock return. To show this, we argue as follows: Suppose that at time t, an investor owns a commodity with a price S_t. Then, we suggest the following common trading strategy. The investor sells this commodity at price S_t and immediately invests this amount S_t in a bank account at a one-period risk-free interest rate $rf_{t\to t+1}$. At the same time, the investor engages in a futures contract that will deliver this commodity at price $F_{t,t+1}$ at time $t+1$. Then, this investor receives a (riskless) net cash flow that equals $S_t\left(1+rf_{t\to t+1}\right)-F_{t,t+1}$ at time $t+1$,which is commonly labeled as the net convenience yield and can be both positive or negative. Note that the net convenience yield is the monetary amount that the counterparty of this investor either requires or is willing to pay in order to hold this commodity from time t to $t+1$ because of the (latent) convenience yield net of storage costs, which the investor values at $S_t\left(1+rf_{t\to t+1}\right)-F_{t,t+1}$.

If the net convenience yield is negative, it implies that the investor is paying the counterparty on spot markets mainly for storing the commodity during the period. If it is positive, the counterparty is paying the investor for enjoying the convenience yield benefits of holding the commodity. We therefore define the net convenience yield of this commodity from time t to $t+1$ that is obtained by the owner of this commodity at time $t+1$ as

$D^{t+1}_{t\to t+1}$, thus [3]

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

Continuing, at time $t+1$, the investor now also has repurchased the commodity at a price $F_{t,t+1}$, which now has values S_{t+1}. So the total value of the investor's assets is equal to $S_{t+1} + S_t\left(1 + rf_{t\to t+1}\right) - F_{t,t+1}$ at time $t+1$, where $D^{t+1}_{t\to t+1} = S_t\left(1 + rf_{t\to t+1}\right) - F_{t,t+1}$. Therefore, the net return on the commodity that this investor can obtain during t to $t+1$ by engaging in this strategy is:

$$R_{t+1} = \frac{S_{t+1} + D^{t+1}_{t\to t+1}}{S_t} - 1 \tag{2}$$

Note that this strategy might not necessarily be attractive to investors. We merely aim to explain how the latent net convenience yield can be collected with this strategy. [4] The latent payoff can also be collected in other ways, e.g., leasing out the commodity, using the commodity in urgent production, other than engaging in futures contract as explained in the above strategy. We can also assume without loss of generality that the net convenience yield from t to $t+1$ is collected at time t. In this case, $D^{t}_{t\to t+1}$ is defined as:

$$D^{t}_{t\to t+1} = \frac{D^{t+1}_{t\to t+1}}{1 + rf_{t\to t+1}} = S_t - \frac{F_{t,t+1}}{1 + rf_{t\to t+1}} \tag{3}$$

where $F_{t,t+1}/\left(1 + rf_{t\to t+1}\right)$ refers to the present value of the futures price $F_{t,t+1}$ at the beginning of the period. This investor sells the commodity at time t at price S_t, but she

[3] $D^{t+1}_{t\to t+1} = S_t\left(1 + rf_{t\to t+1}\right) - F_{t,t+1}$ defines the market value of the net convenience yield. The net convenience yield is likely heterogeneous across investors. We do not consider this heterogeneity. To make it clearly, the net convenience yield $D^{t+1}_{t\to t+1}$ is different from the "basis" that is commonly used in the commodity literature. Basis is defined as $F_{t,t+1} - S_t$. So a high net convenience yield suggests a low basis.

[4] This commodity return is explained from owning a commodity and then engaging in a short position in this paper to show how the net convenience yield is collected. The return can also be obtained by engaging in a long position in a commodity. Assume an investor has an asset that equals to S_t. He buys a commodity at time t at price S_t and holds this commodity until time $t+1$. At time $t+1$, this investor is compensated by the latent payoff, net convenience yield $D^{t+1}_{t\to t+1}$, and sells this commodity at price S_{t+1}. Therefore, at time $t+1$, this investor receives the return $R_{t+1} = \left(S_{t+1} + D^{t+1}_{t\to t+1}\right)/S_t - 1$.

also loses the net convenience yield accrued to holding the commodity $D^t_{t\to t+1}$. So the net asset value at time t is $S_t - D^t_{t\to t+1}$. This investor invests this amount of money into bank account with $rf_{t\to t+1}$ and engages a long position of futures contracts promising to buy the commodity at time $t+1$ at price $F_{t,t+1}$. Therefore, the net cash flow of this investor at time $t+1$ is $\left(S_t - D^t_{t\to t+1}\right)(1 + rf_{t\to t+1}) - F_{t,t+1}$, which equals to zero according to equation (3). At time $t+1$, this investor owns the commodity, which values S_{t+1}. Therefore, an alternative definition of commodity return by engaging in the above strategy is: [5]

$$R_{t+1} = \frac{S_{t+1}}{S_t - D^t_{t\to t+1}} - 1 = \frac{S_t}{F_{t,t+1}}(1 + rf_{t\to t+1}) - 1 \approxeq \frac{S_{t+1} + D^{t+1}_{t\to t+1}}{S_t} - 1 \tag{4}$$

where the approximation is justified since both S_{t+1}/S_t and $F_{t,t+1}/S_t$ are generally close to one and $rf_{t\to t+1}$ is general quite small. Therefore, these two definitions of the commodity return both make economic sense and are quantitively similar, especially with low interest rates.

2.2. Practical implications and measurement

Although the trading strategy discussed in section 2.1 is not necessarily attractive to financial investors, it does have practical implications for investors on futures markets. Define the percentage net convenience yield (the net convenience yield-price ratio, hereafter the percentage yield) as $y_{t\to t+1} = \frac{D^{t+1}_{t\to t+1}}{S_t}$. So $rf_{t\to t+1} - y_{t\to t+1} = rf_{t\to t+1} - \frac{S_t(1+rf_{t\to t+1}) - F_{t,t+1}}{S_t} = \frac{F_{t,t+1}}{S_t} - 1$, which is close to zero. Therefore, $F_{t,t+1} = S_t(1 + rf_{t\to t+1}) - D^{t+1}_{t\to t+1} = S_t(1 + rf_{t\to t+1} - y_{t\to t+1}) \approx S_t e^{rf_{t\to t+1} - y_{t\to t+1}}$. Consider a common trading strategy in futures contracts: An investor holds a futures contract maturing at time $t+n$ from time t to time $t+1$. The excess futures return on a fully collateralized basis that can be

[5] For a derivation of equation (4), see equation (A.3) in Appendix A.2.

obtained is: [6]

$$R_{fut,t\rightarrow t+1} = \frac{F_{t+1,t+n}}{F_{t,t+n}} - 1 \approx cg_{t+1} - rf_{t\rightarrow t+1} + y_{t\rightarrow t+1} \quad (5)$$

where $F_{t,t+n}$ and $F_{t+1,t+n}$ refer to the prices at time t and $t+1$ of futures contract maturing at time $t+n$. Therefore, we calculate the futures return with prices of the same contract. Equation (5) suggests that the return by holding a commodity from time t to time $t+1$ can be replicated by holding a futures contract of this commodity within the same period. Thus the net convenience yield is already included in futures returns. The commodity futures or spot excess return can be decomposed into excess capital gain $cg_{t+1} - rf_{t\rightarrow t+1} = S_{t+1}/S_t - 1 - rf_{t\rightarrow t+1}$ and percentage yield $y_{t+1} = y_{t\rightarrow t+1} = D^{t+1}_{t\rightarrow t+1}/S_t$. In the remainder of the paper, we do not specifically classify spot and futures returns and we refer to "commodity returns" which includes the net convenience yield. The other two common trading strategies of futures contracts can also be replicated with the strategy holding a commodity within that period. The relevant details are presented in Appendix A.1

Although the net convenience yield is a latent payoff to the owner of a commodity, it does not only matter to investors on spot markets. As discussed in section 2.1, this latent payoff is actually collected by investors engaging in a long position of futures contracts. The net convenience yield can however also be inferred from futures prices. Recall that the net convenience yield $D^t_{t\rightarrow t+1}$ is defined as $D^t_{t\rightarrow t+1} = S_t - \frac{F_{t,t+1}}{1+rf_{t\rightarrow t+1}}$. Similarly, the net convenience yield in the period from time t to $t+2$ obtained at time is t defined as:

$$D^t_{t\rightarrow t+2} = S_t - \frac{F_{t,t+2}}{(1+rf_{t\rightarrow t+1})(1+rf_{t+1\rightarrow t+2})} \quad (6)$$

Therefore, the net convenience yield from time $t+1$ to $t+2$ and discounted to time t

[6] Fully collateral futures return means that the investor invests a cash amount equivalent to the current value of futures contract in a "safe" asset as collateral. See equation (A.4) in Appendix A.2 for a detailed derivation of equation (5).

is: [7]

$$D^{t}_{t+1\to t+2} = D^{t}_{t\to t+2} - D^{t}_{t\to t+1} = \frac{F_{t,t+1} - \frac{F_{t,t+2}}{1+rf_{t+1\to t+2}}}{1 + rf_{t\to t+1}} \tag{7}$$

Equation (7) also implies that at time t the investor expects a net convenience yield from time $t+1$ to $t+2$, which discounted to time $t+1$ is:

$$D^{t+1}_{t+1\to t+2} = F_{t,t+1} - \frac{F_{t,t+2}}{1 + rf_{t+1\to t+2}} \tag{8}$$

So we can extract the net convenience yield from futures prices alone. According to equation (8), we have that: [8]

$$\begin{aligned} R_{t+1} &= \frac{S_{t+1}}{S_t - D^{t}_{t\to t+1}} - 1 \approx \frac{F_{t+1,t+2} + F_{t,t+1}\left(1 + rf_{t\to t+1}\right) - F_{t,t+2}}{F_{t,t+1}} - 1 \\ &\approx \frac{S_{t+1} + D^{t+1}_{t\to t+1}}{S_t} - 1 = \frac{S_{t+1} + S_t\left(1 + rf_{t\to t+1}\right) - F_{t,t+1}}{S_t} - 1 \end{aligned} \tag{9}$$

Spot prices, however, are not subject unique markets and are less liquid (e.g., Szymanowska et al., 2014). Similar to the term structure of interest rates, there is a term structure of futures prices. In this analogy, it is as if we use the closest forward rate to proxy the short rate of interest. As suggested by equation (9), we proxy spot contracts with futures contracts that expire one period later and proxy the nearest futures contract with the one that expires one period after the spot contract matures, which is a common practice in the commodity literature (e.g., Fama and French, 1987; He et al., 2019; Szymanowska et al., 2014). By doing so, we can also make sure the spot price and futures price are on the same commodity with the same detailed specifications. In practice, the futures contract might not expire at the end of a month. Using the proxies of spot and futures prices ensures us to calculate the commodity return and net convenience yield from the end of month t to the end of month $t+1$, which aligns the return measurement period of risk factors.

[7] For a derivation of equation (7), see equation (A.5) in Appendix A.2.
[8] For a derivation of equation (9), see equation (A.6) in Appendix A.2.

As such, we proxy the spot price S_t by $F_{t,t+1}$ and we proxy $F_{t,t+1}$ by $F_{t,t+2}$. Accordingly, the percentage yield $y_{t+1} = y_{t \to t+1} = \frac{D_{t \to t+1}^{t+1}}{S_t} = 1 + rf_{t \to t+1} - \frac{F_{t,t+1}}{S_t}$ is proxied by $y_{t+1} = 1 + rf_{t \to t+1} - \frac{F_{t,t+2}}{F_{t,t+1}}$, the capital gain $cg_{t+1} = \frac{S_{t+1}}{S_t} - 1$ is proxied by $cg_{t+1} = \frac{F_{t+1,t+2}}{F_{t,t+1}} - 1$ and the return $R_{t+1} = \frac{S_{t+1} + D_{t \to t+1}^{t+1}}{S_t} - 1$ is proxied by $R_{t+1} = \frac{F_{t+1,t+2} + F_{t,t+1}(1 + rf_{t \to t+1}) - F_{t,t+2}}{F_{t,t+1}} - 1$. To check accuracy, we compare the returns, capital gains and percentage yields using real spot and futures prices of regularly traded commodities, such as crude oil, gold and soybean. The two series with and without price proxies for returns, capital gains and percentage yields are quite similar (See Figure B.1 in Appendix B).

In sum, we decompose commodity returns (spot returns or futures returns) into capital gains and percentage yields according to equation (5). This decomposition enables us to study why the risk factors, if at all, explain the cross-section of commodity returns - it might because the risk factors explain the cross-section of capital gains, or percentage yields, or both.

2.3. Asset pricing tests

To test the various asset pricing models as being used in previous studies, we apply the Fama and MacBeth (1973) two-step procedure. [9] This provides us both with time-series asset pricing tests in the first stage, and gives an estimate of the risk premium of the risk factors in the second-stage cross-sectional regressions. This approach also is commonly used in the related literature (e.g., Brooks et al., 2016; Daskalaki et al., 2014; De Roon and Szymanowska, 2010; Hollstein et al., 2021a; Lübbers and Posch, 2016).

In the first step, we estimate the factor loadings or exposure to the risk factors for each

[9] The Fama and MacBeth (1973) two-step procedure includes two steps. The first step is simple time-series regression of individual assets. The second step is cross-sectional regression. We can do only the time-series regressions if the factors are excess returns on traded assets. By doing so, we restrict the risk premium to be the average of the factors. However, the factors might not be the excess returns on traded assets (i.e., consumption growth), and it might have sampling error if we simply measure the risk premium as the average of the traded assets. In these cases, we need to explicitly run the cross-sectional regressions to estimate the risk premiums with all assets, where the factor loadings are firstly estimated from the first-step time-series regressions. Therefore, we choose the Fama and MacBeth (1973) two-step procedure to estimate the various asset pricing models.

asset separately by running N time-series regressions:

$$R^e_{i,t} = a_i + f_t' \beta_{i,f} + \epsilon_{i,t}, \qquad t = 1, \cdots, T, \ \ i = 1, \cdots, N \tag{10}$$

where $R^e_{i,t}$ refers to the excess return, excess capital gain or percentage yield of commodity (or portfolio) i at time t. f_t is a vector of the risk factors and $\beta_{i,f}$ is a vector of loadings on each factor in f_t, and a_i and $\epsilon_{i,t}$ represent the constant and error term. When the factors are excess returns on traded assets, the implication from asset pricing theory is that the intercepts a_i should be (jointly) zero.

In the second step, we estimate the risk premium of each factor, by running a cross-sectional regression at time t:

$$R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f} \lambda_{f,t} + \epsilon_{i,t}, \qquad t = 1, \cdots, T, \ \ i = 1, \cdots, N \tag{11}$$

As such, we regress the excess return, excess capital gain or percentage yield of commodity or portfolio i on a constant $\lambda_{0,t}$ and $\hat{\beta}'_{i,f}$ estimated from the time-series regressions in the first step; see equation (10). Here, $\lambda_{f,t}$ is a vector of risk premiums, and $\epsilon_{i,t}$ is the error term. By running T cross-sectional regressions at second-stage, we get time-series estimates of λ_0 and λ_f. The final estimates of λ_0 and λ_f are the average values of the time-series estimates, i.e., $\hat{\lambda}_0 = \frac{\sum_{t=1}^{T} \hat{\lambda}_{0,t}}{T}$ and $\hat{\lambda}_f = \frac{\sum_{t=1}^{T} \hat{\lambda}_{f,t}}{T}$.

Asset pricing theory suggests that a risk factor should be significantly priced if it is to explain the variation in expected commodity returns. Furthermore, the intercept λ_0 should be zero if a model captures all the risk that the investor needs to be compensated for because λ_0 represents a zero-beta return. [10] Therefore, we study the performance of the models discussed above by testing whether $\hat{\lambda}_0$ and $\hat{\lambda}_f$ are significantly different from zero. The t-statistics are calculated using Newey and West (1987) procedure with 1 lag

[10] This is only an implication if the factors are traded assets as well; for e.g. the *CCAPM* the intercept can be non-zero.

to correct autocorrelation, in line with Bakshi et al. (2019), Prokopczuk et al. (2021), and Szymanowska et al. (2014). To check the robustness of our findings, we also test the model using rolling-window betas based on estimations of equation (10) for estimation windows of various length.

3. Data

3.1. Commodity prices and commodity-specific factors

We collect commodity end-of-month close futures price data from the Commodity Research Bureau (CRB). Since financial investors on futures markets do not want to deliver physical commodities, they start to close the position of a futures contract from 4 to 6 weeks before the contract expires and roll over to the next futures contract (e.g., Brunetti and Reiffen, 2014; Szymanowska et al., 2014). Therefore, there might exist "erratic" prices for the futures contracts during the delivery month and the prior month. In order to avoid using those "erratic" prices, we close the position of a futures contract at the end of the month prior to the month previous the delivery date and roll over to the next nearest futures contract in the meantime, following e.g., Boons and Prado (2019), He et al. (2019), Hollstein et al. (2021a), Prokopczuk et al. (2021), and Szymanowska et al. (2014). Therefore, we use the futures contract maturing two months later as the spot contract, and use the futures contract maturing two months after the spot contract expires as the nearest-to-maturity contract, in line with He et al. (2019) and Szymanowska et al. (2014). For instance, the spot contract and nearest-to-maturity contract in March are proxied with the futures contracts expiring in May and July respectively. Moreover, some commodities do not have maturing futures contracts for each month. For example, copper only has six different futures contracts a year. In order to minimize the problem arising from irregular delivery dates, we select 23 commodities, most of them have maturing futures contracts every two months, and construct bimonthly futures price data. [11] In addition to the 21 commodities studied by Szymanowska et al. (2014), natural gas and gas oil are included in our dataset. Some studies use commodity prices after 1980 (e.g., Daskalaki et al., 2014; He et al., 2019; Prokopczuk et al., 2021; Shang et al., 2016; Szymanowska et al., 2014), while some studies use a longer time series at least as early as 1970 (e.g., Bakshi et al., 2019; Boons and Prado, 2019; De Roon and Szymanowska, 2010; Hollstein et al., 2021a; Yang, 2013). In this paper, we use unbalanced panel data for these commodities to use all available information, consistent with Szymanowska et al. (2014). Our sample starts in September 1960 to make sure that there are at least 2 commodities in each of the portfolios sorted on commodity momentum and percentage yield, as in Hollstein et al. (2021a), and our sample ends in September 2020. Detailed information about the 23 commodities is shown in Table C.1 in Appendix C.

As to the commodity-specific factors, we consider a commodity market factor ($CMKT$) and two factors related to the theory of storage, including a yield factor ($YIELD$) and a commodity momentum factor ($CMOM$). $CMKT$ refers to the excess return of an equally-weighted commodity portfolio with all the available commodities (e.g., Bakshi et al., 2019; Prokopczuk et al., 2021). In order to construct the $YIELD$ and $CMOM$ factors, we apply univariate sorts on yield or commodity prior returns. At the end of every second month, the 23 commodities are sorted into four portfolios according to the quartiles of percentage yield in the prior two months (one period) and four portfolios according to the quartiles of commodity cumulative return in the prior twelve months. [12] We then calculate the portfo-

[11]For the commodities that do not have the futures contracts maturing in two or four months, we use the futures contracts with the nearest maturity after two or four months. For instance, copper has the futures contracts that expire on January, March, May, July, September and December. On September, we use the futures contract expiring in December instead of November as the spot contract. For few commodities that have the futures contracts that expire evenly on February, April, June, August, October and December, e.g., gold, live cattle and lean hogs, we roll over their position three months before their expiration.

[12]The percentage net convenience yield defined as: $y_{t+1} = y_{t\rightarrow t+1} = \frac{D^{t+1}_{t\rightarrow t+1}}{S_t} = 1 + rf_{t\rightarrow t+1} - \frac{F_{t,t+1}}{S_t}$, where $D^{t+1}_{t\rightarrow t+1}$ refers to the net convenience yield from time t to time $t+1$ achieved at time $t+1$. S_t and $F_{t,t+1}$ refers to commodity spot and futures prices at time t. It might happen that $\frac{F_{t,t+1}}{S_t}$ is the same for some commodities so that most commodities are sorted into one portfolio. In this case, we use the percentage yield from time

lio return in the following two months as the equally-weighted return of the commodities in that portfolio. The $YIELD$ factor is the average return of commodities in the two portfolios with high percentage yield minus the average return of commodities in the two portfolios with low percentage yield. Similarly, the $CMOM$ factor is the average return of commodities in the two portfolios with high returns during the prior twelve months minus the average return of commodities in the two portfolios with low returns in the prior twelve months. The portfolios are rebalanced every two months. Finally, we test the ability of these commodity-specific factors to explain the cross-sectional variation of commodity returns with four models, including three one-factor models with $CMKT$, $YIELD$, and $CMOM$ separately (hereafter $CF1_{CMKT}$, $CF1_{YIELD}$, and $CF1_{CMOM}$) and a three factor model with all the three factors (hereafter $CF3$).

3.2. Common asset pricing factors

We also study the ability of asset pricing factors that are commonly used to price the cross-section of stock returns to explain the cross-section of commodity returns instead. As to the asset pricing factors, we consider the Consumption-based Capital Asset Pricing Model ($CCAPM$) by adopting a consumption growth factor (CG), the Capital Asset Pricing Model ($CAPM$) by adopting an equity market excess return factor (MKT) and the Fama and French (1993) three-factor model (hereafter $FF3$) consisting of a size factor (SMB), a value factor (HML) and again the MKT factor. We also test the Carhart (1997) four-factor model (hereafter $FF4$) comprising a momentum factor (MOM) in addition to the MKT, SMB and HML factors, and the Fama and French (2015) five-factor model (hereafter $FF5$) including a profitability factor (RMW) and an investment factor (CMA) next to the MKT, SMB and HML factors.

We calculate the consumption growth per capita for the $CCAPM$ model as follows. The monthly population data and seasonally adjusted personal consumption expenditures on

$t-1$ to t to sort commodities at time $t+1$.

nondurable goods and services are available from the FRED website and are transformed to bimonthly frequency by taking the average over two months. [13] The consumption growth factor is then defined as the log growth of consumption per capita every two months. In addition, the monthly data of other asset pricing factors and the risk-free interest rate are from the Kenneth French's website. [14] The risk-free interest rate and stock market return are compounded to bimonthly frequency. The size, value, profitability, and investment factors are constructed with six portfolios formed on size and book-to-market, the six portfolios formed on size and operating profitability, and the six portfolios formed on size and investment. For details about these portfolios to construct risk factors, see Kenneth French's website. The monthly returns of these portfolios are compounded to bimonthly returns as well. MKT is the stock market return in excess of the interest rate. SMB is the return by taking a long position in the nine small portfolios and short position in the nine large stock portfolios. Similarly, HML is the average return of the two high book-to-market portfolios minus the average return of the two low book-to-market portfolios. RMW represents the difference between the average returns of the two portfolios with robust profitability and the average returns of the two portfolios with weak profitability. CMA refers to the average return of the two portfolios of conservative investment minus the average return of the two portfolios of aggressive investment. The momentum factor is constructed with the six portfolios sorted on size and returns in the prior twelve months skipping the most recent month, available from Kenneth French's website. Similarly, the monthly portfolio returns are compounded to bimonthly returns and MOM is the return by taking a long position in the two portfolios with high prior returns and a short position in the two portfolios with low prior returns.

The data for the asset pricing factors are available from September 1963. Therefore, for the regressions of equation (10) and (11), we use the sample from September 1963

[13] The FRED website is https://fred.stlouisfed.org/.

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

to September 2020. As discussed in section 2.3, if these widely used asset pricing and commodity-specific factors have significant risk premiums (the coefficients in equation (11) are significant), these factors are significantly priced and can help explain the cross-sectional variations of commodity returns.

3.3. Data description

In order to show that the commodity spot returns *with* the net convenience yield can be replicated with futures returns within that period, we display the summary statistics of the two returns of individual commodities and commodity portfolios in Table 1. The spot returns with net convenience yields are quantitively similar to the corresponding futures returns and the standard deviations are quite similar as well, which is consistent with the suggestion of equation (5). These findings hold for individual commodities as well as commodity portfolios. The spot returns have the same practical implications once they explicitly include the latent payoff. These findings provide evidence that we do not have to make a distinction between the spot return with yield and the futures return. In the following analysis, we just refer to ”commodity return”.

The commodity capital gains and percentage yields are shown in Table 1 as well. As shown in Panel A, we observe that the commodity returns do vary a lot across individual commodities, similar to the findings of Daskalaki et al. (2014), Hollstein et al. (2021a), Lübbers and Posch (2016), and Yan and Garcia (2017). The individual commodity returns range from -6.29% for natural gas to 17.14% for gasoline on an annual basis, while those capital gains range from 4.04% for feeder cattle to 13.38% for natural gas. Notably, the annualized average return of natural gas decreases substantially after including the net convenience yield (from 13.38% to -6.29% annually), implying that the net convenience yield for natural gas is negative on average (-19.66% on annual basis), likely because of large associated storage costs. The average commodity returns for most commodities are significantly different from zero and larger than the associated capital gains, which implies that the net convenience yields for most commodities are positive on average (exceptions are corn, wheat, oats, rough rice, coffee, lumber, silver, gold, and natural gas), as shown in Table 1. The positive net convenience yields (the real convenience yield net of the storage cost) on average imply that the compensation for the latent payoff related to "convenience" seems to outweigh storage costs or other holding costs. Interestingly, the percentage yields of individual commodities are less volatile than commodity returns and capital gains. The most volatile percentage yield is of natural gas with an annualized standard deviation of 23.70%, while the least volatile percentage yield is of gold with an annualized standard deviation of 0.55%. The absolute percentage yields of most commodities are smaller than their capital gains, while the variation among individual percentage yields is larger than the variation among capital gains.

Furthermore, almost all commodities underperform the equity market portfolio ($Portfolio_M$) in terms of the Sharpe ratio and/or Sortino ratio. Therefore, individual commodities are not attractive as stand-alone investments, in line with the findings of Sakkas and Tessaromatis (2020). Yet, the equally-weighted portfolio consisting of the commodity and stock market portfolio, $Portfolio_{C+M}$, performs better than the equity portfolio. Although $Portfolio_{C+M}$ has a lower average return than the stock market portfolio, it also has lower volatility. Simply put, investors can obtain diversification benefits of commodities because of decreasing risk, not by increasing return (see also Bessler and Wolff, 2015). Furthermore, there is consistence with the performance of capital gains. The equally-weighted commodity portfolio return ($Portfolio_C$) performs better than the capital gains of $Portfolio_C$ and performs comparable to the equity market portfolio $Portfolio_M$.

Table 1 also describes the commodity portfolios sorted along the percentage (net convenience) yield and commodity momentum separately in Panel B and C. There exist monotonic patterns in the portfolios sorted on the percentage yield and commodity momentum. The portfolios with higher percentage yield or higher prior return achieve higher returns, which is consistent with the results of Hollstein et al. (2021a) and Szymanowska et al. (2014). These patterns support storage theory because low inventory tends to lead to high commodity prices as well as high convenience yields. However, the increasing pattern disappears for the capital gains. In this case, the portfolios with higher percentage yield or prior returns now have lower capital gains. The variation across portfolio percentage yields are larger than the variation across portfolio capital gains. There are large return spreads among these portfolios, which supports the usefulness of these portfolios as test assets in addition to individual commodities.

The correlations among commodity spot return, capital gain and futures return series consisting of average individual commodity returns (column 2, 6 and 10 in Panel A) are shown in Panel D in Table 1. The correlation among these three return series is of interest to our paper because our aim is to explain the cross-section of commodity returns. The spot return and futures return are highly correlated and the correlation is about to one, which is in line with equation (5). Therefore, our results with the spot return have the same implication for futures return. The correlation between spot return or futures return and capital gain is quite low (-0.02), which suggests that the cross-sectional property of capital gains is, to a great degree, different from that of commodity returns because of the percentage yields. These findings indicate that the percentage yield is quite important to study the cross-sectional variation among commodity returns. [15]

The summary statistics of the risk factors used in this paper are shown in Table 2. The $YIELD$ and $CMOM$ factors have positive return (7.79% for $YIELD$ factor and 5.99% for $CMOM$ factor annually), as shown in Panel B. Therefore, investors can achieve positive returns by engaging a long position in the two portfolios with the highest percentage yield (or momentum) and a short position in the two portfolios with the lowest percentage yield (or momentum). This finding suggests that these two factors are informative about the

[15] We also calculate the correlations among time-series spot return with yield, capital gain and futures return for each commodity. The correlation between time-series spot return with yield and futures return is close to 1 for all commodities. The correlation between time-series spot return or futures return and capital gain is larger than 0.9 for most commodities. Therefore, percentage yield does not change the time-series properties of return series, which might be because the percentage yield is smaller than capital gain for most commodities.

Table 1: Description of the commodities in the dataset.

	Mean (Ann.)	Std. (Ann.)	Shp	Sotn	Mean (Ann.)	Std. (Ann.)	Shp	Sotn	Mean (Ann.)	Std. (Ann.)	Mean (Ann.)	Std. (Ann.)
	Spot Return with yield (R)				Capital gains (cg)				Yield(y)		Futures(R_{fut})	
Panel A: Individual commodities (%)												
Corn	1.92	23.92	-4.26	-6.57	5.08	24.87	1.10	1.67	-3.16***	7.41	1.96	23.97
Soybean	10.02***	26.38	8.66	16.57	6.18*	27.77	2.59	4.24	3.85***	7.28	9.92***	26.82
Soybean oil	9.07**	27.27	7.00	11.78	5.66	26.78	1.91	2.94	3.41***	6.89	9.43**	27.74
Soybean meal	13.89***	31.65	12.18	25.35	7.87*	32.96	4.27	7.67	6.02***	7.59	13.81***	31.99
Wheat	2.17	24.99	-3.66	-5.66	4.98	25.81	0.91	1.44	-2.81**	8.27	2.29	24.67
Oats	3.58	26.61	-1.27	-1.97	5.98*	27.33	2.35	3.79	-2.40	9.29	3.86	26.34
Rough rice	-2.95	25.63	-9.06	-13.34	5.02	28.10	3.31	5.17	-7.97***	8.95	-3.15	25.13
Coffee	7.07	35.64	2.98	5.12	7.18	35.62	3.09	5.23	-0.11	8.58	7.35	35.62
Cocoa	7.61*	31.07	4.21	7.18	7.02*	30.92	3.44	5.59	0.59	6.96	7.88*	31.25
Orange juice	8.64*	31.69	5.28	8.99	6.95	32.07	3.06	5.04	1.69	8.05	8.80**	31.54
Live cattle	9.79***	16.63	12.92	20.28	4.58**	18.78	0.11	0.15	5.21***	7.84	9.71***	16.69
Feeder cattle	7.66***	14.67	9.33	14.06	4.04*	15.22	-0.74	-1.06	3.63***	5.07	7.69***	14.63
Lean hogs	10.13***	26.21	8.72	13.84	7.50*	32.49	3.72	5.72	2.63	19.85	10.20***	26.11
Lumber	2.86	30.40	-2.19	-3.15	8.93**	31.54	5.71	8.94	-6.07***	11.49	3.22	29.86
Cotton	6.66**	23.61	3.90	6.15	4.74	25.94	0.52	0.73	1.92	10.13	6.53*	23.72
Silver	8.34*	32.95	4.68	7.97	9.74**	32.83	6.44	11.12	-1.40***	1.66	8.40*	32.61
Copper	14.53***	27.24	15.14	26.23	7.52**	26.90	4.70	7.25	7.02***	6.04	14.87***	27.52
Gold	6.51**	20.14	4.35	7.17	7.08**	20.17	5.49	9.22	-0.57***	0.55	6.53**	19.85
Gas oil	11.66*	33.76	10.49	17.21	9.36	34.80	7.46	11.97	2.30	7.43	11.50*	33.50
Natural gas	-6.29	44.69	-8.11	-11.91	13.38	50.14	8.81	14.90	-19.66***	23.70	-5.95	43.18
Crude oil	11.40*	36.63	8.88	13.43	8.27	38.74	5.07	7.90	3.13	9.96	11.14*	36.10
Gasoline	17.14***	35.83	15.93	24.80	9.50	40.04	6.44	9.99	7.63***	14.55	16.77***	35.29
Heating oil	10.64**	33.85	7.76	12.51	7.72	34.67	4.12	6.44	2.92	9.11	10.71**	33.69
$Portfolio_C$	8.50***	13.59	12.32	20.27	7.06***	13.55	7.92	12.46				
$Portfolio_M$	11.29***	16.27	16.94	24.45	11.29***	16.27	16.94	24.45				
$Portfolio_{C+M}$	10.06***	11.31	19.93	28.81	9.28***	11.38	16.91	24.38				
Panel B: Commodity portfolios sorted on the percentage convenience yield (%)												
P1 (Low)	2.79	17.77	-3.73	-5.62	12.47***	18.49	17.66	33.71	-9.68***	5.43	2.91	17.29
P2	5.96**	17.32	3.66	5.80	6.62***	17.60	5.12	8.00	-0.66	4.26	5.98**	17.24
P3	10.26***	15.72	15.08	25.57	5.42**	15.98	2.52	3.78	4.84***	4.85	10.31***	15.83
P4 (High)	16.45***	20.62	23.93	42.32	2.81	21.19	-3.09	-4.40	13.64***	6.74	16.68***	21.05
Panel C: Commodity portfolios sorted on commodity momentum (%)												
P1 (Low)	4.24*	18.40	-0.46	-0.75	13.30***	18.92	18.92	37.36	-9.06***	5.30	4.34*	18.04
P2	7.46***	15.74	7.80	12.42	8.04***	15.92	9.15	14.89	-0.58	4.09	7.57***	15.63
P3	8.57***	15.02	11.24	17.89	3.84*	15.20	-1.61	-2.25	4.73***	4.93	8.60***	15.11
P4 (High)	15.02***	23.17	18.68	34.74	1.65	23.40	-4.87	-7.19	13.37***	6.61	15.20***	23.60

Panel D: Correlation among different returns series consisting of average individual returns

	R	cg	R_{fut}
R	1.00		
cg	-0.02	1.00	
R_{fut}	1.00	-0.02	1.00

Note: This table reports the annualized average return and standard deviations of individual commodities and portfolios. The Sharpe ratio is $Shp = E\left(R_i^e\right)/\sigma\left(R_i^e\right)$. The Sortino ratio is $Sotn = E\left(R_i^e\right)/\sqrt{\sum_{t=1}^{T}\left(Min\left(0, R_i^e\right)\right)^2/T}$. $Portfolio_C$ is the equally-weighted commodity portfolios. $Portfolio_M$ is the stock market portfolio. $Portfolio_{C+M}$ is an equally-weighted commodity and stock market portfolio. Spot return R is defined as $R_{t+1} = \left(S_{t+1} + D_{t\to t+1}^{t+1}\right)/S_t - 1$. Capital gain cg is defined as $cg_{t+1} = S_{t+1}/S_t - 1$. Futures return R_{fut} is defined as $R_{fut,t\to t+1} = F_{t+1,t+2}/F_{t,t+2} - 1 + rf_{t\to t+1}$. Yield is defined as $y_{t+1} = D_{t\to t+1}/S_t$. The significance of returns are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The sample of individual commodities starts from different time. The portfolios sorted by percentage yield starts from January 1961 and the portfolios sorted by momentum starts from November 1961.

risks of commodity markets. Additionally, the commodity momentum factor has a lower average return and a lower volatility compared to the momentum factor based on the stock market, which is consistent with the finding of Hollstein et al. (2021a).

Table 2: Summary statistics of risk factors (%).

Factors	Mean (Ann.)	Std. Dev (Ann.)	Min (Ann.)	Max (Ann.)	Obs.
Panel A: Asset pricing factors					
CG	2.71	1.11	-23.55	21.47	343
MKT	6.79	16.36	-175.99	119.96	343
SMB	2.70	10.42	-57.84	86.58	343
HML	2.91	10.58	-95.07	108.90	343
MOM	7.82	15.58	-315.92	141.18	343
RMW	3.02	7.80	-85.11	126.66	343
CMA	3.04	7.31	-64.57	75.18	343
Panel B: Commodity-specific factors					
CMKT	4.32	13.80	-145.91	185.77	343
YIELD	7.79	13.33	-101.26	195.20	343
CMOM	5.99	14.61	-106.91	167.22	343

Note: This table shows the summary statistics of the annualized risk factors from September 1963 to September 2020. *CG* refers to the consumption growth factor. *MKT* refers to the equity market excess return factor. *SMB* refers to the size factor. *HML* refers to the value factor. *MOM* refers to the equity market momentum factor. *RMW* refers to the profitability factor. *CMA* refers to the investment factor. *CMKT* refers to the commodity market factor. *YIELD* refers to factor related to the percentage net convenience yield. *CMOM* refers to the commodity momentum factor.

4. Results

4.1. The cross-section of expected returns of individual commodities

We assess the ability of the asset pricing factors and commodity-specific factors to explain the cross-section of individual commodity returns with the methods introduced in section 2.3. Although we use the commodity spot return with the net convenience yield in analysis, the results have the same implication for futures returns and are comparable to the studies with futures returns because the two return series are quantitively similar. We find that both the asset pricing models and the commodity-specific models play a role in explaining the cross-section of individual commodity returns and illustrate this below.

The results of the Fama and MacBeth (1973) two-step procedure estimations of the cross-section of expected return of the different commodities are reported in Table 3. In addition to the risk premium (λ_f) and intercept (λ_0), we also report the R^2 in the cross-sectional regressions as an informal and intuitive measure of fit. The R^2 represents the fraction of the cross-sectional variation of the commodity returns that the model can explain. Among the asset pricing models, the Fama and French (1993) three-factor model, Carhart (1997) four-factor model and Fama and French (2015) five-factor model are able to explain the individual commodity returns. The intercepts are insignificantly different from zero for these three asset pricing models, suggesting that the common average return among individual commodities that cannot be captured by the three models are insignificantly different from zero. For the Fama and French (1993) three-factor model and Carhart (1997) four-factor model, the value factor (HML) has a positive and significant risk premium, 2.20% and 1.95% respectively on a bimonthly basis (roughly implying 13.2% and 11.7% per year). These two models explain on average 32% and 39% of the cross-sectional variation of expected individual commodity returns. For the Fama and French (2015) five-factor model, both the value factor and investment factor (CMA) have positive and significant risk premiums, (2.66% for HML and 1.95% for CMA). This model explains on average 46% of the cross-sectional variation of individual commodity returns. Therefore, it appears that the value and investment factors are significantly priced. The positive risk premium suggests that investors are compensated for the exposure to the risk related to the equity value and investment effect. The good performance of Fama and French (1993) three-factor model, Carhart (1997) four-factor model and Fama and French (2015) five-factor model are consistent with Hollstein et al. (2021a). However, Daskalaki et al. (2014) reject the Fama and French (1993) three-factor model and Carhart (1997) four-factor model. This might be because we omit the erratic futures price behavior in the delivery month and the previous month, in line with Hollstein et al. (2021a), while Daskalaki et al. (2014) only exclude the prices in the delivery month. Other asset pricing models considered in Table 3, the $CCAPM$ and $CAPM$ models, are rejected because they have either insignificant risk premiums (coefficients of the risk factors' loadings in equation (11)) or significant intercepts, as in Bodie and Rosansky (1980) and Daskalaki et al. (2014). The unsatisfactory performance of the $CCAPM$ and $CAPM$ models in explaining the cross-section of individual commodity returns is perhaps not that surprising because they perform poorly for common stock returns as well (e.g., Campbell and Cochrane, 2000; Cochrane, 1996;

Jagannathan and Wang, 1996; Kang et al., 2011).

For the commodity-specific models, the one-factor model with the commodity market excess return factor ($CMKT$), $CF1_{CMKT}$ model, does not do a very good job in explaining the cross-section of individual commodity returns because of the insignificant risk premium, i.e. the $CMKT$ factor is insignificantly priced. This might be because commodities only comprise a small portion of the overall financial market compared to common stocks or bonds (e.g., Shang et al., 2016). The one-factor model with yield factor ($YIELD$), $CF1_{YIELD}$ model, also performs poorly because of the significant intercept. But the $YIELD$ factor has a significant risk premium in $CF1_{YIELD}$ model. So the $YIELD$ factor does help explain the cross-section of individual commodities to some extent, although there exists a common average return that cannot be captured by the $YIELD$ factor. Another one-factor model using the commodity momentum factor ($CMOM$), $CF1_{CMOM}$ model, has an insignificant intercept and a significant risk premium for the $CMOM$ factor at 3.40% on a bimonthly basis (20.4% annually) and is significant at the 1% level. This model explains on average 13% of the cross-sectional variation in expected individual commodity returns. These findings are different from those of Daskalaki et al. (2014), which suggests that the *basis* (related to the $YIELD$ factor) and commodity momentum factor do not explain the variation across individual commodities at all. The three-factor model, $CF3$, including $CMKT$, $YIELD$ and $CMOM$ factors, performs satisfactory and explains on average 30% of the cross-sectional variation in individual commodity returns. In the $CF3$ model, both the intercept and the risk premium of $CMKT$ are statistically insignificant. The bimonthly risk premium of the $YIELD$ factor is 2.34% (14.04% annually), and is significant at the 1% level. The bimonthly risk premium of the $CMOM$ factor is 3.44% (20.64% annually) and significant at the 5% level and similar to the estimate in the $CF1_{CMOM}$ model as well (20.4% annually). All the significant risk premiums of the asset pricing and commodity-specific factors are different from the mean values of the corresponding risk factors as shown in Table 2 in section 3.3. This difference supports our choice to estimate the risk premium with the Fama and MacBeth (1973) two-step procedure because it allows us to estimate the risk premiums with all available individual commodities rather than only looking at the sample mean of the risk factors.

Table 3: Fama-MacBeth cross-sectional regressions for individual commodities (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
$CCAPM$	0.13										0.23	14
	(1.39)										(0.51)	
$CAPM$		0.13									0.72*	10
		(0.12)									(1.96)	
$FF3$		0.11	1.15	2.20**							0.35	32
		(0.11)	(1.24)	(2.21)							(0.92)	
$FF4$		0.79	1.46	1.95*	2.22						0.38	39
		(0.63)	(1.49)	(1.96)	(1.33)						(0.95)	
$FF5$		-0.84	1.35	2.66*		-1.70	1.95*				0.21	46
		(-0.66)	(1.30)	(1.96)		(-1.38)	(1.65)				(0.45)	
$CF1_{CMKT}$								0.70			-0.01	12
								(1.15)			(-0.02)	
$CF1_{YIELD}$									2.70***		0.73**	7
									(3.30)		(2.27)	
$CF1_{CMOM}$										3.40***	0.43	13
										(2.67)	(1.38)	
$CF3$								0.27	2.34***	3.44**	0.52	30
								(0.45)	(2.78)	(2.33)	(1.06)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for individual commodities: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess return of commodity i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. The sample is from September 1963 to September 2020. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Even though Table 3 suggests that the $FF3$, $FF4$, $FF5$, $CF1_{CMOM}$ and $CF3$ models can explain the cross-section of returns of individual commodities, because they have insignificant intercepts and significant risk premiums for risk factors, it is not possible to point at one single model (or factor) which performs best. In line with Bakshi et al. (2019), Brooks et al. (2016), and Jagannathan and Wang (1996), we visualize the performance of the studied models in explaining the cross-sectional variation in expected individual commodity

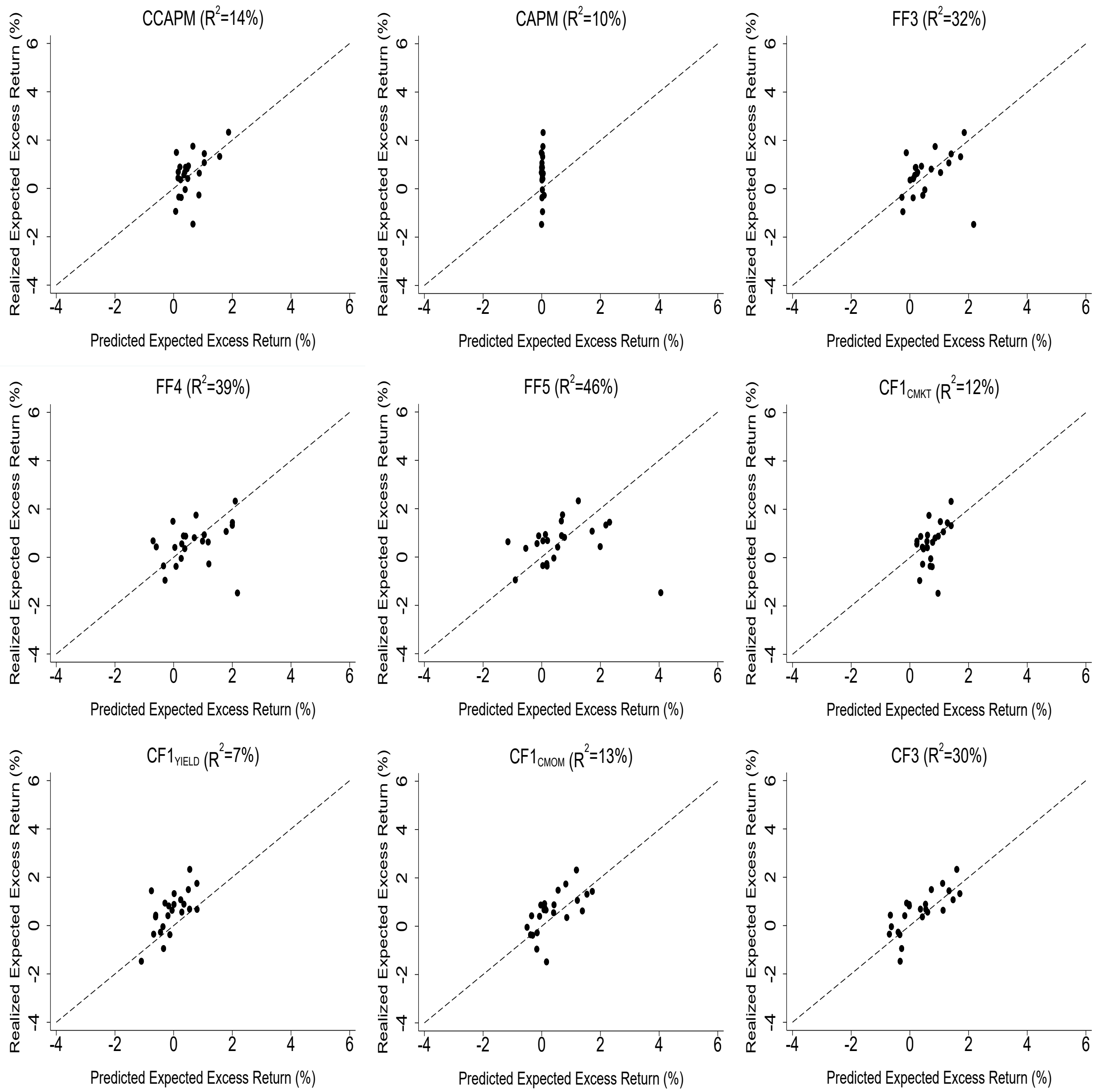

Figure 1: Predicted and Realized expected returns for individual commodities. *Note:* The predicted expected returns of the Fama and MacBeth (1973) two-step procedure are calculated with: $E\left(R_i^e\right) = \hat{\beta}'_{i,f}\lambda_{f,t}$, where $\hat{\beta}'_{i,f}$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). λ_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 September 1963 to September 2020. The R^2 is the average value of the R_t^2 of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

returns by plotting the predicted expected excess return versus the realized expected excess return of individual commodities in Figure 1. The predicted expected excess return is calculated as the sum of the products of risk premiums and corresponding risk loadings. The realized expected excess return is proxied by the average excess return of individual commodities. The distance of the scatters to the 45-degree line reflects the pricing errors of the corresponding models (a scatter represents a commodity). The closer the scatters of a model to the line, the smaller the pricing error and thus the better the performance of the particular model.

Figure 1 suggests that the $CF3$ model performs best among all the studied asset pricing models and commodity-specific models since the scatters are closest to the 45-degree line. The three asset pricing models $FF3$, $FF4$ and $FF5$ perform well in capturing the variation among commodity returns except natural gas, the scatter most distant from the 45-degree line. Generally, $FF3$, $FF4$ and $FF5$ models perform poorer than but competitively to the $CF3$ model even though the $FF3$, $FF4$ and $FF5$ models explains 32%, 39% and 46% of the cross-section of individual commodities, while the $CF3$ model only explains 30% (see the average R^2 in Figure 1, which is also reported in Table 3). Intuitively one may think that because the $FF5$ model consists of more factors, it mechanically increases the proportion of the cross-section explained by the $FF5$ model. While this may be true for time-series regressions, in the two-step procedure it does not necessarily mean that $FF5$ model has a lower pricing error in the cross-section (recall that shorter distance to the 45-degree line implies lower pricing error). Asset pricing factors and commodity-specific factors have explanatory power for the cross-section of individual commodity returns, in line with Bakshi et al. (2019) and Hollstein et al. (2021a). For example, investors on commodity markets require compensation because of the exposure on risks related to the value factor (HML), investment factor (CMA), the yield factor ($YIELD$), or the commodity momentum factor ($CMOM$).

In all, we establish that there are common risk factors that help explain the individual commodity returns, albeit far from perfect. As such, the commodities we investigate cannot be qualified as fully heterogeneous (see also Lübbers and Posch, 2016). We find that the value factor (HML) and investment factor (CMA) are able to explain part of the cross-section of returns of individual commodities. This is consistent with the studies that suggest that commodity risks are somehow priced in relation to stock markets (e.g., Boons et al., 2014; Brooks et al., 2016), suggesting an increasing integration between commodity and stock markets.

4.2. The cross-section of expected returns of commodity portfolios

In order to compare with the studies using commodity portfolios, we use commodity portfolios as our test assets in this section, which is also common practice in asset pricing tests using common stock returns. One advantage to use these portfolios is that they can eliminate idiosyncratic risk among individual commodities, providing better estimates for factor betas. The idiosyncratic risk should not be priced if investors can diversify away this risk by trading commodity portfolios (e.g., Fernandez-Perez et al., 2016). Constructing dynamic portfolios also has the benefit that it potentially gives larger differences in expected returns for the model to explain. Therefore, we carefully study the cross-section of commodity portfolios in addition to individual commodities, which provides an alternative way to test which factors drive commodity returns.

Although a common practice to construct stock portfolios is to use double sorts, e.g., size and value, we construct commodity portfolios with single sort, as in Bakshi et al. (2019), Dhume (2010) and Sakkas and Tessaromatis (2020), because the number of commodity futures is very limited and is much less than the number of available common stocks. We use eight commodity portfolios as test assets consisting of four portfolios sorted on percentage yield and four portfolios sorted on commodity momentum. Although the small number of portfolios causes some concerns for the results, these concerns are alleviated by the results for individual commodities as discussed in section 4.1 and subject to robustness checks (see details in section 4.4).

Table 4: Fama-MacBeth cross-sectional regressions for commodity portfolios (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
CCAPM	0.52***										-1.39***	27
	(4.53)										(-2.73)	
CAPM		-9.74***									1.83***	23
		(-4.51)									(4.15)	
*FF*3		-1.12	2.34	5.22***							-0.21	54
		(-0.29)	(0.61)	(2.64)							(-0.24)	
*FF*4		-22.10***	8.32**	-6.72*	17.00***						3.99***	71
		(-3.23)	(1.97)	(-1.82)	(3.00)						(2.73)	
*FF*5		8.98	21.00***	7.28**		-3.11	-3.95**				-3.60*	85
		(1.40)	(3.19)	(2.46)		(-1.39)	(-2.31)				(-1.97)	
$CF1_{CMKT}$								3.41***			-2.67**	22
								(2.98)			(-2.41)	
$CF1_{YIELD}$									1.87***		0.71**	25
									(5.41)		(2.16)	
$CF1_{CMOM}$										1.47***	0.59*	27
										(4.16)	(1.83)	
*CF*3								1.03	1.63***	1.06***	-0.32	59
								(0.94)	(5.17)	(3.20)	(-0.29)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for commodity portfolios sorted on the percentage yield and commodity momentum: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess return of portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. The sample is from September 1963 to September 2020. *CCAPM* represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (*CG*). *CAPM* represents the Capital Asset Pricing model including a marker excess return factor (*MKT*). *FF*3 refers to the Fama and French (1993) three-factor model consisting of *MKT*, a size factor (*SMB*), and a value factor (*HML*). *FF*4 refers to Carhart (1997) four-factor model comprising *MKT*, *SMB*, *HML* and a momentum factor (*MOM*). *FF*5 is Fama and French (2015) five-factor model including a profitability factor (*RMW*) and an investment factor (*CMA*) except the *MKT*, *SMB* and *HML* factors. $CF1_{CMKT}$ is the model only including commodity excess return factor (*CMKT*). $CF1_{YIELD}$ is the model only including yield factor (*YIELD*). $CF1_{CMOM}$ is the model only including commodity momentum factor (*CMOM*). *CF*3 is the model including *CMKT*, *YIELD*, and *CMOM*.

The regression results for these portfolios with the Fama and MacBeth (1973) two-step procedure are displayed in Table 4. The table shows that all risk factors except the profitability factor (*RMW*) are significantly priced. However, only *FF*3 and *CF*3 models have insignificant intercepts. In the *FF*3 model, the value factor *HML* is positively and significantly priced. The risk premium of *HML* factors is 5.22% on bimonthly basis and is significantly at the 1% level. The *FF*3 model explains 54% of the variation in the cross-section of commodity portfolio returns. With regards to the commodity-specific models, the three one-factor models with *CMKT*, *YIELD*, and *CMOM* factors as a single factor perform poorly when judged by the intercepts but have significant risk premiums for risk factors. The performance of $CF1_{YIELD}$ is comparable to Szymanowska et al. (2014). Szymanowska et al. (2014) explain (short roll) returns of nearest-to-maturity futures port-

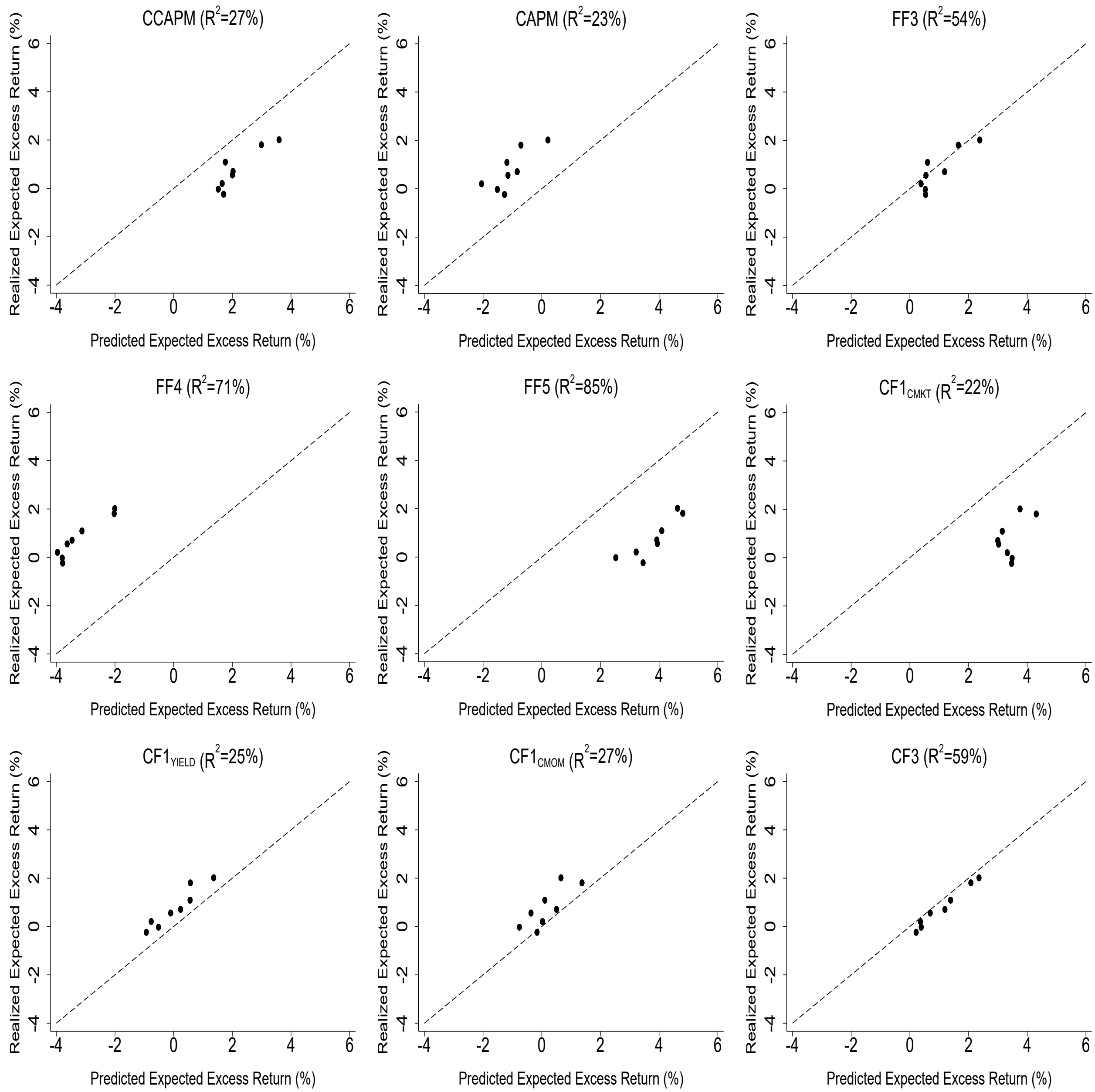

Figure 2: Predicted and Realized expected returns for commodity portfolios. *Note:* The predicted expected returns of the Fama and MacBeth (1973) two-step procedure are calculated with: $E\left(R_i^e\right) = \hat{\beta}_{i,f}' \lambda_{f,t}$, where $\hat{\beta}_{i,f}'$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). λ_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 September 1963 to September 2020. The R^2 is the average value of the R_t^2 of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

folios with time-series regressions and suggest that basis factor has a good fit to the four portfolio sorted either with basis or with commodity momentum. The difference might be because that we stack the portfolios and estimate the risk premium with Fama and MacBeth (1973) two-step procedure. In the $CF3$ model, the risk premium of $YIELD$ factor is 1.63% bimonthly (9.78% annually) and significant at the 1% level. The risk premium of $CMOM$ is 1.06% bimonthly (6.36% annually) and significant at the 1% level, which is quite close to the historical average return of $CMOM$ (5.99% annually). The $CF3$ model explains 59% of the variation across commodity portfolio returns. The decent performance of the $CF3$ model is in line with Bakshi et al. (2019).

To visually illustrate which model (factor) performs better in explaining the cross-section of commodity portfolios, Figure 2 compares the performance of the various models by plotting the predicted against the realized expected excess returns of the commodity portfolios. It shows that the $CF3$ model seems to perform best because the scatters for $CF3$ model are closest to the 45-degree line, followed by the $FF3$ model.

To sum up, it shows there are common risk factors that help explain the excess return in the cross-section of the commodity portfolios, such as the value factor, yield factor and commodity momentum factor, which also perform well for individual commodity returns as discussed in section 4.1. The value factor is significantly priced across individual commodities and portfolios, perhaps because the value effect exists across asset classes such as stocks, bonds and commodities and the corresponding value returns are strongly correlated (e.g., Asness et al., 2013). The results for commodity portfolios also suggest that commodity and stock markets are somewhat integrated because the common asset pricing factors are priced across commodity portfolios.

4.3. Studying the source of the explanatory ability of risk factors

As an extension of the related studies, we investigate why the risk factors can explain the cross-section of individual commodities and portfolios in this section. We decompose commodity returns into capital gains and percentage yield and replicate the analysis in section 4.1 and 4.2 with capital gains and percentage yields. By doing so, we can check whether the ability of risk factors in explaining the cross-section of commodity returns comes from capital gains, or percentage yields or both. As such, we assess the effect of the net convenience yield in the assessment of the performance of the various asset pricing models.

Table 5 reports the results of regression estimations of Fama and MacBeth (1973) two-step procedure with excess capital gains. Panel A shows the results for individual commodities. Here, the asset pricing models and commodity-specific models do not explain the cross-section of individual commodity capital gains at all because no factors are significantly priced. The regression results for the commodity portfolios are shown in Panel B. Mostly, the significantly priced risk factors across portfolio returns shown in Table 4 are also significantly priced across portfolio capital gains such as CG, MKT, HML, $YIELD$ and $CMOM$. Surprisingly, the $CAPM$ model performs well in explaining the cross-sectional portfolio capital gains. The MKT factor is significantly priced and the risk premium is 5.00% on a bimonthly basis (30% annually). Other commonly used asset pricing models perform poorly in explaining the cross-section of portfolio capital gains because the intercepts (λ_0) are significant. Nevertheless, the asset pricing factors, e.g., MKT and HML are significantly priced, suggesting that these asset pricing factors do have some ability to explain the cross-section of portfolio capital gains. Specifically, the $FF3$ model that performs satisfactorily for portfolio returns cannot capture all capital gains.

Among the commodity-specific models, only the $CF1_{YIELD}$ and $CF3$ models have significant risk premiums and insignificant intercepts. $CF1_{YIELD}$ explains 24% of the cross-sectional portfolio capital gains. The $YIELD$ factor is significantly priced (-1.33% bimonthly or -7.98% annually). The $CF3$ model explains 58% of the cross-sectional portfolio capital gains. The risk premium of the $YIELD$ factor is -0.91% bimonthly (-5.46% per annually) and the risk premium of $CMOM$ factor is -1.47% bimonthly (-8.82% per annually). Notably, the $CF3$ model also performs well for portfolio returns.

Table 5: Fama-MacBeth cross-sectional regressions for commodity capital gains (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Individual commodities												
$CCAPM$	0.08										0.22	13
	(0.87)										(0.57)	
$CAPM$		0.24									0.43	9
		(0.25)									(1.17)	
$FF3$		0.12	0.30	0.82							0.30	30
		(0.12)	(0.34)	(0.74)							(0.80)	
$FF4$		0.45	0.45	0.71	1.10						0.33	38
		(0.37)	(0.50)	(0.64)	(0.68)						(0.85)	
$FF5$		-0.46	0.39	1.17		-0.23	0.90				0.30	44
		(-0.37)	(0.39)	(0.79)		(-0.21)	(0.76)				(0.71)	
$CF1_{CMKT}$								0.28			0.17	12
								(0.48)			(0.38)	
$CF1_{YIELD}$									0.06		0.44	7
									(0.08)		(1.37)	
$CF1_{CMOM}$										1.38	0.39	11
										(1.10)	(1.25)	
$CF3$								0.26	0.05	0.94	0.22	28
								(0.45)	(0.06)	(0.67)	(0.46)	
Panel B: Commodity portfolios												
$CCAPM$	-0.46***										2.02***	26
	(-3.28)										(3.74)	
$CAPM$		5.00**									-0.25	23
		(2.30)									(-0.55)	
$FF3$		-12.30***	-4.30	-8.87***							3.58***	56
		(-3.15)	(-1.54)	(-4.61)							(4.28)	
$FF4$		-11.30	-4.55	-8.38**	4.73						3.39**	74
		(-1.60)	(-1.44)	(-2.49)	(0.90)						(2.25)	
$FF5$		-10.00**	-3.57	-7.26***		0.64	-1.20				2.95**	83
		(-2.06)	(-1.11)	(-2.72)		(0.30)	(-0.90)				(2.48)	
$CF1_{CMKT}$								-1.72			2.09*	20
								(-1.45)			(1.85)	
$CF1_{YIELD}$									-1.33***		0.42	24
									(-3.71)		(1.29)	
$CF1_{CMOM}$										-1.46***	0.55*	26
										(-4.01)	(1.71)	
$CF3$								1.73	-0.91***	-1.47***	-1.28	58
								(1.46)	(-2.73)	(-4.24)	(-1.13)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for commodity capital gains: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess capital gains of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. The sample is from September 1963 to September 2020. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table 6 reports the results of the regression estimates of the Fama and MacBeth (1973) two-step procedure with percentage yields. Panel A shows the results for individual commodities. All the significantly priced risk factors, HML, $YIELD$ and $CMOM$, across in-

Table 6: Fama-MacBeth cross-sectional regressions for percentage yield (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
						Panel A: Individual commodities						
$CCAPM$	-0.04										0.24**	10
	(-0.37)										(2.17)	
$CAPM$		3.75									0.32***	7
		(1.48)									(3.42)	
$FF3$		3.93*	-0.14	-3.95*							0.45***	28
		(1.74)	(-0.09)	(-1.66)							(4.33)	
$FF4$		1.59	-0.67	0.14	-4.18						0.42***	34
		(0.63)	(-0.39)	(0.05)	(-1.22)						(4.26)	
$FF5$		4.56	1.67	-3.12		0.57	-2.64				0.42***	46
		(1.55)	(0.97)	(-1.04)		(0.34)	(-1.28)				(3.70)	
$CF1_{CMKT}$								6.10**			0.10	10
								(2.06)			(0.81)	
$CF1_{YIELD}$									6.96***		0.15	20
									(3.34)		(1.43)	
$CF1_{CMOM}$										9.51***	0.13	20
										(4.02)	(1.23)	
$CF3$								5.56**	5.18***	9.79***	-0.01	37
								(2.07)	(2.71)	(3.99)	(-0.07)	
						Panel B: Commodity portfolios						
$CCAPM$	3.40***										-1.71***	30
	(18.49)										(-13.74)	
$CAPM$		-28.40***									-0.28**	15
		(-11.33)									(-2.26)	
$FF3$		-77.60***	34.60***	-39.80***							0.06	48
		(-19.79)	(17.14)	(-14.54)							(0.42)	
$FF4$		-81.70***	35.70***	-49.00***	50.00***						0.02	58
		(-19.98)	(17.29)	(-14.26)	(11.52)						(0.11)	
$FF5$		-27.80***	12.50***	-40.30***		16.00***	16.30***				4.42***	90
		(-5.29)	(6.22)	(-7.37)		(4.13)	(6.43)				(12.83)	
$CF1_{CMKT}$								84.60***			-2.39***	38
								(22.11)			(-17.97)	
$CF1_{YIELD}$									-18.50***		0.71***	9
									(-4.57)		(5.14)	
$CF1_{CMOM}$										70.20***	-1.09***	20
										(18.21)	(-9.69)	
$CF3$								117.80**	35.40**	-11.20*	-3.61**	57
								(21.92)	(7.89)	(-2.51)	(-19.24)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for commodity percentage yields: $y_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $y_{i,t}$ is the percentage yield of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** 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 is from September 1963 to September 2020. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

dividual returns are significantly priced across individual percentage yields as well. Although all the commonly used asset pricing models have intercepts that are significantly different from zero, the MKT factor and HML factor are significantly priced in $FF3$. The risk premiums of MKT and HML are 3.93% and -3.95% separately on bimonthly basis. All

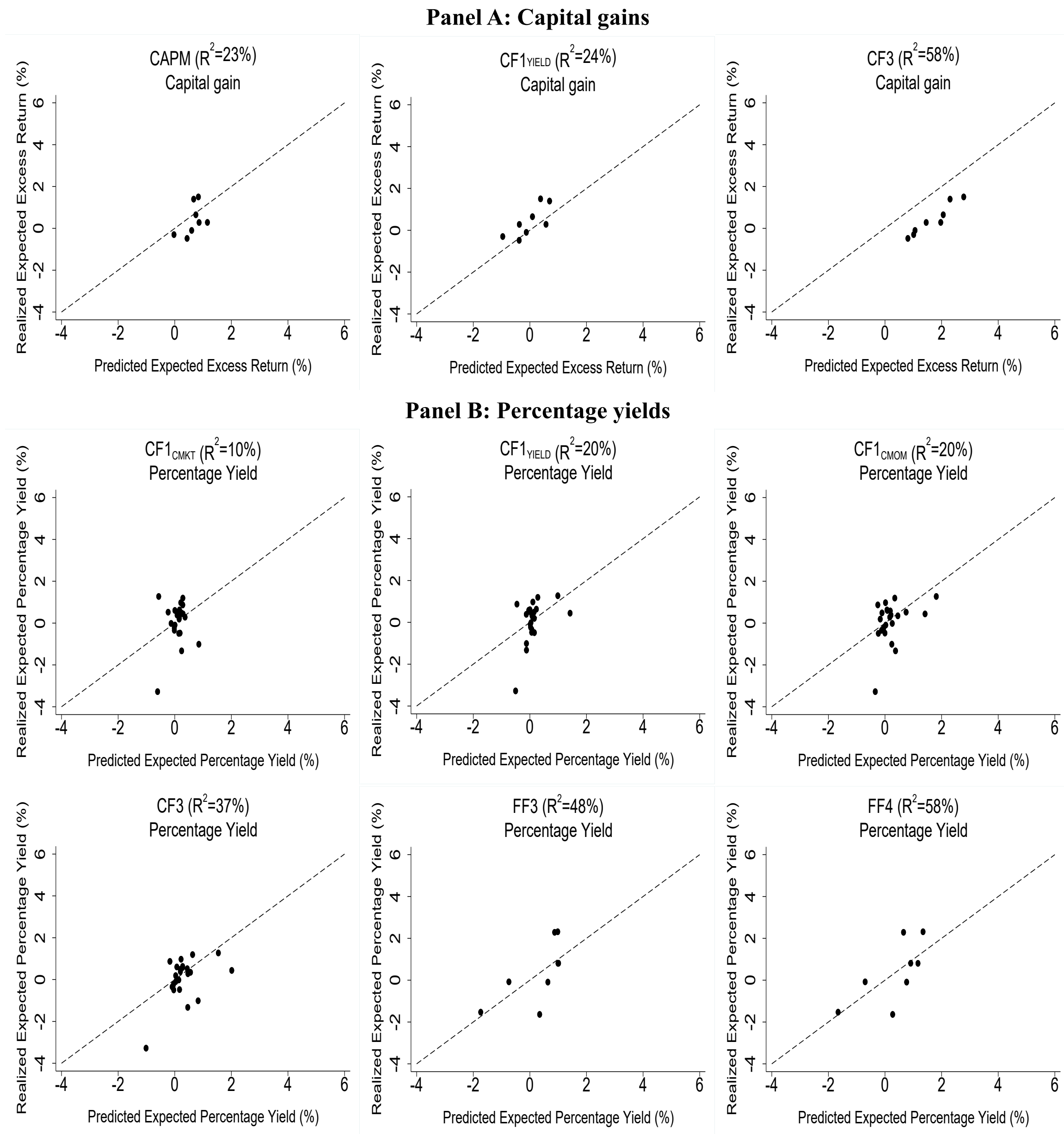

Figure 3: Predicted and realized expected capital gains and percentage yield. *Note:* The predicted expected excess capital gains and percentage yield of the Fama and MacBeth (1973) two-step procedure are calculated with: $\hat{\beta}'_{i,f}\lambda_{f,t}$, where $\hat{\beta}'_{i,f}$ is the estimated beta with the time-series regressions (the first step) of Fama and MacBeth (1973). λ_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 September 1963 to September 2020. The R^2 is the average value of the R_t^2 of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

the commodity-specific models perform well in explaining the cross-section of percentage yields. In $CF1_{CMKT}$, the $CMKT$ factor is significantly priced (6.10% bimonthly) and this model explains 10% of the variation of cross-sectional percentage yields. In $CF1_{YIELD}$ model, the $YIELD$ factor is significantly priced and the risk premium is 6.96% bimonthly. $CF1_{YIELD}$ model explains 20% of the cross-sectional percentage yields. The $CF1_{CMOM}$ model has a significant risk premium of 9.51% bimonthly for the $CMOM$ factor and explains 20% of the variation of cross-sectional percentage yields. The $CF3$ model explains 37% of the cross-section of individual percentage yields. The risk premiums are 5.56% for the $CMKT$ factor, 5.18% for the $YIELD$ factor and 9.79% for the $CMOM$ factor on bimonthly basis.

Panel B in Table 6 displays the regressions results with percentage yields of portfolios. The risk factors that are significantly priced across portfolio returns are also significantly priced across portfolio percentage yields. Particularly, all the studied risk factors have significant risk premiums, suggesting that they have some ability to explain the cross-section of portfolio percentage yields. Among all the studied asset pricing models and commodity-specific models, $FF3$ and $FF4$ models perform well in explaining the cross section of portfolio percentage yields. In $FF3$ model, the MKT, SMB and HML are significantly priced, the risk premiums are -77.60%, 34.60%, and -39.80% on a bimonthly basis. The $FF3$ model explains 48% of the variation of cross-sectional portfolio percentage yields. In the $FF4$ model, the MKT, SMB, HML and MOM are significantly priced as well. The risk premiums are -81.70%, 35.70%, -49.00%, and 50%, respectively. The $FF4$ model explains 58% of the total variation. Note that the $FF3$ model performs well in explaining the cross-section of portfolio returns, too.

We plot the predicted and realized expected excess capital gains and percentage yields for those models that perform relatively well in Figure 3. Panel A shows the performance of $CAPM$, $CF1_{YIELD}$ and $CF3$ in explaining the cross-section of portfolio capital gains. Among these three models, $CF1_{YIELD}$ performs best, suggested by the distance of the scatters to the 45-degree line. The performance of the models in explaining the cross-section of yields is shown in Panel B. For individual percentage yields, $CF1_{CMOM}$ and $CF3$ perform competitively. For portfolios percentage yields, $FF3$ and $FF4$ have similar performance in explaining the variation of percentage yields.

In sum, risk factors cannot explain the variation in the cross-section of individual capital gains at all. The risk factors that help explain the cross-section of individual returns also have the ability to explain the variation of percentage yields across individual commodities. As such, the ability of risk factors or models in explaining the cross-section of commodity returns discussed in section 4.1 mainly comes from the returns accrued to percentage yields. This might be because the variation across individual percentage yields are larger than the variation across individual capital gains, although the absolute percentage yields are smaller than capital gains, as shown in Table 1. As to commodity portfolios, the risk factors that are significantly priced across portfolio returns are also priced across portfolio capital gains and portfolio percentage yields. Recall that the $FF3$ and $CF3$ models perform well in explaining the cross-section of portfolio returns. The $FF3$ model performs well for portfolio percentage yields and the $CF3$ model performs well for portfolio capital gains. As such, the ability of risk factors or models in explaining the cross-section of portfolio returns discussed in section 4.2 comes from both capital gains and percentage yields.

4.4. Sensitivity and robustness checks

In this section, we perform sensitivity and robustness checks regarding the results reported in sections 4.1, 4.2 and 4.3. In particular, we investigate the role of the sample period, the estimation strategy employed, the seasonality in prices and the reinvestment of convenience yields. The results are shown in Appendix C.

First, it could be that our results are driven by inclusion of the period after the financialization of commodities when large investment inflows occurred into commodity futures markets. We therefore test whether the results for commodity returns, capital gains and percentage yields are sensitive to the selected sample period. We divide the full sample with one breakpoint, January 2004. Basak and Pavlova (2016) argue that this is the time when the financialization started. We repeat the analysis with two subsamples. The first sample runs from March 1987 to November 2003. The second runs from January 2004 to September 2020, in order to ensure that these two subsamples have the same length.

The results for individual commodities are shown in Table C.2 in Appendix C. It appears that the $CCAPM$, $FF4$ and $CF1_{CMOM}$ models are able to explain the cross-section of individual commodity returns in the subsample before financialization and that the $FF3$, $FF5$, $CF1_{YIELD}$, $CF1_{CMOM}$ and $CF3$ models explain the cross-section of individual commodity returns in the subsample after financialization. In addition, Table C.3 in Appendix C shows the results for commodity portfolios for these subsamples. The $CCAPM$, $CAPM$, $FF3$, $FF4$, $FF5$, $CF1_{CMKT}$, and $CF1_{CMOM}$ explain the cross-section of portfolio returns in the subsample before financialization, while the $FF3$, $FF4$, $CF1_{YIELD}$ and $CF3$ models have explanatory power in the subsample after financialization. Therefore, we conclude that the explanatory ability of risk factors to the cross-section of commodity returns are not highly sensitive to the subsample selection at both the individual commodity and commodity portfolio level. These results suggest that financialization does not improve the performance of the studied models. Prokopczuk et al. (2021) suggest this might result from the fact that the effect of financialization on commodity returns is not persistent. The results for capital gains are shown in Table C.4 and C.5. No risk factors are priced at all in the two subsamples across individual capital gains, while there exist models, e.g., $CF1_{YIELD}$ and $CF3$ perform well for portfolio capital gains in both subsamples. Table C.6 and C.7 in Appendix C display that there exist risk factors e.g., SMB, HML, $CMKT$, $YIELD$ and $CMOM$, priced in the two subsamples across individual and portfolio percentage yields. Therefore, the bottom line is that the ability of risk factors to explain the cross-section of individual returns comes from percentage yields, while the ability of risk factors to explain the cross-section of portfolios returns comes from both capital gains and percentage yields, and these results are not sensitive to the selection of subsamples.

Second, the risk factor loadings might vary over time. Therefore, we test whether the results for the commodity returns, capital gains and percentage yields are robust to the estimation method. More specifically, we estimate the risk loadings in the first step of Fama and MacBeth (1973) procedure with rolling windows. In order to ensure that we have enough observations to accurately estimate the time-varying risk loadings (betas) and risk premiums - a short estimation window allows for more variation in the betas, but due to the lower number of observations also adds noise (recall that we have bimonthly data), we use rolling windows of six and ten years. The results are shown in Tables C.8 to C.13 in Appendix C. With a rolling window of six years, $FF5$ performs well in explaining the cross-section of individual commodities, while With a rolling window of six years, $FF5$ performs well in explaining the cross-section of individual commodities, while $CAPM$, $FF3$, $FF4$ and $CF1_{CMOM}$ models have significant intercepts but with significant risk premium for MKT and $CMOM$. For the cross-section of portfolio returns, $CAPM$ and $CF3$ perform well. $FF4$, $CF1_{YIELD}$, $CF1_{CMOM}$ also have significant risk premiums for MKT, $YIELD$ and $CMOM$ but with significant intercepts. As to capital gains, only the $CF1_{CMOM}$ model has both a significant risk premium and insignificant intercept for individual capital gains, while $FF5$, $CF1_{YIELD}$, and $CF3$ performs satisfactory for portfolio capital gains. As to percentage yields, $FF4$, $CF1_{CMOM}$, and $CF3$ have good performance for individual percentage yields. $FF3$ and $CF1_{CMKT}$ have a good fit for portfolio percentage yields. Similar results are found with rolling window of ten years. As such, the ability of risk factors or models to explain the cross-section of commodity returns, capital gains and percentage yields appears to be robust to estimations using rolling-window betas.

Finally, we also test the effect of seasonality in commodity prices and convenience yields with annual return and annual convenience yields at bimonthly frequency. The related asset pricing factors are transformed to annual consumption growth or annual returns in the same way as discussed in section 3.2. There is an issue about how the convenience yield is then reinvested within a year. van Binsbergen and Koijen (2010) argue that different reinvestments of dividend matter to the time-series characteristics. Therefore, we assume that the convenience yield is reinvested either in the equity market or at the risk-free interest rate. At the end of every second month, we sort the 23 commodities into four portfolios either with the percentage yield in the last year or the return in the last year and calculate the returns by holding the portfolios in the following twelve months. [16] The commodity-specific factors are constructed in the same way as discussed in section 3.1. The results with convenience yield reinvested at the equity market return for commodity returns, capital gains, and percentage yields are shown in Tables C.14-C.16. Regarding commodity returns, $FF4$, $FF5$ and $CF3$ perform well for individual commodity returns, while $FF3$, $FF4$ and $CF3$ perform well for portfolio returns. As to capital gains, no risk factors are significantly priced at all across individual capital gains, while $CAPM$, $FF3$, $FF4$, $CF1_{YIELD}$ and $CF1_{CMOM}$ perform satisfactory. As to percentage yields, SMB, $CMKT$, $YIELD$ and $CMOM$ are significantly priced across individual percentage yields and $CF1_{CMKT}$ and $CF3$ perform well. All risk factors except CMA are significantly priced across portfolio percentage yields and $FF3$ and $FF4$ have good fit. Again, similar results are found with convenience yield reinvested at the risk-free rate, as shown in Table C.17-C.19 in Appendix C. Therefore, the two ways of reinvestment of convenience yields only have little influence on the explanatory ability of risk factors. This findings does not necessarily contradict van Binsbergen and Koijen (2010), because it might be possible that the cross-sectional variation does not change much if the time-series of return or percentage yields vary to a similar degree for all commodities.

In sum, there exist asset pricing and commodity-specific factors that help explain the cross-section of returns. The ability of risk factors to explain the cross-section of individual returns comes from percentage yields, while the ability of risk factors to explain the

[16] The percentage yield in a year is defined as: $y_{t\to t+6} = \frac{D^{t+6}_{t\to t+6}}{S_t}$. The annual return is defined as: $R_{t+6} = \frac{S_{t+6}+D^{t+6}_{t\to t+6}}{S_t} - 1$.

cross-section of portfolios returns comes from both capital gains and percentage yields. These baseline results are not sensitive to the selection of subsamples, estimation methods, seasonality and the reinvestment of convenience yields.

5. Conclusion

We study which factors explain the cross-section of commodity returns for both individual commodities and portfolios as well as where this explanatory ability results from. Commodities have become a popular investment next to stocks and bonds and their returns are imperfectly correlated. We posit that the commodities are not orthogonal, implying that there will be some risk factors that can help explain the cross-section of individual commodities. Furthermore, this implies that commodities are integrated with stocks to at least some extent. This suggests that the widely used asset pricing factors can have explanatory power for the cross-section of commodity returns at both the individual and the portfolio level. However, there is no consensus about which factors explain the cross-section of commodity returns. We address this issue by accounting for the role of the net convenience yield. This is the net benefit associated with holding the underlying commodity, rather than the associated derivative or contract. We argue that commodity spot returns should include the net convenience yield too. This contrast with only accounting for the relative price changes of commodity spot prices (i.e., capital gains).

We decompose the commodity (spot or futures) returns into capital gains and percentage yields. We show this decomposition adds value to our understanding of excess returns in commodity markets, especially the source of the ability of risk factors to explain the cross-section of commodity returns. We apply widely used asset pricing factors (consumption growth, market excess return, size, value, momentum, profitability, and investment strategy) and commodity-specific factors (commodity market excess returns, commodity momentum factor, and the commodity yield factor) to explain the cross-section of commodity returns. Based on a sample of 23 commodities and a period of more than fifty years of observations, we establish several asset pricing and commodity-specific factors that explain the cross-section of commodity returns (value factor, commodity momentum factor, yield factor). As to individual commodities, the commodity-specific three-factor model performs best with significant risk premiums for commodity momentum and yield factors, while Fama and French (1993) three-factor model and Carhart (1997) four-factor model perform competitively with significant risk premium for value factor. As to commodity portfolios sorted on the percentage yield and commodity momentum, the commodity-specific three-factor model still performs best with significant risk premium for commodity momentum and yield factors, followed by Fama and French (1993) three-factor model, with significant risk premiums for value factor. Therefore, it appears that risk factors that stem either from the asset pricing factors or from the commodity-specific factors provide explanatory power for the cross-section of individual commodities and portfolios, suggesting that commodities have become somewhat integrated with stocks (i.e., financialization).

In order to explain why the risk factors help explain the cross-section of commodity returns, we investigate their ability to explain the cross-section of capital gains and percentage yields. For individual capital gains, it shows no risk factors are priced at all. For portfolio capital gains, most of the risk factors are significantly priced though. The Capital Asset Pricing model, commodity-specific one-factor model with yield factor and commodity-specific three-factor model perform well in explaining the cross-section of portfolios capital gains because of the significant risk premium for equity market excess return, commodity yield and momentum factors and insignificant intercepts. The commodity-specific one-factor model with yield factor performs best among these three models. For individual percentage yields, some asset pricing and commodity-specific factors are significantly priced. The four commodity-specific models perform well in explaining the cross-section of individual percentage yields, while equity market excess return and value factors are also significantly priced in Fama and French (1993) three-factor model. As to portfolio percentage yield, all the risk factors are significantly priced. Fama and French (1993) three-factor model and Carhart (1997) four-factor model perform well with insignificant intercepts. As such, the ability of risk factors to explain the cross-section of individual returns mainly is rooted in the percentage yield. The ability of risk factors to explain the cross-section of portfolio returns results from both capital gains and percentage yields. The commodity-specific models perform better in explaining the cross-section of portfolio capital gains, whereas the asset pricing models perform better in explaining the cross-section of portfolio percentage yields. We tested the sensitivity of our results in relation to sample selection, the use of estimation methods with a rolling window, to seasonality, and to the reinvestment of convenience yields. It turns out that the results remain qualitatively the same.

Appendix A. Practical implications, measurement and derivations

Appendix A.1. Practical implications and measurement

Recall that $D^{t+1}_{t\to t+1} = S_t\left(1 + rf_{t\to t+1}\right) - F_{t,t+1}$, $y_{t\to t+1} = \frac{D^{t+1}_{t\to t+1}}{S_t}$. So $rf_{t\to t+1} - y_{t\to t+1} = rf_{t\to t+1} - \frac{S_t(1+rf_{t\to t+1})-F_{t,t+1}}{S_t} = \frac{F_{t,t+1}}{S_t} - 1$, which is close to zero. Therefore, $F_{t,t+1} = S_t\left(1 + rf_{t\to t+1}\right) - D^{t+1}_{t\to t+1} = S_t\left(1 + rf_{t\to t+1} - y_{t\to t+1}\right) \approx S_t e^{rf_{t\to t+1} - y_{t\to t+1}}$. Consider a trading strategy that holds a futures contract until maturity. The excess futures return on fully collateral basis obtained by the investor is:

$$\begin{aligned} R_{fut,t\to t+n} &= \frac{S_{t+n}}{F_{t,t+n}} - 1 \approx \ln\left(\frac{S_{t+n}}{F_{t,t+n}}\right) = \ln\left(\frac{S_{t+n}}{S_t e^{rf_{t\to t+n} - y_{t\to t+n}}}\right) \\ &= \ln\left(\frac{S_{t+n}}{S_t}\right) - rf_{t\to t+n} + y_{t\to t+n} \approx \frac{S_{t+n}}{S_t} - 1 - rf_{t\to t+n} + y_{t\to t+n} \\ &\approx \frac{S_{t+n} + D^{t+n}_{t\to t+n}}{S_t} - 1 - rf_{t\to t+n} \end{aligned} \tag{A.1}$$

where $F_{t,t+n}$ refers to the price at time t of futures contract maturing at time $t+n$. Consider another trading strategy: At time t, an investor engages a long position of a futures contract maturing at time $t+n$ at price $F_{t,t+n}$ and ends this contract at time $t+n-1$ at price $F_{t+n-1,t+n}$,that is one period before the delivery date. The net futures excess return on a fully collateralized basis is:

$$\begin{aligned} R_{fut,t\to t+n-1} &= \frac{F_{t+n-1,t+n}}{F_{t,t+n}} - 1 \approx \ln\left(\frac{S_{t+n-1}e^{rf_{t+n-1\to t+n} - y_{t+n-1\to t+n}}}{S_t e^{rf_{t\to t+n} - y_{t\to t+n}}}\right) \\ &\approx \frac{S_{t+n-1}}{S_t} - 1 - rf_{t\to t+n-1} + y_{t\to t+n-1} \\ &= \frac{S_{t+n-1} + D_{t\to t+n-1}^{t+n-1}}{S_t} - 1 - rf_{t\to t+n-1} \end{aligned} \tag{A.2}$$

Appendix A.2. Derivations

Derivation of equation (4) in the main text:

$$\begin{aligned} R_{t+1} &= \frac{S_{t+1}}{S_t - D_{t\to t+1}^{t}} - 1 = \frac{S_{t+1}}{F_{t,t+1}}\left(1 + rf_{t\to t+1}\right) - 1 \\ &\approx \ln\left(\frac{S_{t+1}}{F_{t,t+1}}\left(1 + rf_{t\to t+1}\right)\right) \approx \ln\left(\frac{S_{t+1}}{S_t}\frac{S_t}{F_{t,t+1}}\right) + rf_{t\to t+1} \\ &\approx \left(\frac{S_{t+1}}{S_t} - 1\right) - \left(\frac{F_{t,t+1}}{S_t} - 1\right) + rf_{t\to t+1} = \frac{S_{t+1}}{S_t} - \frac{F_{t,t+1}}{S_t} + 1 + rf_{t\to t+1} - 1 \\ &= \frac{S_{t+1} + S_t\left(1 + rf_{t\to t+1}\right) - F_{t,t+1}}{S_t} - 1 = \frac{S_{t+1} + D_{t\to t+1}^{t+1}}{S_t} - 1 \end{aligned} \tag{A.3}$$

Derivation of equation (5) in the main text:

$$\begin{aligned} R_{fut,t\to t+1} &= \frac{F_{t+1,t+n}}{F_{t,t+n}} - 1 \approx \ln\left(\frac{S_{t+1}e^{rf_{t+1\to t+n} - y_{t+1\to t+n}}}{S_t e^{(rf_{t\to t+1} - y_{t\to t+1}) + (rf_{t+1\to t+n} - y_{t+1\to t+n})}}\right) \\ &= \ln\left(\frac{S_{t+1}}{S_t}\right) - rf_{t\to t+1} + y_{t\to t+1} \approx \frac{S_{t+1}}{S_t} - 1 - rf_{t\to t+1} + \frac{D_{t\to t+1}^{t+1}}{S_t} \\ &= \frac{S_{t+1} + D_{t\to t+1}^{t+1}}{S_t} - 1 - rf_{t\to t+1} = cg_{t+1} - rf_{t\to t+1} + y_{t\to t+1} \end{aligned} \tag{A.4}$$

Derivation of equation (7) in the main text:

$$
\begin{aligned}
D^{t}_{t+1\to t+2} &= D^{t}_{t\to t+2} - D^{t}_{t\to t+1} \\
&= S_t - \frac{F_{t,t+2}}{\left(1+rf_{t\to t+1}\right)\left(1+rf_{t+1\to t+2}\right)} - \left(S_t - \frac{F_{t,t+1}}{1+rf_{t\to t+1}}\right) \\
&= \frac{F_{t,t+1}}{1+rf_{t\to t+1}} - \frac{F_{t,t+2}}{\left(1+rf_{t\to t+1}\right)\left(1+rf_{t+1\to t+2}\right)} \\
&= \frac{F_{t,t+1} - \frac{F_{t,t+2}}{1+rf_{t+1\to t+2}}}{1+rf_{t\to t+1}}
\end{aligned}
\tag{A.5}
$$

Derivation of equation (9)) in the main text:

$$
\begin{aligned}
R_{t+1} &= \frac{S_{t+1}}{S_t - D^{t}_{t\to t+1}} - 1 = \frac{S_{t+1} - \frac{F_{t+1,t+2}}{(1+rf_{t+1\to t+2})} + \frac{F_{t+1,t+2}}{(1+rf_{t+1\to t+2})}}{\frac{F_{t,t+1}}{(1+rf_{t\to t+1})}} - 1 \\
&= \frac{\frac{F_{t+1,t+2}}{(1+rf_{t+1\to t+2})} + D^{t+1}_{t+1\to t+2}}{\frac{F_{t,t+1}}{(1+rf_{t\to t+1})}} - 1 = \frac{\frac{F_{t+1,t+2}}{(1+rf_{t+1\to t+2})} + F_{t,t+1} - \frac{F_{t,t+2}}{(1+rf_{t+1\to t+2})}}{\frac{F_{t,t+1}}{(1+rf_{t\to t+1})}} - 1 \\
&= \frac{F_{t+1,t+2}\frac{(1+rf_{t\to t+1})}{(1+rf_{t+1\to t+2})} + F_{t,t+1}\left(1+rf_{t\to t+1}\right) - F_{t,t+2}\frac{(1+rf_{t\to t+1})}{(1+rf_{t+1\to t+2})}}{F_{t,t+1}} - 1 \\
&\approx \frac{F_{t+1,t+2} + F_{t,t+1}\left(1+rf_{t\to t+1}\right) - F_{t,t+2}}{F_{t,t+1}} - 1 \\
&\approx \frac{S_{t+1} + D^{t+1}_{t\to t+1}}{S_t} - 1 = \frac{S_{t+1} + S_t\left(1+rf_{t\to t+1}\right) - F_{t,t+1}}{S_t} - 1
\end{aligned}
\tag{A.6}
$$

Appendix B. Accuracy check of price approximation

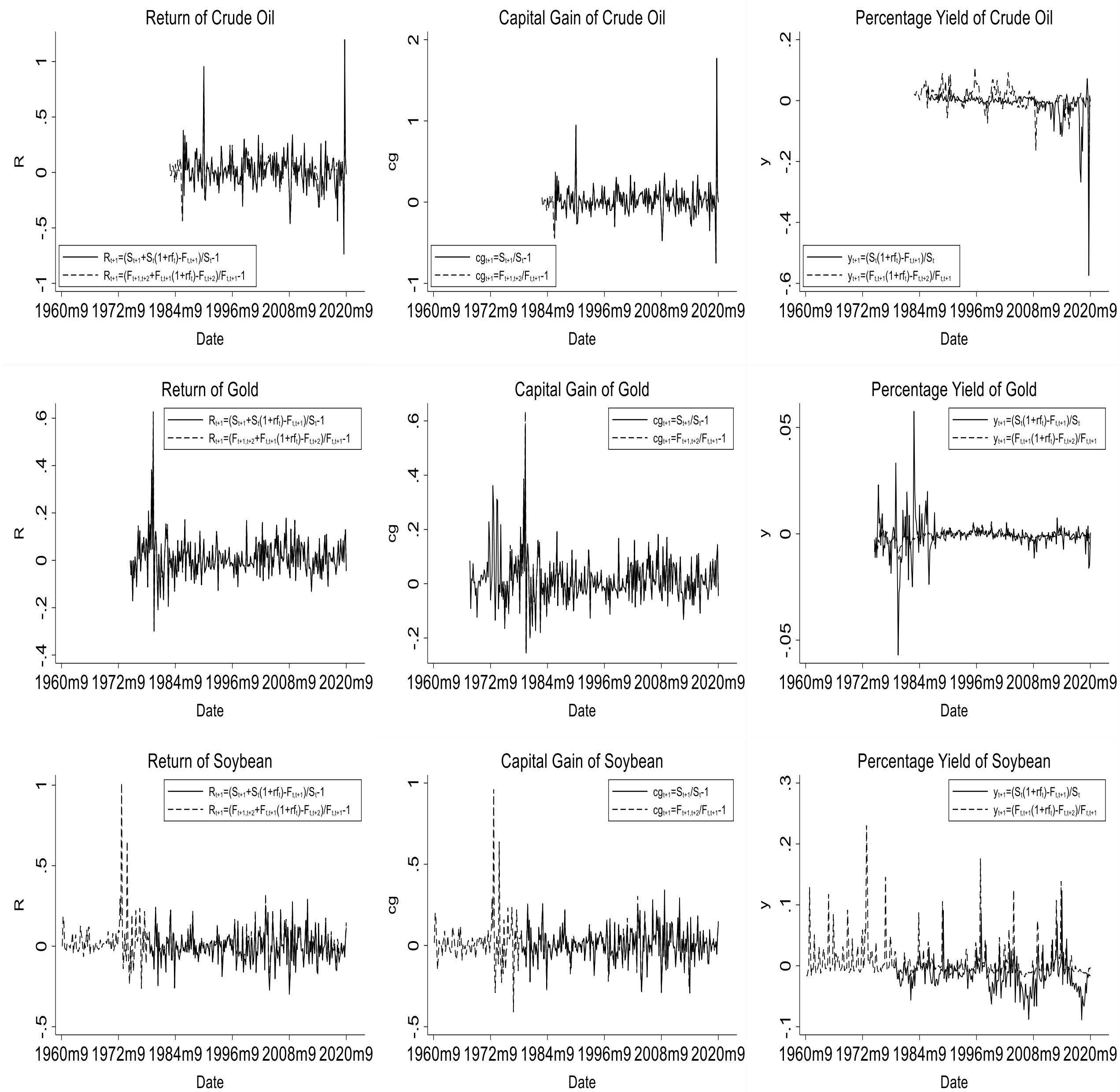

Figure B.1: Comparisons of return, capital gain and percentage yield. *Note:* For the real spot prices, we use crude oil WTI midland US FOB price from January 1986 to September 2020, gold spot multi-contributor price from March 1986 to September 2020 and No.1 Yellow soybean spot price from January 1979 to September 2020. The data is from Thomson Reuters Eikon. The currencies of spot prices are the same with those of corresponding futures prices.

Appendix C. Tables

Table C.1: Detailed information about the 23 commodities in the dataset.

			Delivery Month		
Commodities	RS	Exchange	Available	Used	Initial Date
Soybean oil	ZL	CBOT	1 3 5 7 8 9 10 12	1 3 5 7 9 12	1960 09
Soybean meal	ZM	CBOT	1 3 5 7 8 9 10 12	1 3 5 7 9 12	1960 09
Soybean	ZS	CBOT	1 3 5 7 8 9 11	1 3 5 7 9 11	1960 09
Copper	HG	COMEX	1 3 5 7 9 12	1 3 5 7 9 12	1960 09
Cocoa	CC	ICEUS	3 5 7 9 12	3 5 7 9 12	1960 09
Cotton	CT	ICEUS	3 5 7 10 12	3 5 7 10 12	1960 09
Live cattle	LE	CME	2 4 6 8 10 12	2 4 6 8 10 12	1965 01
Silver	SI	COMEX	3 5 7 9 12	3 5 7 9 12	1967 07
Orange juice	OJ	ICEUS	1 3 5 7 9 11	1 3 5 7 9 11	1967 09
Lean hogs	HE	CME	2 4 5 6 7 8 10 12	2 4 6 8 10 12	1968 11
Lumber	LS	CME	1 3 5 7 9 11	1 3 5 7 9 11	1970 01
Oats	ZO	CBOT	3 5 7 9 12	3 5 7 9 12	1960 09
Corn	ZC	CBOT	3 5 7 9 12	3 5 7 9 12	1960 09
Wheat	ZW	CBOT	3 5 7 9 12	3 5 7 9 12	1960 09
Coffee	KC	ICEUS	3 5 7 9 12	3 5 7 9 12	1972 11
Gold	GC	COMEX	2 4 6 8 10 12	2 4 6 8 10 12	1975 01
Feeder cattle	GF	CME	1 3 4 5 8 9 10 11	1 3 5 8 9 11	1977 01
Heating oil	HO	NYMEX	ALL	1 3 5 7 9 11	1979 01
Crude oil	CL	NYMEX	ALL	1 3 5 7 9 11	1983 05
Gasoline	RB	NYMEX	ALL	1 3 5 7 9 11	1985 01
Gas oil	LF	ICE	ALL	1 3 5 7 9 11	1986 07
Rough rice	ZR	CBOT	1 3 5 7 9 11	1 3 5 7 9 11	1989 05
Natural gas	NG	NYMEX	ALL	1 3 5 7 9 11	1990 05

Note: This table describes the detailed information about the 23 commodities, including the name, root symbol (RS), the exchange on which they are traded, the available delivery month, the used delivery month to construct the price data, and the initial date of the price series. NYMEX is the New York Mercantile Exchange. COMEX is the Commodity Exchange. CBOT is the Chicago Board of Trade. ICE is the Intercontinental Exchange. ICEUS is the ICE Futures U.S. CME is the Chicago Mercantile Exchange.

Table C.2: Fama-MacBeth cross-sectional regressions for individual commodity returns in subsamples (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Individual commodity returns in subsample 03/1987-11/2003												
$CCAPM$	0.11*										0.17	12
	(1.90)										(0.45)	
$CAPM$		-2.15									0.31	15
		(-1.26)									(0.87)	
$FF3$		-1.77	-2.61	2.15							0.49	33
		(-1.11)	(-1.58)	(1.42)							(1.26)	
$FF4$		-1.06	-3.03*	2.90**	1.18						0.68	42
		(-0.73)	(-1.86)	(1.99)	(0.51)						(1.60)	
$FF5$		-0.97	-0.73	1.53		-1.59	1.34				-0.05	45
		(-0.62)	(-0.53)	(0.97)		(-0.91)	(1.00)				(-0.13)	
$CF1_{CMKT}$								1.05			-0.56	17
								(1.56)			(-0.90)	
$CF1_{YIELD}$									-0.49		0.43	9
									(-0.38)		(1.25)	
$CF1_{CMOM}$										3.99*	0.38	18
										(1.89)	(1.04)	
$CF3$								0.78	1.70	2.94	-0.27	32
								(1.23)	(1.60)	(1.51)	(-0.47)	
Panel B: Individual commodity returns in subsample 01/2004-09/2020												
$CCAPM$	0.08										-0.18	14
	(0.69)										(-0.31)	
$CAPM$		1.07									-0.48	14
		(1.12)									(-0.89)	
$FF3$		0.80	1.25*	-1.00							0.03	31
		(0.92)	(1.92)	(-0.86)							(0.07)	
$FF4$		0.68	1.07	0.31	-4.37*						-0.17	39
		(0.77)	(1.60)	(0.27)	(-1.91)						(-0.34)	
$FF5$		0.46	1.11*	-1.51		-0.05	-0.92*				0.06	44
		(0.49)	(1.72)	(-1.34)		(-0.11)	(-1.78)				(0.12)	
$CF1_{CMKT}$								0.50			-0.36	11
								(0.60)			(-0.66)	
$CF1_{YIELD}$									2.59**		0.04	12
									(2.58)		(0.06)	
$CF1_{CMOM}$										2.57**	-0.17	15
										(2.10)	(-0.27)	
$CF3$								0.14	2.11**	1.92	0.01	28
								(0.18)	(2.47)	(1.46)	(0.01)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for for individual commodities in subsamples: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess return commodity i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.3: Fama-MacBeth cross-sectional regressions for commodity portfolios in subsamples (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Portfolio returns in subsample 03/1987-11/2003												
$CCAPM$	0.25***										-0.26	28
	(3.75)										(-0.62)	
$CAPM$		-9.43***									-0.31	23
		(-3.24)									(-0.74)	
$FF3$		-6.57**	-2.43	7.19***							0.02	57
		(-2.24)	(-0.71)	(2.99)							(0.04)	
$FF4$		-6.58**	-2.39	6.85**	0.80						0.03	71
		(-2.23)	(-0.71)	(2.05)	(0.13)						(0.07)	
$FF5$		1.34	14.20	12.10**		-1.47	10.30**				-1.70	83
		(0.14)	(1.02)	(2.13)		(-0.26)	(2.10)				(-1.42)	
$CF1_{CMKT}$								1.49*			-0.92	17
								(1.68)			(-1.05)	
$CF1_{YIELD}$									1.67***		0.76*	26
									(3.06)		(1.97)	
$CF1_{CMOM}$										1.94***	0.49	29
										(2.98)	(1.28)	
$CF3$								2.00**	1.49***	1.38**	-1.47*	62
								(2.19)	(2.83)	(2.18)	(-1.67)	
Panel B: Portfolio returns in subsample 01/2004-09/2020												
$CCAPM$	0.26										-0.93	19
	(1.40)										(-1.05)	
$CAPM$		3.46									-1.89	22
		(1.62)									(-1.50)	
$FF3$		-0.72	3.42***	0.96							0.94	57
		(-0.24)	(3.76)	(0.57)							(0.52)	
$FF4$		0.23	3.29***	1.11	-1.41						0.33	70
		(0.04)	(2.98)	(0.57)	(-0.20)						(0.10)	
$FF5$		-0.41	1.65	-0.52		0.91	1.12				1.82	86
		(-0.11)	(1.00)	(-0.15)		(0.61)	(0.58)				(0.82)	
$CF1_{CMKT}$								0.88			-0.73	20
								(0.37)			(-0.32)	
$CF1_{YIELD}$									1.36**		0.07	21
									(2.51)		(0.11)	
$CF1_{CMOM}$										0.40	0.09	22
										(0.77)	(0.15)	
$CF3$								0.02	1.79***	0.02	0.12	54
								(0.01)	(3.58)	(0.03)	(0.05)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for commodity portfolios in subsamples: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess return of portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.4: Fama-MacBeth cross-sectional regressions for individual capital gains in subsamples (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Individual capital gains in subsample 03/1987-11/2003												
$CCAPM$	0.06										-0.06	11
	(0.99)										(-0.17)	
$CAPM$		-0.75									0.03	14
		(-0.46)									(0.09)	
$FF3$		-0.56	-1.07	1.64							0.09	31
		(-0.38)	(-0.77)	(0.96)							(0.25)	
$FF4$		-1.00	-1.30	2.24	-0.87						0.07	40
		(-0.65)	(-0.96)	(1.35)	(-0.45)						(0.18)	
$FF5$		-0.70	-0.95	1.93		1.02	1.30				0.03	42
		(-0.44)	(-0.76)	(0.95)		(0.54)	(0.85)				(0.09)	
$CF1_{CMKT}$								0.58			-0.47	16
								(0.86)			(-0.78)	
$CF1_{YIELD}$									-0.56		0.04	8
									(-0.42)		(0.12)	
$CF1_{CMOM}$										1.54	0.05	15
										(0.77)	(0.14)	
$CF3$								0.74	0.71	0.29	-0.59	30
								(1.17)	(0.65)	(0.16)	(-1.12)	
Panel B: Individual capital gains in subsample 01/2004-09/2020												
$CCAPM$	0.05										0.80	14
	(0.50)										(1.39)	
$CAPM$		0.52									0.72	14
		(0.54)									(1.23)	
$FF3$		0.43	0.28	-0.22							0.82	29
		(0.46)	(0.39)	(-0.19)							(1.63)	
$FF4$		0.42	0.27	-0.16	-0.29						0.81*	36
		(0.45)	(0.37)	(-0.14)	(-0.13)						(1.67)	
$FF5$		0.40	0.28	-0.15		0.02	-0.07				0.84*	42
		(0.41)	(0.39)	(-0.13)		(0.03)	(-0.13)				(1.78)	
$CF1_{CMKT}$								0.47			0.55	12
								(0.55)			(0.96)	
$CF1_{YIELD}$									0.49		1.01	10
									(0.52)		(1.56)	
$CF1_{CMOM}$										0.58	0.98	13
										(0.46)	(1.53)	
$CF3$								0.44	0.42	0.21	0.59	26
								(0.53)	(0.53)	(0.16)	(1.16)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for individual capital gains in subsamples: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess capital gain of commodity i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.5: Fama-MacBeth cross-sectional regressions for portfolio capital gains in subsamples (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Portfolio capital gains in subsample 03/1987-11/2003												
$CCAPM$	-0.13**										0.48	27
	(-2.31)										(1.23)	
$CAPM$		-0.54									0.04	18
		(-0.17)									(0.08)	
$FF3$		-1.63	-1.61	-5.82**							-0.14	52
		(-0.51)	(-0.71)	(-2.56)							(-0.30)	
$FF4$		-2.55	-1.28	-3.23	-3.34						-0.40	70
		(-0.85)	(-0.55)	(-1.15)	(-0.68)						(-0.79)	
$FF5$		1.46	-2.25	-3.99		-2.65	-3.43				0.35	87
		(0.27)	(-0.47)	(-1.05)		(-0.83)	(-1.24)				(0.52)	
$CF1_{CMKT}$								0.74			-0.63	18
								(0.76)			(-0.70)	
$CF1_{YIELD}$									-1.53***		-0.08	23
									(-2.77)		(-0.21)	
$CF1_{CMOM}$										-1.11*	0.15	26
										(-1.68)	(0.39)	
$CF3$								1.35	-1.37**	-1.35**	-1.19	61
								(1.29)	(-2.49)	(-2.07)	(-1.27)	
Panel B: Portfolio capital gains in subsample 01/2004-09/2020												
$CCAPM$	-0.27										2.10**	20
	(-1.35)										(2.11)	
$CAPM$		-6.54**									4.87***	22
		(-2.45)									(3.02)	
$FF3$		-11.70***	-0.24	-6.06***							8.57***	57
		(-2.65)	(-0.24)	(-3.17)							(3.21)	
$FF4$		3.86	-1.46	-1.58	-11.70						-1.72	73
		(0.54)	(-1.32)	(-0.62)	(-1.59)						(-0.38)	
$FF5$		-19.20***	-1.28	-10.40***		2.81	-5.06*				11.60***	86
		(-2.95)	(-0.77)	(-4.06)		(2.74)	(-1.86)				(3.63)	
$CF1_{CMKT}$								-4.66*			5.68**	19
								(-1.85)			(2.30)	
$CF1_{YIELD}$									-1.51***		1.02	21
									(-2.65)		(1.56)	
$CF1_{CMOM}$										-2.05***	1.18*	24
										(-3.71)	(1.81)	
$CF3$								1.87	-0.56	-2.19***	-0.98	54
								(0.79)	(-1.06)	(-4.05)	(-0.42)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for for portfolio capital gains in subsamples: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess capital gain of portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions.$CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.6: Fama-MacBeth cross-sectional regressions for individual percentage yield in subsamples (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Individual percentage yield in subsample 03/1987-11/2003												
$CCAPM$	-0.06										0.42**	11
	(-0.62)										(2.61)	
$CAPM$		-2.32									0.42**	18
		(-0.70)									(2.61)	
$FF3$		1.59	3.21**	-3.89*							0.33**	39
		(0.59)	(2.60)	(-1.91)							(2.06)	
$FF4$		0.21	2.58**	-2.45	-1.17						0.37**	46
		(0.08)	(2.04)	(-1.13)	(-0.37)						(2.52)	
$FF5$		1.24	1.77	-3.35		1.51	0.76				0.37***	53
		(0.50)	(1.47)	(-1.62)		(0.75)	(0.64)				(2.76)	
$CF1_{CMKT}$								0.68			0.37**	10
								(0.54)			(2.11)	
$CF1_{YIELD}$									6.69**		0.36**	21
									(2.21)		(2.25)	
$CF1_{CMOM}$										4.44*	0.40**	20
										(1.76)	(2.49)	
$CF3$								1.33	6.43**	3.50	0.29*	35
								(1.05)	(2.36)	(1.53)	(1.70)	
Panel B: Individual percentage yield in subsample 01/2004-09/2020												
$CCAPM$	0.26										-0.87***	13
	(1.36)										(-6.08)	
$CAPM$		5.43									-0.83	9
		(2.75)									(-5.95)	
$FF3$		7.04**	0.20	2.69							-1.00***	43
		(2.46)	(0.21)	(1.10)							(-7.16)	
$FF4$		7.14**	-1.67	4.49*	-14.80***						-0.85***	49
		(2.50)	(-1.51)	(1.94)	(-5.14)						(-6.38)	
$FF5$		11.40***	2.90**	9.49***		-3.13***	5.75***				-0.80***	57
		(3.96)	(2.54)	(3.60)	(-2.69)		(4.96)				(-7.15)	
$CF1_{CMKT}$								9.71***			-0.82***	7
								(3.14)			(-6.31)	
$CF1_{YIELD}$									-0.17		-0.88***	25
									(-0.10)		(-6.69)	
$CF1_{CMOM}$										-1.15	-0.83***	22
										(-0.44)	(-6.98)	
$CF3$								9.78***	0.29	0.88	-0.82***	37
								(3.45)	(0.18)	(0.43)	(-7.81)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for individual percentage yields in subsamples: $y_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $y_{i,t}$ is the percentage yield of commodity i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** 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. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.7: Fama-MacBeth cross-sectional regressions for portfolio percentage yield in subsamples .

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Portfolio percentage yield in subsample 03/1987-11/2003												
$CCAPM$	-1.15***										0.90***	48
	(-14.06)										(5.44)	
$CAPM$		-41.00***									0.94***	38
		(-12.64)									(5.80)	
$FF3$		-45.70***	-1.69	20.60***							0.71***	57
		(-12.80)	(-1.31)	(5.85)							(4.68)	
$FF4$		-81.40***	-11.70***	60.00***	-39.10***						1.26***	74
		(-13.67)	(-6.73)	(9.71)	(-8.74)						(7.33)	
$FF5$		-29.00***	8.53***	8.07**		-26.80***	10.50				1.56***	91
		(-6.03)	(6.49)	(2.05)		(-8.14)	(1.23)				(5.70)	
$CF1_{CMKT}$								-30.70***			1.49***	28
								(-12.75)			(8.85)	
$CF1_{YIELD}$									17.40***		0.39***	10
									(3.69)		(2.21)	
$CF1_{CMOM}$										43.10***	0.45***	47
										(14.51)	(2.74)	
$CF3$								-22.20***	14.60**	36.40***	1.21***	76
								(-10.24)	(2.57)	(9.58)	(5.95)	
Panel B: Portfolio percentage yield in subsample 01/2004-09/2020												
$CCAPM$	2.55***										-0.74***	32
	(10.53)										(-5.23)	
$CAPM$		35.30***									-0.57***	47
		(11.74)									(-4.05)	
$FF3$		34.70***	28.60***	13.20***							0.17	68
		(10.50)	(8.60)	(5.24)							(1.20)	
$FF4$		34.50***	37.30***	22.70***	-51.50***						1.16***	77
		34.50***	(10.78)	(9.61)	(-9.86)						(5.66)	
$FF5$		37.00***	35.40***	31.90***		-5.90**	17.20***				1.43***	90
		(11.11)	(8.94)	(9.13)		(-2.56)	(10.35)				(7.81)	
$CF1_{CMKT}$								60.80***			-0.48***	53
								(12.44)			(-3.50)	
$CF1_{YIELD}$									7.96***		-0.96***	6
									(3.98)		(-6.60)	
$CF1_{CMOM}$										-10.70***	-0.34***	11
										(-3.37)	(-2.47)	
$CF3$								69.90***	-10.30***	6.35	-0.49***	74
								(12.50)	(-6.20)	(1.62)	(-3.20)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for portfolio percentage yields in subsamples: $y_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $y_{i,t}$ is the percentage yield of portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** 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. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.8: Fama-MacBeth cross-sectional regressions for commodity returns with betas estimated using a rolling window of 6 years (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Individual commodities												
$CCAPM$	0.00										0.82**	13
	(-0.08)										(2.10)	
$CAPM$		-1.43**									0.81**	12
		(-2.39)									(2.10)	
$FF3$		-1.24*	-0.62	-0.12							0.72**	31
		(-1.89)	(-0.92)	(-0.21)							(2.10)	
$FF4$		-1.79**	-0.95	0.75	0.59						0.95**	39
		(-2.52)	(-1.26)	(1.16)	(0.78)						(2.59)	
$FF5$		-1.21	-0.43	0.24		0.40	0.90*				0.66	45
		(-1.45)	(-0.52)	(0.41)		(0.89)	(1.93)				(1.49)	
$CF1_{CMKT}$								0.07			0.63	12
								(0.18)			(1.59)	
$CF1_{YIELD}$									0.50		0.75*	10
									(1.08)		(1.93)	
$CF1_{CMOM}$										-0.99*	0.77*	13
										(-1.77)	(1.93)	
$CF3$								0.03	0.72	-0.81	0.71*	30
								(0.06)	(1.63)	(-1.22)	(1.65)	
Panel B: Commodity portfolios												
$CCAPM$	0.04										0.54	21
	(0.96)										(1.12)	
$CAPM$		-1.93*									0.52	20
		(-1.83)									(1.12)	
$FF3$		-2.08	-0.84	1.20							1.50*	52
		(-1.24)	(-0.71)	(0.93)							(1.92)	
$FF4$		-3.64*	0.44	1.39	2.98						2.18**	70
		(-1.72)	(0.29)	(0.81)	(1.25)						(2.53)	
$FF5$		-2.38	2.00	2.29		-0.68	1.41				2.53**	82
		(-0.95)	(0.95)	(0.93)		(-0.49)	(0.83)				(2.15)	
$CF1_{CMKT}$								-0.39			1.12	18
								(-0.48)			(1.16)	
$CF1_{YIELD}$									1.35***		0.71*	23
									(4.31)		(1.89)	
$CF1_{CMOM}$										1.18***	0.73*	25
										(3.60)	(1.94)	
$CF3$								1.31	1.35***	1.03***	-0.57	57
								(1.29)	(4.16)	(2.88)	(-0.51)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure rolling window of six years: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess return of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.9: Fama-MacBeth cross-sectional regressions for capital gains with betas estimated using a rolling window of 6 years (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Capital gains of individual commodities												
$CCAPM$	0.00										0.64*	12
	(-0.02)										(1.69)	
$CAPM$		-0.34									0.65*	11
		(-0.57)									(1.76)	
$FF3$		-0.42	-0.54	0.07							0.61*	30
		(-0.66)	(-0.82)	(0.12)							(1.79)	
$FF4$		-0.56	-0.85	0.25	-0.03						0.68*	39
		(-0.85)	(-1.15)	(0.42)	(-0.05)						(1.86)	
$FF5$		-0.62	-0.97	0.19		0.57	0.86				0.91**	45
		(-0.88)	(-1.04)	(0.30)		(1.35)	(1.53)				(2.07)	
$CF1_{CMKT}$								-0.09			0.62	11
								(-0.24)			(1.46)	
$CF1_{YIELD}$									-0.03		0.56	10
									(-0.06)		(1.48)	
$CF1_{CMOM}$										-1.14**	0.57	12
										(-2.11)	(1.46)	
$CF3$								-0.15	0.06	-1.12*	0.69*	29
								(-0.33)	(0.12)	(-1.77)	(1.71)	
Panel B:Capital gains of portfolios												
$CCAPM$	-0.08*										1.08**	20
	(-1.97)										(2.44)	
$CAPM$		-0.37									0.95**	19
		(-0.37)									(2.00)	
$FF3$		0.29	-0.31	1.01							0.76	50
		(0.20)	(-0.33)	(0.93)							(1.27)	
$FF4$		1.48	-0.06	1.73	-3.83						0.73	68
		(0.77)	(-0.05)	(0.85)	(-1.07)						(1.06)	
$FF5$		-5.20	-1.37	4.07		1.02	5.54*				1.37	83
		(-0.94)	(-0.60)	(1.58)		(0.42)	(1.90)				(1.07)	
$CF1_{CMKT}$								-0.49			0.97	18
								(-0.57)			(1.03)	
$CF1_{YIELD}$									-1.14***		0.42	22
									(-3.53)		(1.12)	
$CF1_{CMOM}$										-1.28***	0.59	23
										(-3.83)	(1.63)	
$CF3$								-0.27	-1.14***	-1.40***	0.82	57
								(-0.23)	(-3.34)	(-3.88)	(0.67)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure with rolling window of six years: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess capital gain of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.10: Fama-MacBeth cross-sectional regressions for percentage yield with betas estimated using a rolling window of 6 years (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A:Percentage yield of individual commodities												
$CCAPM$	-0.01										0.22**	13
	(-0.34)										(2.01)	
$CAPM$		0.25									0.15	15
		(0.22)									(1.32)	
$FF3$		1.65	0.20	-0.15							0.15	38
		(1.43)	(0.27)	(-0.20)							(1.51)	
$FF4$		0.96	-0.01	1.56*	-4.12***						0.13	45
		(0.80)	(-0.01)	(1.82)	(-3.79)						(1.48)	
$FF5$		1.50	-0.18	-0.55		-0.52	0.26				0.25**	54
		(1.21)	(-0.24)	(-0.69)		(-0.80)	(0.39)				(2.58)	
$CF1_{CMKT}$								1.37			0.26**	14
								(1.43)			(2.35)	
$CF1_{YIELD}$									-0.94		0.23**	15
									(-0.88)		(2.15)	
$CF1_{CMOM}$										-3.62***	0.16	14
										(-3.38)	(1.46)	
$CF3$								1.54	-1.72*	-3.76***	0.14	36
								(1.47)	(-1.75)	(-3.32)	(1.36)	
Panel B:Percentage yield of Portfolios												
$CCAPM$	-0.07										0.06	22
	(-0.76)										(0.40)	
$CAPM$		-1.56									0.17	22
		(-0.80)									(1.29)	
$FF3$		4.39*	-1.94	-1.01							0.10	62
		(1.89)	(-1.23)	(-0.58)							(0.68)	
$FF4$		0.55	-3.73	-0.97	2.70						0.11	76
		(0.18)	(-1.58)	(-0.45)	(1.10)						(0.62)	
$FF5$		1.02	-4.60**	1.01		5.07***	1.36				0.56**	89
		(0.29)	(-2.01)	(0.44)		(3.50)	(0.67)				(2.43)	
$CF1_{CMKT}$								6.96**			0.16	17
								(2.24)			(1.10)	
$CF1_{YIELD}$									-3.17		0.48***	20
									(-1.61)		(3.81)	
$CF1_{CMOM}$										2.81	0.04	25
										(1.22)	(0.35)	
$CF3$								10.10**	2.05	5.12**	-0.34**	54
								(2.56)	(0.86)	(2.24)	(-2.10)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure with rolling window of six years: $y_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $y_{i,t}$ is the percentage yield of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** 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. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.11: Fama-MacBeth cross-sectional regressions for commodity returns with betas estimated using a rolling window of 10 years (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Individual commodities												
$CCAPM$	0.02										0.25	12
	(0.44)										(0.61)	
$CAPM$		-0.45									0.32	13
		(-0.64)									(0.92)	
$FF3$		0.06	0.76	0.21							0.18	31
		(0.08)	(1.25)	(0.21)							(0.48)	
$FF4$		0.98	1.99**	0.71	0.91						0.10	40
		(1.06)	(2.24)	(0.79)	(0.97)						(0.29)	
$FF5$		0.73	1.65*	0.67		-0.62	0.52				-0.20	44
		(0.81)	(1.82)	(0.75)		(-1.03)	(0.95)				(-0.39)	
$CF1_{CMKT}$								-0.19			0.47	12
								(-0.46)			(1.15)	
$CF1_{YIELD}$									0.48		0.30	9
									(0.97)		(0.85)	
$CF1_{CMOM}$										0.09	0.28	12
										(0.13)	(0.80)	
$CF3$								0.08	1.13**	0.23	0.19	31
								(0.16)	(2.11)	(0.24)	(0.41)	
Panel B: Commodity portfolios												
$CCAPM$	0.04										0.58	21
	(0.79)										(0.99)	
$CAPM$		-4.84***									0.92*	20
		(-4.17)									(1.76)	
$FF3$		-5.97***	-0.78	1.57							1.71***	52
		(-4.34)	(-0.61)	(1.26)							(2.76)	
$FF4$		-5.77***	-2.43	1.80	4.26						1.53*	67
		(-2.73)	(-1.19)	(1.08)	(1.47)						(1.71)	
$FF5$		-3.50	0.71	-0.28		0.22	-1.70				3.36**	84
		(-1.17)	(0.30)	(-0.08)		(0.13)	(-0.66)				(2.54)	
$CF1_{CMKT}$								-0.54			0.95	18
								(-0.61)			(1.01)	
$CF1_{YIELD}$									1.42***		0.47	23
									(4.34)		(1.34)	
$CF1_{CMOM}$										1.12***	0.34	25
										(3.26)	(1.00)	
$CF3$								0.14	1.50***	0.93**	0.24	56
								(0.14)	(4.68)	(2.53)	(0.24)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure with rolling window of ten years: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess return of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.12: Fama-MacBeth cross-sectional regressions for capital gain with betas estimated using a rolling window of 10 years (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Capital gains of individual commodities												
$CCAPM$	0.01										0.21	11
	(0.37)										(0.54)	
$CAPM$		0.22									0.33	12
		(0.32)									(0.93)	
$FF3$		0.28	0.06	0.56							0.24	31
		(0.40)	(0.11)	(0.65)							(0.63)	
$FF4$		0.85	0.86	0.72	0.63						0.17	40
		(0.96)	(1.01)	(0.90)	(0.75)						(0.47)	
$FF5$		0.51	0.74	1.17		0.18	0.72				0.09	44
		(0.59)	(0.83)	(1.47)		(0.33)	(1.16)				(0.17)	
$CF1_{CMKT}$								-0.09			0.28	11
								(-0.20)			(0.65)	
$CF1_{YIELD}$									-0.39		0.11	9
									(-0.81)		(0.33)	
$CF1_{CMOM}$										-0.24	0.17	11
										(-0.36)	(0.48)	
$CF3$								0.17	-0.11	-0.01	0.01	30
								(0.34)	(-0.19)	(-0.02)	(0.03)	
Panel B: Capital gains of portfolios												
$CCAPM$	-0.12**										1.47**	22
	(-2.42)										(2.59)	
$CAPM$		0.42									1.08*	19
		(0.30)									(1.85)	
$FF3$		0.28	-1.53	-2.30							1.33**	49
		(0.15)	(-1.28)	(-1.60)							(2.02)	
$FF4$		-0.96	-1.63	-1.15	-4.65						1.07	67
		(-0.33)	(-1.15)	(-0.52)	(-1.25)						(1.39)	
$FF5$		-0.80	4.76	4.85		-5.96	1.01				-3.12	83
		(-0.13)	(0.85)	(1.10)		(-1.36)	(0.18)				(-0.72)	
$CF1_{CMKT}$								-1.17			1.41	17
								(-1.31)			(1.50)	
$CF1_{YIELD}$									-1.32***		0.24	23
									(-3.83)		(0.67)	
$CF1_{CMOM}$										-1.46***	0.39	24
										(-4.18)	(1.11)	
$CF3$								0.88	-1.03***	-1.58***	-0.60	55
								(0.83)	(-3.08)	(-4.19)	(-0.55)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure with rolling window of ten years: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess capital gain of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.13: Fama-MacBeth cross-sectional regressions for percentage yield with betas estimated using a rolling window of 10 years (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A:Percentage yield of individual commodities												
$CCAPM$	-0.02										0.03	12
	(-0.30)										(0.24)	
$CAPM$		3.88***									0.05	15
		(2.64)									(0.42)	
$FF3$		4.11***	1.13	-2.45**							-0.01	35
		(2.78)	(1.48)	(-2.54)							(-0.13)	
$FF4$		3.32**	0.30	-1.45	-6.94***						-0.05	43
		(2.22)	(0.36)	(-1.42)	(-4.21)						(-0.50)	
$FF5$		3.38**	0.95	-1.87*		-1.38*	0.26				0.06	51
		(2.13)	(1.15)	(-1.81)		(-1.91)	(0.31)				(0.56)	
$CF1_{CMKT}$								-0.16			0.22*	13
								(-0.12)			(1.72)	
$CF1_{YIELD}$									-2.57**		0.20*	15
									(-1.98)		(1.66)	
$CF1_{CMOM}$										-5.34***	0.04	12
										(-4.05)	(0.37)	
$CF3$								0.50	-2.81**	-5.79***	0.14	32
								(0.37)	(-2.05)	(-3.78)	(1.16)	
Panel B:Percentage yield of Portfolios												
$CCAPM$	0.00										-0.03	21
	(-0.00)										(-0.21)	
$CAPM$		-4.93*									0.22*	23
		(-1.74)									(1.81)	
$FF3$		0.82	1.20	-0.01							-0.32**	58
		(0.22)	(0.55)	(-0.00)							(-2.04)	
$FF4$		0.49	3.38	0.31	-4.64						-0.45**	71
		(0.12)	(1.31)	(0.11)	(-1.31)						(-2.49)	
$FF5$		27.70	12.60	-9.12		-10.50*	-5.26				0.74	86
		(0.72)	(0.64)	(-0.86)		(-1.75)	(-1.03)				(1.09)	
$CF1_{CMKT}$								4.79*			0.18	18
								(1.81)			(1.38)	
$CF1_{YIELD}$									-6.28**		0.56***	21
									(-2.46)		(5.00)	
$CF1_{CMOM}$										2.41	-0.04	26
										(0.86)	(-0.36)	
$CF3$								8.77**	-12.60***	-1.50	-0.15	61
								(2.13)	(-3.06)	(-0.44)	(-0.75)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure rolling window of ten years: $y_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $y_{i,t}$ is the percentage yield of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.14: Fama-MacBeth cross-sectional regressions for annual return with convenience yield reinvested with equity market return (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Individual commodities												
$CCAPM$	0.02										3.76	7
	(0.34)										(1.23)	
$CAPM$		-0.19									4.42*	10
		(-0.05)									(1.93)	
$FF3$		1.53	6.87	4.54							3.27	32
		(0.32)	(1.63)	(0.82)							(1.24)	
$FF4$		1.02	5.02	4.99	-11.30**						3.20	41
		(0.22)	(1.26)	(0.96)	(-2.11)						(1.22)	
$FF5$		2.63	8.90**	0.53		-7.51**	-0.49				0.88	46
		(0.57)	(2.04)	(0.09)		(-2.20)	(-0.14)				(0.38)	
$CF1_{CMKT}$								5.82			-1.44	12
								(1.58)			(-0.53)	
$CF1_{YIELD}$									11.30**		6.31***	14
									(2.42)		(2.82)	
$CF1_{CMOM}$										20.50***	4.70**	11
										(2.87)	(1.98)	
$CF3$								5.63	14.60***	7.44	-0.81	31
								(1.43)	(3.03)	(1.03)	(-0.27)	
Panel B: Commodity portfolios												
$CCAPM$	-0.27										11.40**	19
	(-1.58)										(2.24)	
$CAPM$		-6.21									4.70**	18
		(-0.95)									(2.02)	
$FF3$		5.94	-12.60	14.50*							1.43	56
		(0.64)	(-1.47)	(1.91)							(0.45)	
$FF4$		-1.25	-5.66	10.30	-6.96*						3.04	70
		(-0.07)	(-0.31)	(0.80)	(-1.67)						(0.64)	
$FF5$		16.20	-24.50	10.40		4.85	-13.70				-0.68	87
		(1.33)	(-1.40)	(0.77)		(0.60)	(-1.10)				(-0.09)	
$CF1_{CMKT}$								-3.91			8.80*	16
								(-0.73)			(1.74)	
$CF1_{YIELD}$									3.55*		5.47**	26
									(1.82)		(2.36)	
$CF1_{CMOM}$										2.85	4.76**	26
										(1.65)	(2.03)	
$CF3$								4.90	3.51*	1.64	-0.17	57
								(0.87)	(1.82)	(1.12)	(-0.03)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for cfor annual returns: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess annual return of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. The sample ranges from May 1965 to September 2020. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.15: Fama-MacBeth cross-sectional regressions for annual capital gains with convenience yield reinvested with equity market return (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
						Panel A: Panel A: Individual capital gains						
$CCAPM$	0.09										1.31	9
	(1.07)										(0.64)	
$CAPM$		0.61									1.68	11
		(0.16)									(0.84)	
$FF3$		-0.49	5.15	1.57							0.98	29
		(-0.13)	(1.37)	(0.38)							(0.47)	
$FF4$		-0.15	5.16	1.66	1.36						1.02	39
		(-0.04)	(1.39)	(0.39)	(0.30)						(0.48)	
$FF5$		-0.95	4.63	0.26		-3.15	-0.06				0.16	44
		(-0.26)	(1.16)	(0.06)		(-0.95)	(-0.02)				(0.09)	
$CF1_{CMKT}$								2.91			-0.58	13
								(0.89)			(-0.28)	
$CF1_{YIELD}$									0.41		1.96	13
									(0.08)		(1.04)	
$CF1_{CMOM}$										4.88	1.95	10
										(0.68)	(0.97)	
$CF3$								1.63	-0.99	4.12	0.44	31
								(0.46)	(-0.20)	(0.54)	(0.18)	
						Panel B: Portfolios capital gains						
$CCAPM$	1.18***										-6.62***	30
	(7.92)										(-2.96)	
$CAPM$		46.00***									-0.92	26
		(8.00)									(-0.46)	
$FF3$		49.80***	3.38	-18.40***							-0.63	54
		(6.57)	(0.63)	(-2.77)							(-0.30)	
$FF4$		55.70***	-2.24	-13.50	0.92						-0.52	66
		(5.07)	(-0.27)	(-1.39)	(0.17)						(-0.25)	
$FF5$		39.70***	-16.70	12.10		-28.80***	18.40***				-10.10*	87
		(3.04)	(-1.11)	(1.65)		(-2.64)	(4.47)				(-1.84)	
$CF1_{CMKT}$								24.20***			-17.70***	17
								(3.33)			(-3.24)	
$CF1_{YIELD}$									-11.40***		0.03	28
									(-5.63)		(0.02)	
$CF1_{CMOM}$										-13.71***	1.76	31
										(-7.90)	(0.90)	
$CF3$								-17.60**	-9.16***	-13.30***	15.80***	60
								(-2.28)	(-4.49)	(-7.92)	(2.66)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for annual capital gains : $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the annual capital gains of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. The sample ranges from May 1965 to September 2020. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.16: Fama-MacBeth cross-sectional regressions for annual percentage yields with convenience yield reinvested with equity market return (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Panel A: Individual percentage yields												
$CCAPM$	0.03										2.15*	8
	(0.54)										(1.82)	
$CAPM$		0.68									2.66***	6
		(0.13)									(2.69)	
$FF3$		3.55	15.50***	0.01							4.12***	29
		(0.62)	(3.29)	(0.00)							(5.44)	
$FF4$		4.72	14.40***	-4.17	-8.40						5.57***	39
		(0.85)	(2.80)	(-0.82)	(-1.37)						(5.53)	
$FF5$		6.28	21.90***	2.89		-1.14	-5.40				3.89***	46
		(1.00)	(4.80)	(0.85)		(-0.21)	(-1.32)				(4.14)	
$CF1_{CMKT}$								10.40***			0.83	8
								(2.61)			(0.83)	
$CF1_{YIELD}$									22.80***		3.28***	14
									(4.01)		(3.18)	
$CF1_{CMOM}$										27.60***	2.61**	11
										(4.43)	(2.36)	
$CF3$								19.10***	36.20***	11.20*	-0.67	32
								(4.90)	(5.86)	(1.73)	(-0.72)	
Panel B: Portfolios percentage yields												
$CCAPM$	0.72***										-9.36***	14
	(7.17)										(-5.57)	
$CAPM$		240.20***									21.60***	51
		(15.56)									(13.22)	
$FF3$		160.40***	-12.60**	26.40***							3.00	69
		(8.35)	(-2.03)	(2.95)							(1.41)	
$FF4$		-61.60***	-26.40***	101.10***		-78.30***					-8.77	83
		(-2.72)	(-4.47)	(11.02)		(-13.11)					(-4.26)	
$FF5$		191.10***	-42.40***	25.80***		20.40***	5.60				7.61***	91
		(9.15)	(-6.57)	(2.94)		(4.80)	(0.86)				(3.16)	
$CF1_{CMKT}$								52.70***			-8.14***	14
								(9.81)			(-5.99)	
$CF1_{YIELD}$									51.30***		5.34***	43
									(15.26)		(4.85)	
$CF1_{CMOM}$										66.10***	2.14*	48
										(15.93)	(1.94)	
$CF3$								53.10***	38.20***	42.80***	-8.56***	70
								(10.02)	(12.47)	(11.01)	(-6.15)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for annual percentage yield : $y_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $y_{i,t}$ is the annual percentage yield of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** 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 May 1965 to September 2020. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.17: Fama-MacBeth cross-sectional regressions for annual return with convenience yield reinvested with risk-free interest rate (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Individual commodities												
$CCAPM$	0.02										3.93	7
	(0.23)										(1.28)	
$CAPM$		-1.22									4.50*	10
		(-0.31)									(1.95)	
$FF3$		0.33	7.03	4.29							3.46	32
		(0.07)	(1.64)	(0.78)							(1.30)	
$FF4$		-0.11	4.63	5.16	-10.50*						3.18	41
		(-0.03)	(1.15)	(1.00)	(-1.91)						(1.21)	
$FF5$		1.29	8.89**	0.41		-6.68*	-0.69				1.16	46
		(0.29)	(2.03)	(0.07)		(-1.97)	(-0.20)				(0.51)	
$CF1_{CMKT}$								5.85			-1.44	12
								(1.57)			(-0.52)	
$CF1_{YIELD}$									10.80**		6.27***	14
									(2.34)		(2.76)	
$CF1_{CMOM}$										19.00***	4.97**	10
										(2.72)	(2.05)	
$CF3$								5.01	13.00***	8.60	-0.29	30
								(1.22)	(2.84)	(1.23)	(-0.09)	
Panel B: Commodity portfolios												
$CCAPM$	-0.15										8.55*	19
	(-1.10)										(1.97)	
$CAPM$		-7.91									4.56*	22
		(-1.21)									(1.91)	
$FF3$		1.29	-8.64	12.00							2.14	58
		(0.16)	(-1.02)	(1.55)							(0.64)	
$FF4$		-12.20	7.49	-0.22	-5.59						6.08	71
		(-0.78)	(0.43)	(-0.02)	(-1.36)						(1.20)	
$FF5$		10.70	-23.80	18.60		0.56	0.23				-2.84	87
		(0.80)	(-0.91)	(0.89)		(0.06)	(0.02)				(-0.24)	
$CF1_{CMKT}$								-3.69			8.60*	15
								(-0.77)			(1.91)	
$CF1_{YIELD}$									3.13		5.43**	26
									(1.63)		(2.29)	
$CF1_{CMOM}$										2.33	4.81**	27
										(1.34)	(2.01)	
$CF3$								3.20	3.18*	1.19	1.58	57
								(0.65)	(1.67)	(0.80)	(0.33)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for annual returns: $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess annual return of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. The sample ranges from May 1965 to September 2020. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.18: Fama-MacBeth cross-sectional regressions for annual capital gains with convenience yield reinvested with risk-free interest rate (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
Panel A: Individual capital gains												
$CCAPM$	0.09										1.31	9
	(1.07)										(0.64)	
$CAPM$		0.61									1.68	11
		(0.16)									(0.84)	
$FF3$		-0.49	5.15	1.57							0.98	29
		(-0.13)	(1.37)	(0.38)							(0.47)	
$FF4$		-0.15	5.16	1.66	1.36						1.02	39
		(-0.04)	(1.39)	(0.39)	(0.30)						(0.48)	
$FF5$		-0.95	4.63	0.26		-3.15	-0.06				0.16	44
		(-0.26)	(1.16)	(0.06)		(-0.95)	(-0.02)				(0.09)	
$CF1_{CMKT}$								2.93			-0.58	13
								(0.89)			(-0.28)	
$CF1_{YIELD}$									-0.05		1.88	12
									(-0.01)		(0.99)	
$CF1_{CMOM}$										3.10	1.92	9
										(0.47)	(0.96)	
$CF3$								1.38	-1.72	3.61	0.52	31
								(0.39)	(-0.36)	(0.51)	(0.21)	
Panel B: Portfolios capital gains												
$CCAPM$	0.95***										-5.04***	27
	(7.70)										(-2.33)	
$CAPM$		49.5***									-1.09	26
		(8.08)									(-0.55)	
$FF3$		46.40***	11.30**	-17.80***							-0.85	54
		(6.63)	(2.28)	(-2.69)							(-0.42)	
$FF4$		39.2***	19.6***	-26.7***	-6.79						-1.08	65
		(5.42)	(3.68)	(-3.32)	(-1.52)						(-0.53)	
$FF5$		33.70***	-4.83	7.43		-21.70***	16.30***				-6.82	87
		(3.62)	(-0.34)	(0.94)		(-2.08)	(3.59)				(-1.32)	
$CF1_{CMKT}$								26.60***			-19.40***	16
								(3.95)			(-3.89)	
$CF1_{YIELD}$									-11.50***		0.06	29
									(-5.75)		(0.03)	
$CF1_{CMOM}$										-13.60***	1.71	32
										(-7.68)	(0.87)	
$CF3$								-13.80**	-8.64***	-13.10***	12.70**	60
								(-2.11)	(-4.32)	(-7.70)	(2.58)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for annual capital gains : $R^e_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $R^e_{i,t}$ is the excess annual capital gains of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** denote the significance at the 10%, 5% and 1% levels respectively. The R^2 is the average value of the R^2_t of the T cross-sectional regressions. The sample ranges from May 1965 to September 2020. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

Table C.19: Fama-MacBeth cross-sectional regressions for annual percentage yields with convenience yield reinvested with risk-free interest rate (%).

Model	λ_{CG}	λ_{MKT}	λ_{SMB}	λ_{HML}	λ_{MOM}	λ_{RMW}	λ_{CMA}	λ_{CMKT}	λ_{YIELD}	λ_{CMOM}	λ_0	Avg R^2
						Panel A: Individual percentage yields						
$CCAPM$	0.01										2.42**	8
	(0.19)										(2.12)	
$CAPM$		-7.47									2.24**	6
		(-1.45)									(2.28)	
$FF3$		-2.92	13.70***	1.69							3.62***	29
		(-0.51)	(2.71)	(0.45)							(5.02)	
$FF4$		-1.99	12.10**	-4.00	-8.92						5.25***	39
		(-0.36)	(2.13)	(-0.69)	(-1.22)						(4.71)	
$FF5$		-3.44	18.90***	3.83		2.45	-4.69				3.63***	45
		(-0.55)	(3.94)	(1.10)		(0.47)	(-1.12)				(3.94)	
$CF1_{CMKT}$								9.50**			0.97	8
								(2.38)			(0.98)	
$CF1_{YIELD}$									20.80***		3.36***	14
									(3.71)		(3.30)	
$CF1_{CMOM}$										27.4***	2.84**	11
										(4.35)	(2.55)	
$CF3$								18.00***	35.90***	11.90*	-0.54	32
								(4.40)	(5.97)	(1.80)	(-0.58)	
						Panel B: Portfolios percentage yields						
$CCAPM$	0.62***										-7.79***	13
	(6.38)										(-4.80)	
$CAPM$		-217.00***									-16.70***	29
		(-16.33)									(-10.76)	
$FF3$		-78.90***	-12.10**	71.50***							-13.70***	67
		(-7.16)	(-1.97)	(12.34)							(-8.64)	
$FF4$		-30.50***	-29.80***	84.20***	-71.70***						-7.32***	83
		(-3.00)	(-4.97)	(14.62)	(-10.67)						(-4.60)	
$FF5$		-70.20***	-21.10***	69.20***		16.10***	39.40***				-12.40***	83
		(-6.80)	(-2.78)	(12.79)		(3.74)	(7.60)				(-7.10)	
$CF1_{CMKT}$								50.90***			-8.27***	15
								(10.16)			(-6.43)	
$CF1_{YIELD}$									50.10***		5.64***	41
									(15.32)		(5.05)	
$CF1_{CMOM}$										63.20***	2.68**	50
										(16.09)	(2.40)	
$CF3$								43.80***	35.10***	45.60***	-6.80***	70
								(9.18)	(11.63)	(11.30)	(-5.24)	

Note: This table reports the cross-sectional regression results of the Fama and MacBeth (1973) two-step procedure for annual percentage yield : $y_{i,t} = \lambda_{0,t} + \hat{\beta}'_{i,f}\lambda_{f,t} + \epsilon_{i,t}$, where $y_{i,t}$ is the annual percentage yield of commodity or portfolio i at time t. $\hat{\beta}'_{i,f}$ 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 $\epsilon_{i,t}$ are the intercept and error term of the cross-sectional regressions. The final estimates of λ_f and λ_0 are average value of their time-series estimates. The t-statistics are corrected with Newey and West (1987) procedure with 1 lag. *, **, *** 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 May 1965 to September 2020. $CCAPM$ represents the Consumption-based Capital Asset Pricing model including a consumption growth factor (CG). $CAPM$ represents the Capital Asset Pricing model including a marker excess return factor (MKT). $FF3$ refers to the Fama and French (1993) three-factor model consisting of MKT, a size factor (SMB), and a value factor (HML). $FF4$ refers to Carhart (1997) four-factor model comprising MKT, SMB, HML and a momentum factor (MOM). $FF5$ is Fama and French (2015) five-factor model including a profitability factor (RMW) and an investment factor (CMA) except the MKT, SMB and HML factors. $CF1_{CMKT}$ is the model only including commodity excess return factor ($CMKT$). $CF1_{YIELD}$ is the model only including yield factor ($YIELD$). $CF1_{CMOM}$ is the model only including commodity momentum factor ($CMOM$). $CF3$ is the model including $CMKT$, $YIELD$, and $CMOM$.

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