Market Efficiency and the Risks and Returns of Dynamic Trading Strategies with Commodity Futures

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ABSTRACT

This paper investigates dynamic trading strategies, based on structural components of returns, including risk premia, convenience yields, and net hedging pressures for commodity futures. Significant momentum profits are identified in both outright futures and spread trading strategies when the spot premium and the term premium are used to form winner and loser portfolios. The existence of profits from active trading strategies based on momentum is consistent with behavioral finance and behavioral psychology models in which market participants irrationally underreact to information and trends. Profits from active strategies based on winner and loser portfolios are partly conditioned on term structure and net hedging pressure effects. High returns from a popular momentum trading strategy based on a ranking period of 12 months and a holding period of one month dissipate after accounting for hedging pressure effects, consistent with the rational markets model.

Keywords: commodity futures; market efficiency; dynamic trading strategies

JEL Codes: G13, G14.

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1. Introduction

In recent years, commodity market booms and busts have inspired significant interest in this asset class amongst academics and practitioners. As an individual asset class, commodities show several features that distinguish themselves from financial assets, including:

(1) Commodities are real assets that can be used for consumption. They can be packaged as derivative securities for generating returns for investors and for transferring real consumption risk. Therefore, their performance is subject to more factors than financial assets, including but not limited to business cycles, local and global supply-and-demand, technology development, substitute and complementary products.

(2) Based on economic theory, commodity returns in the absence of shocks should mean-revert to the equilibrium marginal rate of production.

(3) Unlike financial assets that are cash-settled at expiration, commodity futures need to be settled by physical delivery; this entails unique storage and shipping costs. For those who want to avoid physical exposure at expiry, contract roll-over is essential. According to Feldman and Till (2006), this roll yield drives the overall yield over the long-term horizon.

(4) Each commodity should be treated as an individual asset class instead of one asset class for all. Erb and Harvey (2006) associate commodity index performance with the performance of its components.

(5) The equilibrium CAPM model does not work well for the commodity markets because some of its critical assumptions are violated: such as an insufficiently

diversifiable base of participants in the commodity markets pointed out by Hirshleifer (1988) and the exclusion from capital assets by Erb and Harvey (2006).

Given this background, much of the extant theoretical and empirical research has looked at commodities apart from financial assets. One strand of literature relates commodity returns to inventory level storage costs as reflected in convenience yields and the cost of carry (e.g. Kaldor (1939), Working (1948), Brennan (1958), Fama and French (1988), Dincerler, Khoker and Simin (2005)). These yields determine the state-time opportunity set for consumption. A second strand focuses on hedging pressures, which constrain the risk transference function (e.g. Working (1953), Cootner (1960), Chang (1985), Carter, Rausser and Schmitz (1983), Bessembinder (1992), and De Roon Goorbergh and Nijman (2000, 2004)).

A third strand looks at market efficiency from a returns predictability perspective (Fama (1991)). Evidence of abnormal returns from momentum or contrarian strategies in strategies based on ***past performance*** or historical data would be inconsistent with the efficient markets paradigm. For example, Erb and Harvey (2006) present a momentum strategy using ***past returns*** commodities that generates significant profits. Miffre and Rallis (2007) identify several additional momentum strategies based on ***past returns*** that on average generate returns averaging 9.38% per annum. These returns are not shown to be not dependent on various market risk factors. This is consistent with ***underreaction*** by investors, a violation of the efficient markets hypothesis. However, based on the theories of storage and hedging/risk transference, one expects the returns and risk premia for commodity futures to be based on a richer set of structural **variables** than ***past performance***. This paper proposes to explore this issue, extending Erb and Harvey

(2006) and Miffre and Rallis (2007) by identifying variables based on the theory, such as the convenience yield and net hedging pressure that might be considered as mitigating factors affecting the returns of active trading strategies in tests of market efficiency. We also examine additional strategies, including several spread trades, and extend the time period for the analysis as further robustness tests of the issue raised by Miffre and Rallis (2007, p. 1870): "Given the interest of institutional investors in investment in commodities, one may question whether the momentum profits identified….will be sustained in the future."

Our focus is on the four commodity futures contracts; NYMEX crude oil, COMEX gold, COMEX copper and CBOT soybean contracts. These contracts are chosen for the following reasons: (i) their liquidity; (ii) their diverse historical term structure and hedging experiences; and (iii) their different sensitivities to the business cycle.

We find that both the term structure and hedging pressure variables based on theory are significant determinants of commodity returns, based on VAR Granger Causality Models. Furthermore, these variables are found to contain information that can be used to construct profitable trading strategies.

The remainder of the paper is organized as follows. Section 2 describes the data. In section 3, Structural VAR models, the commodity returns are presented. Section 4 provides the results for the active trading strategies. The paper concludes with a summary in section 5.

3. Data

Daily closing prices of NYMEX crude oil, COMEX gold, COMEX copper and CBOT soybean from January 1, 1990 to December 31, 2006 are obtained from Bloomberg. Continuous time-series of futures prices are constructed in the order of the first-nearby futures, second-nearby futures, etc. up to one-year maturity or the last contract month before the end of a calendar year, such as November for the soybean contract. The one-year maturity is chosen because it covers a sufficiently long forward period and also has substantial liquidity to deal with. Table 1 provides some summary statistics of the four commodity futures contracts.

Please insert Table 1 about here

The first-nearby futures contract is constructed from the series of prices of the next expiring contract until one week prior to the last trading day of it, at which point the contract is rolled over to the next expiring contract. We adopt the common practice of treating the first-nearby futures price as the spot price, since a united spot market for each commodity does not exist. By extension, the first-nearby futures is literally the second-nearby futures and by analogy, all the next nearby futures contracts are mapped to their subsequent one interval lagged contracts.

For calendar spreads, only the first-nearby futures and futures maturing in six months and in one year are considered because these contracts usually have the longest trading life, normally available for trading 18 months before maturity. These are the most widely used contracts for spreads by practitioners.

Figure 1 shows the term structures and average term structures (based on the average futures prices across maturities) of the four commodities.

Please insert Figure 1 about here

Oil and copper markets are in backwardation on average over the period of the sample. In contrast, the gold market is characterized by contango; the soybean market is also generally in contango with its sharpest slope appearing in the pre-harvest third quarter—from July to September.

Table 2 provides descriptive statistics of the daily returns based on the spot price and the first-nearby futures price. All returns are calculated against the one-day price lag of the same time series and not across contracts with different maturities. Returns of the CRB index (the oldest tradable as well as the most comprehensive commodity index), the Russell 3000 index (a proxy for the U.S. listed equity market portfolio) and the 10-year U.S. Treasury bond (the industry norm of measuring long-term interest rate) are also shown as benchmarks of commodity indices vs. financial asset returns.[1]

Please insert Table 2 about here

All commodity returns show significant departures from the normal distribution, based on the Jarque-Bera estimates. Oil and copper futures exhibit the highest returns, Among commodities, oil futures exhibit the highest volatility while gold futures exhibit the least volatility which is only marginally higher than that of the CRB commodity index.

3.1 Decomposition of futures returns:

Following Roon, Nijman and Veld's (1998), we decompose futures returns into spot premia and term premia by simulating the returns of the strategy of (1) buying a *k*-day contract and (2) buying a *k*-day contract, selling a *n*-day contract and holding the spread

[1] The annualized standard deviations of commodity returns are possibly elevated since commodity returns are normally autocorrelated and asymmetrically distributed.

for k days ($k<n$) where k and n represent number of days until maturity of the first-nearby futures and of distant futures respectively.

From the cost-of-carry model, in a structurally contangoed market, a certain yield $y_t^{(n)}$ based on futures prices, f and spot prices, s [2] can be locked in by longing an asset in the spot market and simultaneously shorting it in the futures market to be delivered at time $t+n$.

$$y_t^{(n)} \equiv \frac{f_t^{(n)} - s_t}{n} \qquad (1)$$

Similarly, the forward yield $h_t^{(k,n)}$ can be earned from time $t+k$ to $t+n$ by taking a long position in the contract to mature at $t+k$, shorting its equivalent to mature at $t+n$ ($k<n$), and holding the spread for k days.

$$h_t^{(k,n)} \equiv \frac{f_t^{(n)} - f_t^{(k)}}{n-k} = \frac{ny_t^{(n)} - ky_t^{(k)}}{n-k} \qquad (2)$$

Re-arranging (2) we obtain:

$$\begin{aligned}(n-k)h_t^{(k,n)} &= ny_t^{(n)} - ky_t^{(k)} \\ &= E_t\left[(n-k)y_{t+k}^{(n-k)}\right] + \Theta_t^{(k,n)}\end{aligned} \qquad (3)$$

$$\Theta_t^{(k,n)} \equiv \sum_{i=0}^{k-1} \theta_t^{(n-i)}$$

where $\Theta_t^{(k,n)}$ is the estimate of the *term premium* and can be rewritten in terms of log spot price and log futures price as:

$$\Theta_t^{(k,n)} = \left(s_{t+k} - f_t^{(k)}\right) - \left(f_{t+k}^{(n-k)} - f_t^{(n)}\right) \qquad (4)$$

[2] The prices are in log form.

It is reasonable to assume that for a naked long position in the first nearby futures contract that matures in k days, the term premium $\pi_{y,t}^{(n)}$ is negligible. In this case, the maturity risk premium is explained by spot premium $\pi_{s,t}$, which is, by definition, the expected spot return in excess of the one-period yield.

$$E_t\left[r_{s,t+k}\right] = E_t\left[s_{t+k} - s_t\right] = ky_t^{(k)} + \pi_{s,t} \quad (5)$$

Rearrange (5) to get the expression of spot premium:

$$\pi_{s,t} = \left(s_{t+k} - f_t^{(k)}\right) \qquad (6)$$

Table 3 provides descriptive statistics for the spot and term premia. In most cases, they are found to be significantly different from zero at conventional levels. Average term premia decline as maturities increase in oil and copper markets and rise in longer-dated gold and soybean markets, implying backwardation (contango) of oil and copper (gold and soybean). A structurally backwardated market carrying an inverse-charge from nearby to distant delivery renders a long spread unprofitable—thus, a positive term premium is needed for remuneration, vice versa for a contangoed market.

Please insert Table 3 about here

Spot price trading risk is high based on volatility of returns. For oil and soybean markets, term volatilities are also high (annualized volatility of 7% and 12% respectively).

3.2 Estimation of the Convenience Yield and Net Hedging Pressure Variables

We estimate the convenience yield proxy using the Fama and French (1988) approach, as the negative of the interest-adjusted basis.[3] Three most widely used contracts—the 3-month,[4] the 6-month and the 12-month futures are used to calculate the short-, intermediate- and long-term convenience yields for each commodity.

The metric used to capture net hedging pressure, H_t, is the difference between the short and long hedge positions of commercial traders divided by their total hedge positions[5], with all positions' information from the semi-monthly[6] report of *Commitments of Traders in Commodity Futures* ("CFTC report" hereafter). A positive H_t means a net short hedging market whereas a negative ratio a net long hedging market.

The convenience yield is calculated as the negative of the interest-adjusted basis. We provide estimates of the convenience yield i under conditions of adequate ("positive" column) and inadequate ("negative" column) inventory levels.

Summary statistics for the convenience yield are provided in Table 4

Please insert Table 4 about here

[3] $\left[F(t,T)-S(t)\right]/S(t)-R(t,T)=\left[W(t,T)-C(t,T)\right]/S(t)$
where *F* and *S* are prices of futures and spot markets, *R* is interest foregone, *W* is storage cost and *C* is convenience yield. Interest-adjusted basis in the left-hand-side can be expressed as difference between relative storage cost and relative convenience yield. For a constant storage cost, the variation of relative convenience yield naturally dominates that of the interest-adjusted basis, so that convenience yield can be approximately expressed as the negative of the interest-adjusted basis.

[4] Since gold futures only mature in even months and soybean futures only in odd months, different contracts other than the three maturities have to be chosen for both. The 4-month futures is used to calculate the short-term convenience yield for gold, and the 7-month and 11-month contracts are used to calculate the intermediate-term and long-term convenience yields for soybean.

[5] $H_t=\frac{\text{short hedge positions - long hedge positions}}{\text{total hedge positions}}$

[6] This report was released bi-weekly until September 1992. From October 1992 on, was released on a weekly basis.

Oil and copper exhibit relatively high average convenience yields, on average. Oil exhibits the highest unconditional convenience yield across commodities. Gold has the lowest and least volatile convenience yield. Convenience yields across all four futures are negative when inventory is abundant ("positive" column) and substantially positive when it is scarce ("negative" column); convenience yields are more volatile at low inventory levels than at high inventory levels; with the exception of copper, volatility increases at a decreasing rate with maturity, consistent with the Samuelson (1965) hypothesis for all commodities except copper

Sample characteristics of the net hedging pressure variables are provided in Table 5.

Please insert Table 5 about here

For the entire observation period, all the four commodity futures are net short hedging markets, supporting Keynes' insurance perspective hypothesis. Net hedging pressure does vary across time and markets. Copper and soybean futures are net short hedging the majority of time, and oil and gold markets vacillate more often. Net short hedging pressure characterizes the gold market from 2001 to 2006.

4. Structural Granger-Causality VAR Estimation of Commodity Returns

This study employs a direct approach[7] to capture the effects of the autoregressive components of commodity returns, which would underpin momentum investment strategies, as well as other variables based on theory which would structurally impact on commodity returns, and estimate a nested Vector Autoregressive (VAR) system. The system includes as *joint variables* the commodity risk premia, convenience yields, and net hedging pressure. Since the spot premium, term premium, convenience yield and net hedging pressure variables are stationary in nature, unrestricted VAR Granger-causality models are appropriate. [8] The testing period is from the issue of the first weekly CFTC report[9] on October 6th 1992 to its last issue in 2006 on December 26th, 2006. The data encompass from 670 to 730 weekly observations across the four markets.

[7] Bessembinder (1992) uses the Fama and MacBeth (1973) two step approach to capture the effect of net hedging pressure on residual risks of commodity futures

[8] Based on Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, the null hypothesis of a unit root is rejected by all the tested time series under all settings at a significance level of 5%. These results are available on request.

[9] The CFTC report was once published every two weeks until the end of September 1992. Ever since October 1992, this report has become a weekly issue and has been disclosed on each Wednesday. To keep as much information intact as possible, weekly data of risk premiums, net hedging pressure and convenience yield are re-calculated and used in this test.

Table 6 provides estimates of VAR Granger-causality models for risk premia, convenience yields (with different maturities), and net hedging pressure for spot premia across markets.[10]

Please insert Table 6 about here

The most striking result of the estimation is that spot premia serve as leading (predictor) variables for all of the variables, both convenience yields and net hedging pressure across all commodities. As such, momentum trading strategies based on recent performance may be well grounded. Convenience yields show market-dependent results. In particular, they lead spot premiums in the oil and soybean markets. On the other hand, net hedging pressure does not lead the spot premium in any market. Bi-directional causality is detected between term slopes of different horizons in all markets, showing that some intertwining of information is contained in each part of the term structure. Causality between the term structure and net hedging pressure is observed only for the metal markets studied. For gold, net hedging pressure uni-directionally leads the term structure while for copper, the overall term structure leads net hedging pressure and net hedging pressure leads the short-term slope only.

We also estimate VAR Granger-causality models for term premia (spread trade returns), convenience yields and net hedging pressure, for the various commodities. Model estimates for Copper and Gold are shown in Table 7 and 8, respectively.[11]

Please insert Tables 7 and 8 about here

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[10] We use the FPE (final prediction error) criterion, the Akaike information criterion, the Schwarz criterion (SC); and the Hannan & Quinn (HQ) criterion and in all cases find an the optimal lag lengths of one.

[11] The detailed results for oil and soybeans are not included, in order to conserve space. These results are available on request.

Aside from the autoregressive components, significant causality effects of term premia and convenience yields for spread returns on term structure and net hedging pressure are observed in the gold spread using the 6-month contract and in all the three copper spreads. Negative (positive) coefficients of gold (copper) spreads can be naturally associated with its contangoed (backwardated) convenience yield shape. Causality between the term structure and net hedging pressure is observed in both spread rates similar to that which obtains in spot returns: Net hedging pressure uni-directionally drives gold's term structure while the term structure leads copper's net hedging pressure.

Perhaps the most important finding in the spread market in these metal markets comes from the significant leading effect of the entire term structure on the term premium. In contrast, no significant relationship between the term structure and the corresponding spot premium. This result is consistent with Roon, Goorbergh and Nijman (2004) who conclude that the term premium should reflect term structure risks. Similar to the spot premium, variation of the term premium explained by term structure decreases with the contract horizon. Hence, the latest short-term convenience yield contains the most relevant information for predicting future term premiums.

Oil Futures

For all three oil spreads, a leading effect from the term premium to the overall term structure and net hedging pressure appears in the 12^{th} and 13^{th} lags, showing that the spread premiums contain information that can be used to forecast the term structure and net hedging pressure in approximately three months away.

The overall term structure improves forecast of term premium across time, but at slightly different lags. In general, the predictive power of term structure shows up in various term premia in most cases up to the third month in the future.

Soybean Futures

For the second soybean spread,[12] all three term premia clearly lead the term structure by one week, one month and three months ahead, respectively.

In sum, both premia Granger-cause the overall term structure and net hedging pressure. While the term structure contains information useful in predicting spot premia in oil and soybean markets, it does demonstrate predictive power with respect to term premiums in all four of the commodity markets studied. This result demonstrates that the term structure risk should be better captured by the term premium than by the spot premium. No significant causality from net hedging pressure to either premium is observed.[13]

5. Returns from Active Trading Strategies

In this section, we use the findings of the previous section on the predictive power of term structure and hedging pressure variables to construct active trading strategies, as tests of market efficiency from a returns predictability perspective (Fama (1991)). Three

[12] The reason to focus on the results of the second soybean spread is that the term structure effect should be most pronounced in the term slope derived from the July contract, since it is the only contract that expires just prior to the upcoming harvest season starting in September. Test results show that it is the case.

[13] As a robustness test, we have also performed the VAR Granger Causality tests using bi-weekly and monthly data. These results are qualitatively similar to those reported here. They are available on request.

active trading strategies are introduced: the momentum/contrarian strategy, the convenience yield strategy, and the net hedging pressure strategy.

5.1 Momentum/contrarian strategies

5.1.1 Portfolio construction

Momentum/contrarian portfolios are established using bi-weekly data from January 1990 to December 2006. To construct the portfolios, past spot premia and term premia for all four commodity futures are ranked at the end of each period. Based on these rankings, we go long (and short) futures or futures spreads in those commodities categorized as "winners" ("losers") with the highest (lowest) premium. After a designated period of time, the positions are rebalanced or unwound. We continue the process of enter-hold-exit during the testing period. To facilitate presentation, each strategy is named after its ranking (R) and holding (H) periods as the *R–H* strategy, with ranking and holding periods set as one month, three months, six months and twelve months. [14]

Miffre and Rallis (2007) build momentum portfolios using an overlapping trading strategy, following Moskowitz and Grinblatt (1999) and Jegadeesh and Titman (2001). Our approach extends this strategy, with some notable differences. First, rather than

[14] It should be noted that trading results are comparable only between outright futures strategies or spread strategies but not across both groups, since negligible costs are incurred when initiating spreads. Spread returns are calculated as:

$$R_{cs} = \frac{P_{endf} - P_{openf}}{(|P_{openl}| + |P_{opens}|)/4}$$

where P_{endf} and P_{openf} are ending and opening balances of spread portfolio, $|P_{openl}|$ and $|P_{opens}|$ are opening balances of long and short sides when spread is initialized. Their absolute sum is then divided by 4 to take account of the offsetting effect of a long-short strategy. The revised calculation solves the "infinitesimal denominator" problem and makes different calendar spreads comparable across time and markets.

performing the rankings based on returns (i.e. changes in the log settlement prices), we perform our rankings using the spot and term premia, as defined in section 3.1. Hence, we extend both the Roon et al calendar spread strategies as well as the Miffe and Rallis (2007) long-only strategy. In addition, Miffre and Rallis (2007) form equally-weighted portfolios. Our study uses a value weighted approach of investing one dollar in both winner and loser portfolios in each period. This method avoids capital-allocation risk introduced by large differences in unit contract prices across commodity markets.

Finally, in this study, returns of winner or loser portfolios are based on the holding-period returns of taking long positions in the corresponding portfolios. The momentum (contrarian) trading return is defined simply as the difference between the winner (loser) portfolio return and loser (winner) portfolio return.

5.1.2 Empirical results

Table 9 provides summary statistics for momentum trading returns for outright positions that use the first nearby contract.[15] . The momentum (contrarian) strategy is deemed a success when the "Momentum" column of the respective table is positive (negative) The purpose of using multiple contracts or spreads to build momentum trading portfolios is two-fold: to check robustness and to empirically test Miffre and Rallis's (2007) assertion that the term structure drives the momentum effect in commodity markets. [16]

Please insert Table 9 about here

[15] We also perform the analysis for contracts that expire in six months and twelve months. They are not included in order to conserve space and are available on request. The results for the longer maturity contracts are largely similar to those reported here, except as noted in the text.

[16] Miffre and Rallis (2007) suggest that momentum profits are related to the market structure, trading in long-term futures could generate more profits.

On the whole, the momentum strategy performs well in most cases, particularly when the holding period is under six months. For the one month holding period and one-month ranking period, the annual return of the strategy is 9.24%, which is slightly lower than that found by Miffre and Rallis (2007) (10.87%). However, in contrast to Erb and Harvey (2006) and Miffre and Rallis (2007) the "one-month holding period and 12 month ranking" strategy does not persist as a dominant strategy for our sample, which extends to 2006, with the return and Sharpe ratio of this strategy of 3.12% and 30.69% respectively.

Table 10 shows the summary results for momentum returns based on a calendar spread that longs the first nearby futures contract and shorts the 12-month futures contract.[17] Please insert Table 10 about here

On the whole, the spread trading strategies compare favorably with those of the outright strategies. The average annual return for the spread strategy with a one month holding period one month ranking portfolio is 7.99% with a Sharpe Ratio of 70.1. For a month holding period the annual return is 4.87% with a Sharpe Ratio of 39.97%. This is noteworthy since spread positions involve less risk.

Extending the ranking and holding period reduces momentum profits. For the outright futures strategy, the significant momentum effect disappears when both periods exceed six months; significant contrarian profits are observed for holding periods of twelve months. Momentum trading with the shortest three-month futures dominates all

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[17] We also perform the analysis for two other calendar spread positions: 1) long the first nearby futures contract and short the second nearby futures contract; 2) long the first nearby futures contract and short the six month futures contract. The results for these alternative positions are largely similar to those reported here, except as noted in the text, and are available on request.

strategies. For the calendar spread strategy, significant contrarian profits dominate all scenarios when ranking and holding periods are longer than three months. Profits decline as we move to shorter (i.e. six month followed by three month) spread positions. Miffre and Rallis's (2007) conjecture of a linkage between the momentum effect and the term structure are thus empirically supported through these trading results.

On the whole a short-term price continuation, analogous to that identified by Jegadeesh and Titman (1993, 2001) for equity markets is also observed for the spread momentum positions, as in the outright positions. For these markets, momentum profits are maximized by longing the most outperforming futures or calendar spread and shorting its most underperforming counterpart in the previous month, holding the pair for one month and continuously rolling it over to the next pair selected with the same criterion at each rebalancing point. This strategy works equally well for outright contracts and calendar spreads with different maturities.

5.2 Momentum strategy return determinants, backwardation and contango

Miffre and Rallis (2007) suggest that high momentum profits are not just based on compensation for risk but are related to backwardation and contango. The results of the previous section support a relationship between the momentum effect and the term structure. A direct test for a momentum—backwardation link, which incorporates other structural determinants of returns based on the theories of storage and hedging is provided by the following regression for both winner and loser portfolios:

$$R_{f,t} = \alpha_0 + \beta_1 cy_t + \beta_2 H_t + \beta_{3i} \sum_{i=1}^{11} D_i + \varepsilon_t \quad (7)$$

where $R_{f,t}$ is the return of longing (shorting) the winner (loser) portfolio, cy_t the portfolio convenience yield, H_t the portfolio net hedging pressure; D_i are monthly dummy variables, while ε_t is the error term. The regressors cy_t and H_t are constructed from the convenience yield and net hedging pressure of the most outperforming and underperforming commodities included in winner and loser portfolios at each period. Returns are regressed on convenience yield derived from corresponding maturity, i.e., 3-month convenience yield is regressed against returns of long-only the 1st-nearby futures and the shortest calendar spread and so on and so forth.[18]

From (7) a linkage between momentum and backwardation (Miffre and Rallis (2007)) would be supported if:

(1) The regression estimate of β_1 is significantly positive (negative) for the long winner (short loser) portfolio for a holding period of 12 months. A positive correlation suggests that winner (loser) wins (loses) more when market becomes more backwardated (contangoed). This is the simplest case since no rebalancing is performed during the one year horizon, and as a consequence the roll yield can be ignored.

(2) Positive or negative estimates of β_1 for portfolio returns under other ranking and holding periods because of the dual forces offsetting each other. However, if the winner (loser) portfolio does have more exposure to backwardated (contangoed)

[18] The effect of backwardation on futures return is complex since the futures excess return is roughly made up of the spot return and the roll return, which both correlate with the term structure, but in opposite directions (see Till (2007)). Increasing backwardation (contango) should diminish (enhance) the spot return and increase (decrease) the roll return. Thus, the overall effect of term structure on the portfolio return should be a balance of both forces, either in backwardation or in contango. As per Till (2007) the spot return is defined as distant futures price divided by nearby futures price, and roll return is the difference between futures return and spot return.

contracts or both, β_1 should, on average, be much larger in absolute value for the winner portfolio than that for the loser portfolio because inventory influences price more in a backwardated market than in a contangoed market.

(3) Since β_1 is determined by the joint correlation between the convenience yield, the spot return and the roll return, the sign of β_1 demonstrates the dominant return explained. For a longed portfolio, in backwardation or contango, spot return always declines with a rising convenience yield while roll return always rises with it, and vice versa for a shorted portfolio. Therefore, a positive β_1 points to an increased term structure effect on roll return (spot return) in a longed (shorted) portfolio and so on and so forth.

Empirical estimates of (7) are shown in Table 11 for the momentum trading returns using the first nearby futures contract. Table 12 shows the results for calendar spread strategy that longs the first nearby futures contract and shorts the 12 month futures contract.[19]

Please insert Tables 11 and 12 about here.

It is clear that the convenience yield has significant explanatory power for momentum trading returns under most of the ranking and holding periods. Consistent with hypothesis one, β_1 is significantly positive and significantly negative for longed

[19] The regressions are also performed for the other outright and spread positions outlined in this paper. The results are very similar to those reported here and are available on request.

winner and shorted loser portfolios that are being held for and beyond six months. Hypothesis two is also supported in most cases, since β_1 is larger in size for winner portfolios than for loser portfolios. Consistent with hypothesis three, both the 6-month and 12-month convenience yields drive the futures roll return. However, the 3-month convenience yield has a greater influence on the roll return of winner portfolios and on the spot return of loser portfolios.

Net hedging pressure is another significant factor of momentum returns in most cases. β_2 is positive for winner portfolios and negative for shorted loser portfolios, which means on average, a rising short hedging pressure boosts both winner and loser returns and a declining short hedging pressure reduces both. The only exception occurs in a scenario with a one-year ranking and one-year holding periods, which could be due to a large number of short hedgers choosing one year as the hedging span and their collective unwinding at the end of one year boosting portfolio returns.

In sum, both convenience yield and net hedging pressure are significant determinants of the returns from momentum strategies. However, the intercept terms of these regressions remain significant, particularly for short term losers for holding periods under six months.[20] Hence, the persistent high returns from momentum strategies cannot be wholly attributable to structural factors. Since convenience yield and net hedging pressure contain information useful for momentum strategies, can they be useful in generating profitable trading strategies on their own? To address this question, we explore two such strategies:

[20] Note however that the intercept term is only mildly significant for the one month holding period/12 month ranking period strategy.

a) taking a long position in a portfolio with the highest convenience yield and short portfolio with the lowest convenience yield.[21] For spread trading, this strategy involves going long the short spread with the highest convenience yield and short the short spread with the lowest convenience yield.

b) long portfolio (short spread) with the highest hedging pressure and short portfolio (short spread) with the lowest hedging pressure.

These two strategies are implemented to examine whether information contained in convenience yield and net hedging pressure are exploited into abnormal profits. Specifically, relative convenience yield and net hedging pressure are used to assign commodities into portfolios. Relative convenience yield (net hedging pressure) is defined as last period's convenience yield (net hedging pressure) divided by average convenience yield (net hedging pressure) in the ranking period. In each period, these two ratios are calculated and ranked to form two portfolios that have the highest and lowest ratios. A relative ratio is used instead of the average convenience yield (net hedging pressure) because the four commodities have very different historical levels of both factors, which invalidates a direct comparison between each other. Four strategies are simulated: two outright futures and two spreads with the shortest and longest maturities. On the whole these trading strategies are less profitable than those based on outright and spread positions presented above.[22]

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[21] This coheres with Miffre and Rallis's (2007) suggestion of consistently trading the most backwardated and contangoed contracts.

[22] Detailed results for the convenience yield and net hedging pressure trading strategies are available on request.

The net hedging pressure strategy is less profitable than the convenience yield strategy. Long-short the long-term spread outperforms all other strategies based on net hedging pressure, and is the only with exploitable profits. This result is consistent with Roon et al (2004), whereby hedging pressure effect can be inferred through spreads. The low hedge ratio portfolio drives the majority of trading profits. For both strategies, trading profits are inversely related to the holding period.

7. Conclusions

This paper explores some structural determinants of profits from momentum based strategies using commodity futures, as tests for market efficiency from a returns predictability perspective. High returns are observed using momentum strategies not only using outright futures positions but also and spread trading strategies, even while the latter might be deemed less risky. On average, spread trading outperforms outright futures trading in capturing the term structure risk and hedging pressure risk.

Convenience yields and hedging pressures, variables consistent with the theories of storage and risk transference for commodity futures are examined as possible determinants of returns. High returns from a popular momentum trading strategy based on a ranking period of 12 months and a holding period of one month dissipate after accounting for hedging pressure effects, consistent with the rational markets model.

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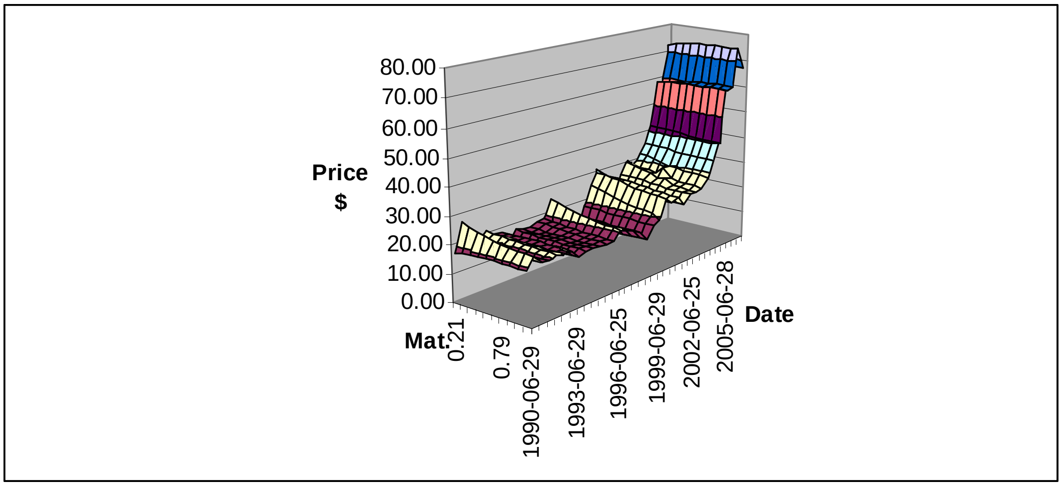
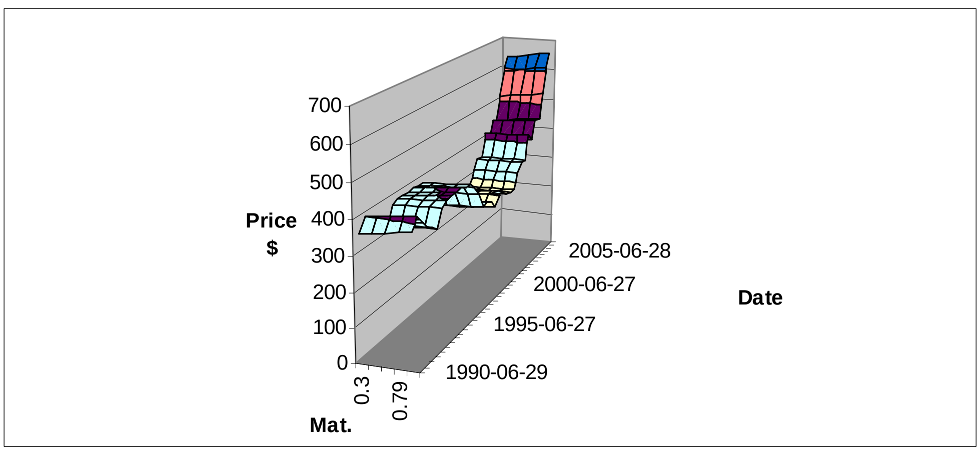
Figure 1: Term Structure of Commodity Futures Prices, June 1990- January 2006

Panel A: Contract Prices, daily data

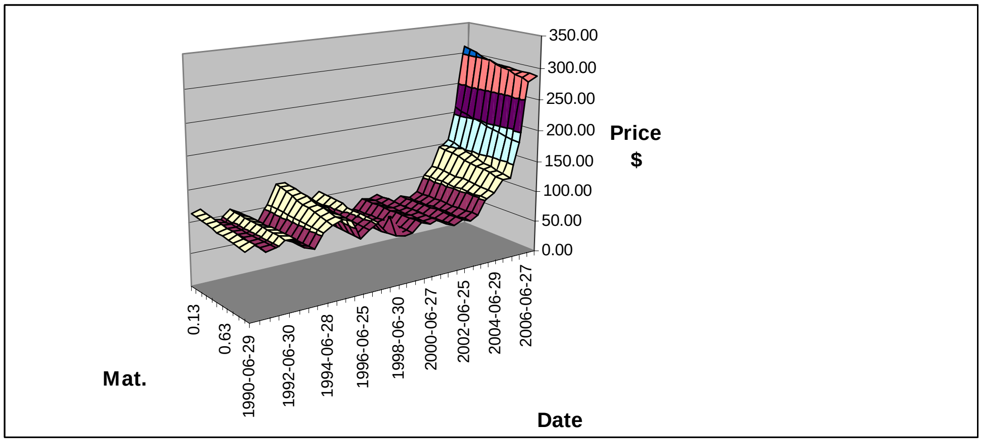
Oil



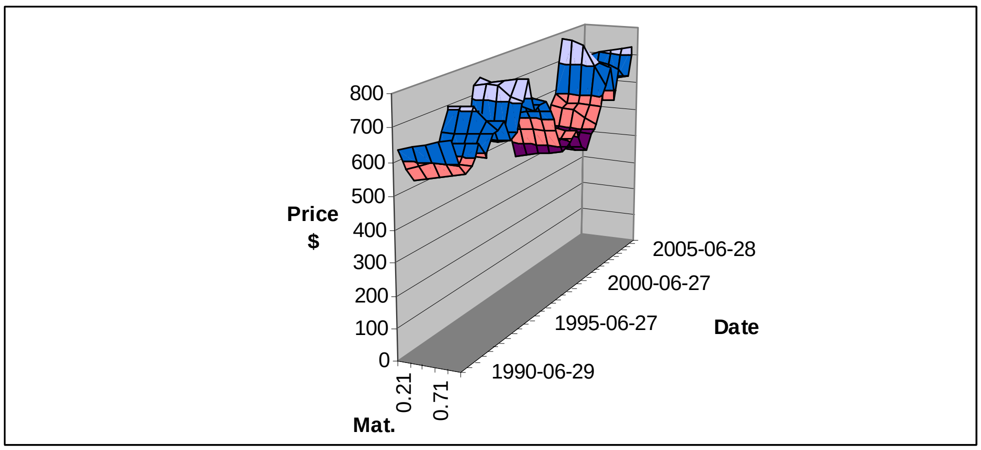
Gold



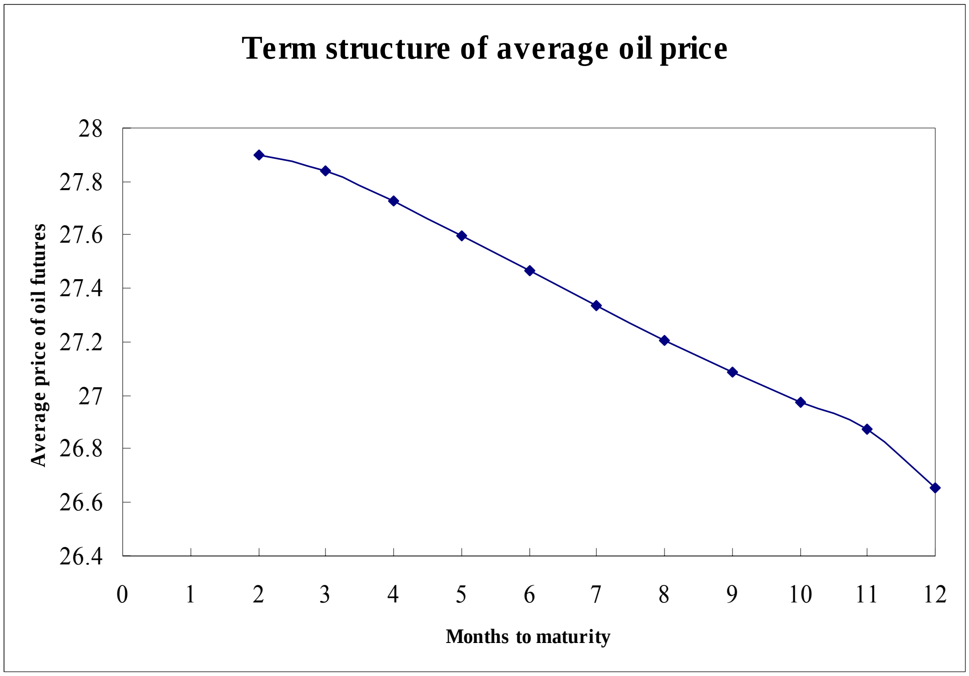
Copper

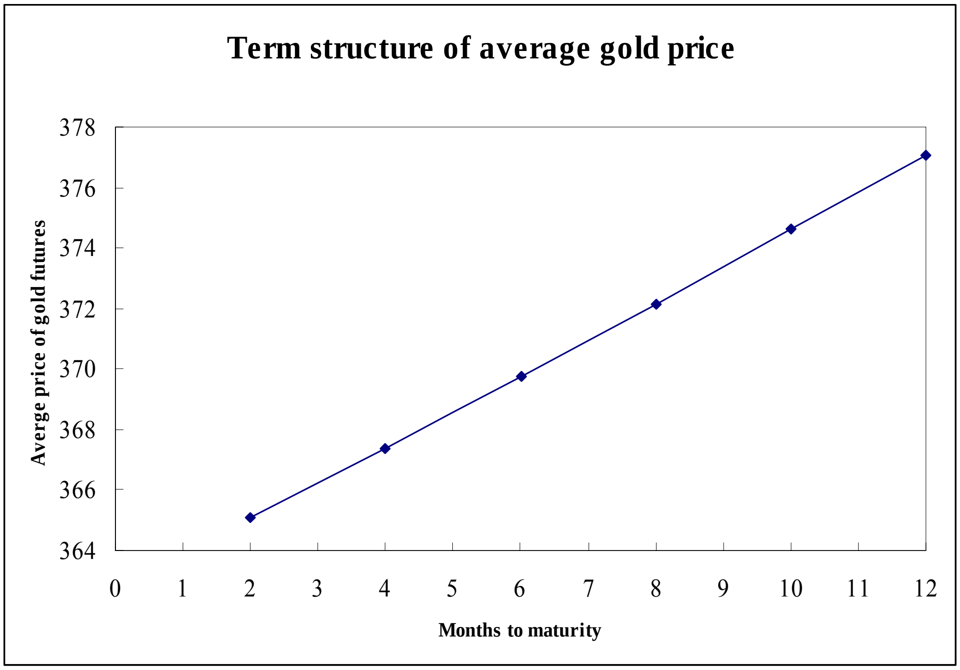


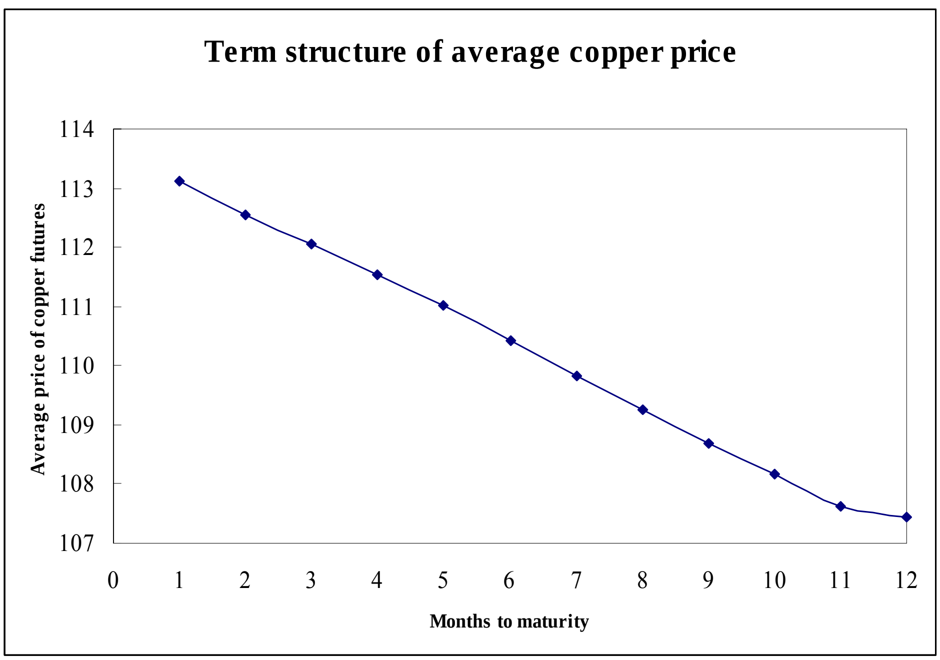
Soybeans



Panel B: Term Structure of Average Commodity Futures Prices, daily data




Term structure of average gold price
Averge price of gold futures
378
376
374
372
370
368
366
364
0
1
2
3
4
5
6
7
8
9
10
11
12
Months to maturity


Term structure of average copper price
Average price of copper futures
114
113
112
111
110
109
108
107
0
1
2
3
4
5
6
7
8
9
10
11
12
Months to maturity

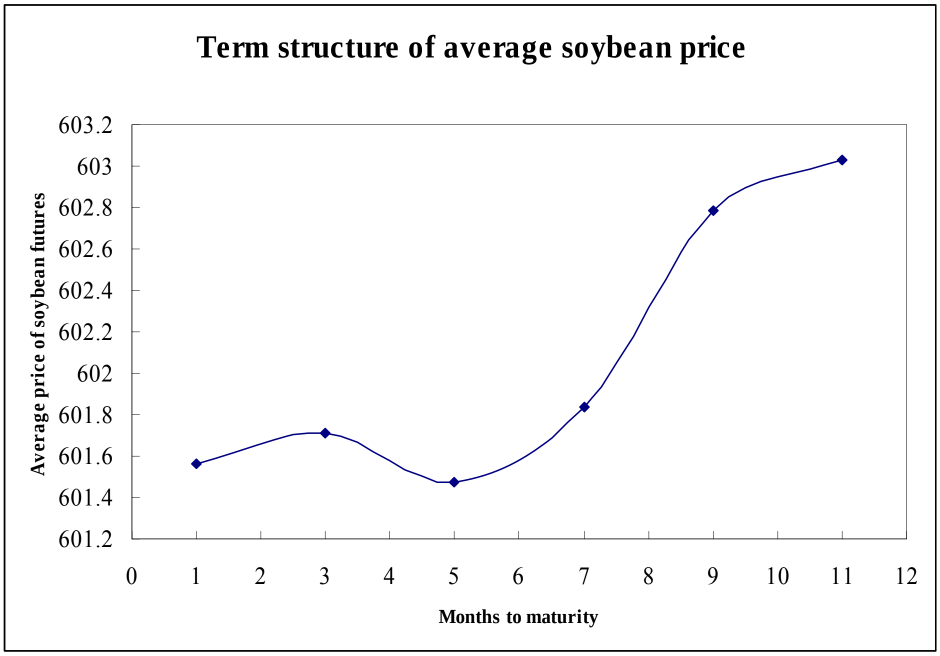

Term structure of average soybean price
603.2
603
602.8
602.6
602.4
602.2
602
601.8
601.6
601.4
601.2
Average price of soybean futures
0
1
2
3
4
5
6
7
8
9
10
11
12
Months to maturity

Table 1: Futures contract information

Contract	Exchange	Delivery months	Last trading day
WTI crude oil	New York Mercantile Exchange	All months	The third business day prior to the 25th calendar day of the month preceding the delivery month.
Gold	Commodity Exchange Inc.	2 4 6 8 10 12	The third to last business day of the maturing delivery month.
Copper	Commodity Exchange Inc.	All months	The third to last business day of the maturing delivery month.
Soybean	Chicago Board of Trade	1 3 5 7 9 11[23]	The business day prior to the 15th calendar day of the contract month.

[23] Soybean futures are also traded for delivery in August. We neglect the August contract when constructing the time-series data in order to make data sets evenly spaced.

Table 2: Summary Statistics on Returns Based on the Spot price and the First-nearby futures price

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Panel A. Daily Returns Results

	N	Mean	Median	Std Dev	Skewness	Kurtosis	Maximum	Minimum	Jarque-Bera
return of Oil SP	4262	0.0230%	0.0646%	0.0229	-1.3447	25.1474	0.1357	-0.3841	88390.31
return of Oil F_1	4260	0.0237%	0.0559%	0.0203	-1.2388	21.9776	0.1235	-0.3282	65016.13
return of Gold SP	4258	0.0103%	0.0000%	0.0091	-0.2433	13.1188	0.0889	-0.0773	18207.74
return of Gold F_1	4254	0.0100%	0.0000%	0.0090	-0.2676	12.5845	0.0883	-0.0775	16333.49
return of Copper SP	4260	0.0233%	0.0000%	0.0154	-0.2334	7.1863	0.1119	-0.1167	3149.40
return of Copper F_1	4256	0.0241%	0.0000%	0.0152	-0.2664	7.2954	0.1156	-0.1152	3322.24
return of Soybean SP	4255	0.0036%	0.0000%	0.0147	-3.3217	74.7963	0.0673	-0.3409	921711.00
return of Soybean F_1	4255	0.0036%	0.0000%	0.0139	-1.2417	21.3397	0.0677	-0.2122	60724.67
return of CRB	4250	0.0060%	0.0166%	0.0063	-0.0517	4.6147	0.0374	-0.0291	463.62
return of R3000	4250	0.0345%	0.0557%	0.0098	-0.1226	6.8065	0.0537	-0.0687	2576.4520
10-y T-bond	4172	-0.0006%	0.0000%	0.0006	0.3540	5.1400	0.0039	-0.0023	883.2510

Return of SP refers to return of spot markets; return of F_1 refers to return of the most nearby futures contracts. Return of CRB commodity index, return of Russell 3000 index and return of 10-year U.S. Treasury bond are listed here as benchmarks.

Returns are calculated with daily data from January 1st 1990 to December 31st 2006. All returns are calculated against the one-day price lag of the same time series and not across contracts with different maturities.

Table 2.

Panel B. Annualized Mean and Standard Deviation of Spot and First Nearby Future Returns

Return	Oil SP	Oil F_1	Gold SP	Gold F_1	Copper SP	Copper F_1	Soybean SP	Soybean F_1	CRB	R3000	10-y T-bond
Annual mean	5.75%	5.93%	2.58%	2.49%	5.83%	6.03%	0.90%	0.90%	1.50%	8.63%	-0.16%
Annual Std Dev	36.22%	32.09%	14.38%	14.29%	24.40%	24.05%	23.27%	21.97%	10.01%	15.51%	0.92%

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Table 3: Summary statistics of spot premium and term premium

Panel A. Daily Returns Results

Daily Mean	***Spot premium*** $\pi_{s,t}=\left(s_{t+k}-f_t^{(k)}\right)$	***Term premium*** $\Theta_t^{(k,n)}=\left(s_{t+k}-f_t^{(k)}\right)-\left(f_{t+k}^{(n-k)}-f_t^{(n)}\right)$									
	k	***p=3***	***p=4***	***p=5***	***p=6***	***p=7***	***p=8***	***p=9***	***p=10***	***p=11***	***p=12***
Oil	1.99%		0.34%	0.32%	0.30%	0.28%	0.27%	0.25%	0.23%	0.23%	0.23%
Gold	0.24%				-0.59%		-0.59%		-0.58%		-0.57%
Copper	1.91%	0.26%	0.24%	0.22%	0.21%	0.20%	0.19%	0.18%	0.18%	0.18%	0.12%
Soybean	-0.07%			-0.19%		-0.16%		-0.17%		-0.19%	

Daily Std Dev	***Spot premium*** $\pi_{s,t}=\left(s_{t+k}-f_t^{(k)}\right)$	***Term premium*** $\Theta_t^{(k,n)}=\left(s_{t+k}-f_t^{(k)}\right)-\left(f_{t+k}^{(n-k)}-f_t^{(n)}\right)$									
	k	***p=3***	***p=4***	***p=5***	***p=6***	***p=7***	***p=8***	***p=9***	***p=10***	***p=11***	***p=12***
Oil	15.84%		2.85%	3.77%	4.60%	5.35%	5.99%	6.56%	7.11%	7.58%	8.01%
Gold	6.83%				0.41%		0.50%		0.59%		0.70%
Copper	12.08%	1.53%	1.91%	2.19%	2.51%	2.80%	3.13%	3.46%	3.78%	4.10%	9.89%
Soybean	12.59%			4.99%		5.97%		5.97%		6.37%	

Returns are calculated with daily data from January 1st 1990 to December 31st 2006.

Spot premium is obtained by longing the 1st-nearby futures mature in *k* days and term premium obtained by longing the same futures maturing at $t+k$ and shorting distant futures maturing at $t+n$ ($k<n$) and holding the spread for *k* days.

p refers to number of months until maturity for contract being shorted. *n* and *k* refer to number of days until maturity for contract being shorted and for the 1st-nearby futures being longed in both strategies respectively. In this paper, the 1st-nearby futures are mature in different months across four markets, i.e. 3 months, 4 months, 2 months and 3 months for oil, gold, copper and soybean respectively.

Table 3

Panel B. Annualized Mean and Standard Deviation of Spot and Term Premium

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Annual Mean	***Spot premium*** $\pi_{s,t}=\left(s_{t+k}-f_t^{(k)}\right)$	***Term premium*** $\Theta_t^{(k,n)}=\left(s_{t+k}-f_t^{(k)}\right)-\left(f_{t+k}^{(n-k)}-f_t^{(n)}\right)$									
	k	***p=3***	***p=4***	***p=5***	***p=6***	***p=7***	***p=8***	***p=9***	***p=10***	***p=11***	***p=12***
Oil	7.95%		4.08%	1.91%	1.20%	0.84%	0.64%	0.49%	0.40%	0.34%	0.30%
Gold	0.72%				-3.54%		-1.76%		-1.16%		-0.86%
Copper	11.45%	3.07%	1.42%	0.88%	0.62%	0.47%	0.38%	0.32%	0.27%	0.24%	0.14%
Soybean	-0.28%			-1.15%		-0.49%		-0.34%		-0.28%	

Annual Std Dev	***Spot premium*** $\pi_{s,t}=\left(s_{t+k}-f_t^{(k)}\right)$	***Term premium*** $\Theta_t^{(k,n)}=\left(s_{t+k}-f_t^{(k)}\right)-\left(f_{t+k}^{(n-k)}-f_t^{(n)}\right)$									
	k	***p=3***	***p=4***	***p=5***	***p=6***	***p=7***	***p=8***	***p=9***	***p=10***	***p=11***	***p=12***
Oil	31.69%		9.88%	9.22%	9.20%	9.26%	9.28%	9.28%	9.31%	9.28%	9.25%
Gold	11.84%				1.00%		0.86%		0.83%		0.85%
Copper	29.58%	5.30%	4.67%	4.39%	4.34%	4.34%	4.42%	4.52%	4.63%	4.73%	10.83%
Soybean	25.18%			12.22%		10.34%		8.44%		7.80%	

T-test results for Significance of Premia:

(1) Oil: spot premium and term premiums up to *p=8* are significantly different from zero at 1% level; term premia *p=9* and *p=10* are significant at the 5% level; the rest are all significant at 10%.

(2) Gold: spot premium is significantly different from zero at the 5% level; the remaining premia are all significant at 1%.

(3) Copper: term premium *p=12* is not significantly different from zero; all other premia are all significant at the 1% level.

(4) Soybean: spot premium is not significantly different from zero; term premium *p=5* is significant at the 5% level; all other premia are significant at 10%

Table 4: Summary Statistics for the Estimated Convenience Yield Under Adequate and Inadequate Inventory Levels, Daily Data

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		Unconditional			Annualized Mean		Annualized Std Dev	
		Annualized Mean	Annualized Std Dev	% Positive	Positive	Negative	Positive	Negative
Oil	3-month	5.60%	4.16%	74.75%	-3.48%	8.75%	1.81%	3.54%
	6-month	8.04%	8.38%	73.14%	-5.60%	13.17%	3.56%	6.62%
	12-month	8.94%	10.24%	81.72%	-5.18%	12.18%	4.14%	8.29%
Gold	4-month	2.39%	0.80%	99.95%	-0.20%	2.39%	0.13%	0.80%
	6-month	1.89%	0.79%	99.60%	-0.04%	1.90%	0.02%	0.79%
	12-month	1.40%	0.88%	99.88%	-0.01%	1.40%	0.01%	0.88%
Copper	3-month	6.56%	4.16%	77.69%	-1.52%	13.18%	0.34%	5.04%
	6-month	7.64%	6.14%	76.45%	-1.33%	10.47%	0.50%	5.73%
	12-month	8.23%	10.39%	81.04%	-1.22%	10.68%	0.65%	10.33%
Soybean	3-month	3.49%	6.19%	50.50%	-2.03%	9.05%	0.67%	7.81%
	7-month	3.44%	7.77%	51.29%	-2.47%	9.20%	1.08%	8.88%
	11-month	3.52%	7.68%	55.23%	-2.02%	8.15%	1.28%	7.98%

The estimated convenience yield is the negative of the interest-adjusted basis, calculated as: $f(t,T) - s(t) - R(t,T)/(T-t)$. We provide estimates of the convenience yield under conditions of adequate ("positive" column) and inadequate ("negative" column) inventory levels.

Three contracts—the 3-month futures, the 6-month futures and the 12-month futures are used to calculate the short-term, intermediate-term and long-term convenience yield for the majority of commodities. Since gold market only trades contracts maturing in even months and soybean market only in odd months, different contracts other than the three maturities have to be chosen for both markets. The 4-month futures is used to calculate the short-term convenience yield for gold, and the 7-month and 11-month contracts are used to calculate the intermediate-term and long-term convenience yields for soybean.

Positive (negative) refers to a positive (negative) interest-adjusted basis, in other words a negative (positive) convenience yield, which holds when inventory is adequate (inadequate).

% Positive (negative) refers to the percentage of observations for which the convenience yield is positive (negative)

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Table 5: Summary statistics of net hedging pressure variable, semi-monthly data

	Mean	Std Dev
Oil	0.57%	5.74%
Gold	12.28%	30.04%
Copper	13.15%	20.91%
Soybean	12.76%	20.99%

		Oil		Gold		Copper		Soybean	
Year	Obs	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
1990	24	-5.36%	3.39%	0.54%	15.64%	3.88%	17.03%	9.70%	10.63%
1991	24	0.82%	4.35%	-7.23%	20.02%	-3.94%	19.46%	19.76%	8.71%
1992	24	-2.12%	5.01%	-6.18%	17.80%	7.83%	20.27%	24.29%	16.50%
1993	24	-3.74%	3.99%	25.79%	25.30%	5.37%	12.55%	42.62%	12.27%
1994	24	3.99%	3.62%	16.89%	19.99%	37.39%	7.15%	16.16%	28.23%
1995	24	5.49%	7.81%	-0.82%	13.99%	14.91%	18.32%	19.68%	18.41%
1996	24	2.43%	3.14%	1.74%	20.18%	18.68%	12.57%	31.26%	12.40%
1997	24	-2.20%	7.03%	-18.10%	11.73%	30.89%	19.66%	12.86%	22.46%
1998	24	-1.87%	4.72%	-9.45%	15.89%	7.58%	13.90%	-9.79%	10.62%
1999	24	7.37%	4.70%	-23.94%	18.10%	19.72%	19.08%	-3.25%	14.78%
2000	24	2.29%	2.58%	-8.19%	16.47%	14.80%	14.22%	27.49%	7.38%
2001	24	-5.31%	4.31%	8.09%	34.04%	-13.88%	10.35%	8.98%	13.53%
2002	24	3.19%	5.62%	40.36%	11.02%	13.30%	14.74%	20.48%	10.06%
2003	24	0.07%	5.37%	47.46%	11.29%	32.01%	15.36%	16.64%	14.55%
2004	24	3.82%	4.00%	45.28%	11.13%	27.12%	9.89%	0.43%	23.34%
2005	24	-0.67%	3.82%	48.73%	15.02%	16.61%	9.72%	-7.55%	13.80%
2006	24	1.44%	2.52%	47.80%	8.04%	-8.76%	12.57%	-12.90%	10.25%

Net hedging pressure is calculated as the difference between short and long hedge positions of commercial traders divided by their total hedge positions.

$$H_t = \frac{\text{short hedge positions - long hedge positions}}{\text{total hedge positions}}$$

Table 6: VAR estimates—Spot Premia(RF_1), convenience yield (CY_p) and net hedging pressure (QT), weekly data, from October 1992 to December 2006

OIL	RF_1	CY_1	CY_2	CY_3	QT
RF_1(-1)	0.89	0.01	0.03	0.04	0.03
t-value	*54.32****	*3.27****	*5.60****	*6.56****	*3.90****
CY_1(-1)	-1.50	0.75	0.16	0.33	-0.04
t-value	*-2.80****	*11.75****	*1.12*	*1.47*	*-0.19*
CY_2(-1)	1.25	0.10	0.75	-0.35	0.09
t-value	*3.00****	*1.96***	*6.50****	*-1.99***	*0.53*
CY_3(-1)	-0.43	-0.02	0.09	1.10	-0.05
t-value	*-2.86****	*-1.10*	*2.14***	*17.42****	*-0.76*
QT(-1)	0.03	0.00	0.00	0.00	0.91
t-value	*0.76*	*-0.32*	*0.19*	*0.28*	*53.21****
C	0.01	0.00	0.00	0.00	0.00
t-value	*2.73****	*2.02***	*-0.77*	*-0.67*	*0.88*

GOLD	RF_1	CY_1	CY_2	CY_3	QT
RF_1(-1)	0.90	0.00	0.00	0.00	0.20
t-value	*55.01****	*-2.17***	*-1.79**	*-1.14*	*4.24****
CY_1(-1)	-0.89	0.11	-0.70	-0.74	-1.86
t-value	*-0.59*	*0.78*	*-5.10****	*-5.05****	*-0.43*
CY_2(-1)	1.04	0.68	1.46	0.57	1.86
t-value	*0.57*	*4.16****	*8.88****	*3.22****	*0.36*
CY_3(-1)	-0.47	-0.10	-0.06	0.89	-0.82
t-value	*-0.95*	*-2.20***	*-1.38*	*18.34****	*-0.57*
QT(-1)	0.00	0.00	0.00	0.00	0.95
t-value	*0.19*	*-4.61****	*-5.15****	*-5.83****	*73.54****
C	0.00	0.00	0.00	0.00	0.02
t-value	*1.48*	*8.15****	*8.25****	*8.24****	*1.76**

COPPER	RF_1	CY_1	CY_2	CY_3	QT
RF_1(-1)	0.93	0.00	0.01	0.02	0.08
t-value	*64.69****	*0.87*	*2.20***	*3.74****	*4.02****
CY_1(-1)	0.05	0.41	-0.27	-0.25	-1.26
t-value	*0.10*	*5.78****	*-2.77****	*-1.74**	*-1.94**
CY_2(-1)	0.09	0.32	1.01	0.02	1.75
t-value	*0.20*	*4.56****	*10.41****	*0.16*	*2.75****
CY_3(-1)	-0.05	-0.04	0.04	1.02	-0.62
t-value	*-0.35*	*-1.71**	*1.44*	*22.80****	*-3.11****
QT(-1)	0.01	0.00	0.00	0.00	0.93
t-value	*0.79*	*-2.41***	*-1.52*	*-1.08*	*68.57****
C	0.00	0.00	0.00	0.00	0.01
t-value	*0.00*	*2.42***	*1.26*	*1.47*	*3.76****

SOYBEAN	RF_1	CY_1	CY_2	CY_3	QT
RF_1(-1)	0.90	-0.02	0.00	0.01	0.07
t-value	*57.66****	*-2.88****	*0.36*	*1.27*	*5.01****
CY_1(-1)	0.22	0.73	-0.26	-0.26	-0.20
t-value	*3.18****	*26.71****	*-8.13****	*-6.97****	*-3.04****
CY_2(-1)	-0.22	0.10	1.00	0.10	0.02
t-value	*-3.05****	*3.47****	*29.54****	*2.61****	*0.32*
CY_3(-1)	0.08	-0.02	0.02	0.92	0.00
t-value	*1.43*	*-1.00*	*0.88*	*31.01****	*0.03*
QT(-1)	0.00	0.00	0.00	0.01	0.98
t-value	*-0.51*	*0.28*	*1.18*	*1.97***	*126.48****
C	0.00	0.00	0.00	0.00	0.00
t-value	*0.64*	*1.41*	*1.34*	*1.82**	*1.55*

Table 7: VAR estimates—Gold Term Premium (SPR_p), Convenience yield (CY_p) and Net Hedging Pressure (QT), weekly data, October 1992 to December 2006

	$GOLDSPR_1$				
	SPR_1	CY_1	CY_2	CY_3	QT
$SPR_1(-1)$	0.7315	-0.0709	-0.0758	-0.0551	-1.9911
	[27.8301]***	[-2.81943]***	[-2.98484]***	[-2.02656]**	[-2.44328]**
$CY_1(-1)$	0.4057	0.2793	-0.5317	-0.6212	-1.6550
	[2.75478]***	[1.98300]**	[-3.73733]***	[-4.07945]***	[-0.36240]
$CY_2(-1)$	-0.6452	0.4235	1.2079	0.3826	0.7087
	[-3.56126]***	[2.44411]**	[6.90206]***	[2.04243]**	[0.12616]
$CY_3(-1)$	0.1840	-0.0250	0.0100	0.9367	-1.0113
	[3.79440]***	[-0.54004]	[0.21287]	[18.6872]***	[-0.67268]
QT(-1)	-0.0003	-0.0021	-0.0023	-0.0027	0.9403
	[-0.63704]	[-5.11399]***	[-5.68145]***	[-6.13351]***	[70.8960]***
C	-0.0013	0.0018	0.0018	0.0021	0.0173
	[-4.48126]***	[6.52379]***	[6.67403]***	[7.12950]***	[1.96945]**
	$GOLDSPR_2$				
	SPR_2	CY_1	CY_2	CY_3	QT
$SPR_2(-1)$	0.8685	-0.0212	-0.0252	-0.0121	-1.2244
	[44.2764]***	[-1.38635]	[-1.63208]	[-0.73294]	[-2.48287]**
$CY_1(-1)$	0.4642	0.2235	-0.5835	-0.6782	-1.2664
	[2.53175]**	[1.56538]	[-4.04539]***	[-4.40100]***	[-0.27476]
$CY_2(-1)$	-0.6127	0.5261	1.3073	0.4801	1.0328
	[-2.77258]***	[3.05684]***	[7.51970]***	[2.58474]***	[0.18591]
$CY_3(-1)$	0.1501	-0.0579	-0.0232	0.9080	-1.4687
	[2.61564]***	[-1.29440]	[-0.51477]	[18.8246]***	[-1.01792]
QT(-1)	-0.0004	-0.0021	-0.0024	-0.0027	0.9331
	[-0.71777]	[-4.78731]***	[-5.38235]***	[-5.64422]***	[66.0697]***
C	-0.0008	0.0020	0.0021	0.0023	0.0229
	[-2.30536]**	[7.72430]***	[7.92011]***	[8.14959]***	[2.74273]***

$GoldSPR_1$ and $GoldSPR_2$ are calendar spreads that both long the 1st-nearby futures but short the 2nd-nearby futures — also the 6-month futures, and the 12-month futures, respectively. For the overlapping of the 2nd-nearby futures and the 6-month futures, only two gold spreads are used in this test.

Table 8: VAR estimates—copper term premium (SPR_p), convenience yield (CY_p) and net hedging pressure (QT), weekly data, from October 1992 to December 2006

COPPERSPR$_1$					
	SPR_1	CY_1	CY_2	CY_3	QT
SPR_1(-1)	0.7593	0.0382	0.1135	0.2018	0.3218
	[29.0232]***	[1.72354]*	[3.71268]***	[4.48076]***	[1.58017]
CY_1(-1)	0.0006	0.4372	-0.2032	-0.1146	-0.9030
	[0.00764]	[6.06686]***	[-2.04669]**	[-0.78324]	[-1.36471]
CY_2(-1)	-0.0694	0.3140	0.9912	-0.0191	1.5308
	[-0.84661]	[4.51872]***	[10.3517]***	[-0.13562]	[2.39900]**
CY_3(-1)	0.0489	-0.0427	0.0303	1.0037	-0.6035
	[1.86253]*	[-1.91832]*	[0.98671]	[22.2095]***	[-2.95365]***
QT(-1)	0.0007	-0.0034	-0.0025	-0.0018	0.9393
	[0.38043]	[-2.27191]**	[-1.19964]	[-0.60090]	[68.3856]***
C	-0.0010	0.0012	0.0011	0.0019	0.0155
	[-2.05030]**	[2.66694]***	[1.83699]*	[2.15841]**	[3.92362]***
COPPERSPR$_2$					
	SPR_2	CY_1	CY_2	CY_3	QT
SPR_2(-1)	0.8402	0.0313	0.0809	0.1437	0.1879
	[39.4657]***	[2.57924]***	[4.85171]***	[5.86461]***	[1.67943]*
CY_1(-1)	-0.3079	0.4156	-0.2660	-0.2262	-1.0765
	[-2.47231]**	[5.84497]***	[-2.72683]***	[-1.57870]	[-1.64469]
CY_2(-1)	0.2370	0.3352	1.0456	0.0775	1.6559
	[1.93770]*	[4.80095]***	[10.9160]***	[0.55036]	[2.57640]***
CY_3(-1)	-0.0496	-0.0464	0.0232	0.9913	-0.6096
	[-1.27489]	[-2.08823]**	[0.76245]	[22.1331]***	[-2.98036]***
QT(-1)	0.0017	-0.0037	-0.0032	-0.0031	0.9374
	[0.66416]	[-2.45755]**	[-1.56672]	[-1.04064]	[68.2793]***
C	0.0001	0.0011	0.0009	0.0016	0.0149
	[0.07883]	[2.57125]**	[1.54231]	[1.80693]*	[3.80901]***
COPPERSPR$_3$					
	SPR_3	CY_1	CY_2	CY_3	QT
SPR_3(-1)	0.8829	0.0156	0.0434	0.0830	0.1161
	[48.6267]***	[2.28550]**	[4.64102]***	[6.09175]***	[1.88915]*
CY_1(-1)	-0.5209	0.4014	-0.2784	-0.2510	-1.0843
	[-2.69116]***	[5.53175]***	[-2.79550]***	[-1.72751]*	[-1.65556]*
CY_2(-1)	0.4495	0.3311	1.0131	0.0219	1.5050
	[2.37656]**	[4.66935]***	[10.4108]***	[0.15404]	[2.35174]**
CY_3(-1)	-0.1186	-0.0396	0.0463	1.0327	-0.5283
	[-1.98860]**	[-1.76895]*	[1.50905]	[23.0581]***	[-2.61727]***
QT(-1)	0.0012	-0.0040	-0.0036	-0.0039	0.9409
	[0.29743]	[-2.59323]***	[-1.68397]*	[-1.25302]	[67.2087]***
C	0.0009	0.0010	0.0006	0.0010	0.0131
	[0.79690]	[2.33555]**	[1.04233]	[1.12918]	[3.31049]***

SPR_1, SPR_2 and SPR_3 are calendar spreads that all long the 1^{st}-nearby futures but short the 2^{nd}-nearby futures, the 6-month futures and the 12-month futures, respectively Rows with numbers in square brackets are *t* statistics. According to Lutkepohl (1993, Chapter 3, pp 69), for the stable time series with standard white noise process, when the sample size is not small, the *t* statistics provided by common regression programs can be used to check the significance of individual variables.

***, ** and * are indicates significance at the 1% level, 5% level and 10% level, respectively.

Table 9: Summary statistics of momentum winner, loser, and momentum (MMT) trading returns, long-only the 1st-nearby futures, bi-weekly data

	Holding period of 1 month			Holding period of 3 month			Holding period of 6 month			Holding period of 12 month		
	Winner	Loser	MMT	Winner	Loser	MMT	Winner	Loser	MMT	Winner	Loser	MMT
Panel A: ranking period of 1 month												
Mean	0.0474	-0.0499	0.0924	0.0337	-0.0250	0.0599	0.0162	-0.0083	0.0239	0.0096	-0.0031	0.0124
t-stat	11.8075***	-12.7826***	18.3919***	8.5752***	-7.4514***	13.1905***	4.0704***	-2.3720**	4.8397**	2.4963**	-0.9544	2.7643***
Std Dev	0.0804	0.0782	0.1006	0.0787	0.0671	0.0909	0.0798	0.0702	0.0990	0.0768	0.0655	0.0897
Sharpe R	0.5896	-0.6383	0.9184	0.4282	-0.3721	0.6587	0.2033	-0.1185	0.2417	0.1247	-0.0477	0.1380
Panel B: ranking period of 3 months												
Mean	0.0412	-0.0374	0.0761	0.0196	-0.0125	0.0329	0.0102	-0.0021	0.0119	0.0060	0.0009	0.0051
t-stat	10.1120***	-9.4505***	14.2127***	4.6339***	-3.4596***	6.3375***z	2.4857**	-0.6007	2.3035**	1.5871	0.2935	1.1103
Std Dev	0.0816	0.0793	0.1073	0.0845	0.0722	0.1038	0.0821	0.0693	0.1031	0.0761	0.0639	0.0919
Sharpe R	0.5050	-0.4719	0.7098	0.2314	-0.1728	0.3165	0.1241	-0.0300	0.1150	0.0793	0.0147	0.0554
Panel C: ranking period of 6 months												
Mean	0.0250	-0.0125	0.0399	0.0112	-0.0042	0.0146	0.0071	0.0037	0.0035	0.0028	0.0063	-0.0031
t-stat	5.4554***	-3.5515***	7.3043***	2.5454**	-1.2662	2.8253**	1.6174	1.2090	0.7256	0.7326	2.0733**	-0.7283
Std Dev	0.0916	0.0704	0.1095	0.0884	0.0658	0.1032	0.0876	0.0620	0.0976	0.0768	0.0613	0.0858
Sharpe R	0.2724	-0.1774	0.3648	0.1271	-0.0632	0.1411	0.0808	0.0604	0.0362	0.0366	0.1035	-0.0364
Panel D: ranking period of 12 months												
Mean	0.0212	-0.0125	0.0312	0.0104	-0.0042	0.0133	0.0050	0.0037	0.0012	0.0000	0.0076	-0.0073
t-stat	5.0708***	-3.5515***	6.1464***	2.5626**	-1.2419	2.7554**	1.1977	1.1825	0.2622	0.0000	2.5210***	-1.6559
Std Dev	0.0838	0.0704	0.1016	0.0813	0.0671	0.0967	0.0835	0.0634	0.0953	0.0761	0.0603	0.0880
Sharpe R	0.2532	-0.1774	0.3069	0.1280	-0.0620	0.1376	0.0598	0.0591	0.0131	0.0000	0.1259	-0.0827

Mean and standard deviation are annualized by multiplying by 26 and $\sqrt{26}$ respectively.

***, ** and * are indicates significance at the 1% level, 5% level and 10% level, respectively.

Table 10: Summary statistics of momentum trading returns, calendar spread that longs the 1st-nearby futures and shorts the 12-month futures, bi-weekly data

	Holding period of 1 month			Holding period of 3 month			Holding period of 6 month			Holding period of 12 month		
	Winner	Loser	MMT	Winner	Loser	MMT	Winner	Loser	MMT	Winner	Loser	MMT
Panel A: ranking period of 1 month												
Mean	4.37%	-3.74%	7.99%	2.62%	-2.08%	4.53%	1.19%	-0.42%	1.66%	0.62%	-0.21%	0.85%
t-stat	9.7882	-9.5869	14.0380	5.2496	-6.7978	7.9989	2.9745	-1.2015	3.3363	1.7069	-0.7924	1.9256
Std Dev	8.94%	7.82%	11.39%	10.00%	6.13%	11.35%	7.98%	6.93%	9.99%	7.32%	5.26%	8.87%
Sharpe R	48.88%	-47.87%	70.10%	26.22%	-33.95%	39.94%	14.85%	-6.00%	16.66%	8.52%	-3.96%	9.62%
Panel B: ranking period of 3 months												
Mean	2.87%	-2.50%	4.87%	1.41%	-0.42%	1.79%	0.50%	0.12%	0.37%	0.22%	0.04%	0.18%
t-stat	5.9136	-6.8823	8.0039	2.7619	-2.2659	3.2103	1.2247	0.3703	0.7306	0.5820	0.1645	0.3921
Std Dev	9.72%	7.26%	12.18%	10.26%	3.68%	11.16%	8.16%	6.75%	10.26%	7.51%	5.06%	9.03%
Sharpe R	29.53%	-34.37%	39.97%	13.79%	-11.32%	16.03%	6.12%	1.85%	3.65%	2.91%	0.82%	1.96%
Panel C: ranking period of 6 months												
Mean	2.00%	-1.25%	2.87%	0.67%	-0.42%	0.96%	0.10%	0.15%	0.00%	-0.10%	0.25%	-0.42%
t-stat	3.8483	-4.4743	4.9469	1.4058	-1.8191	1.8801	0.2482	0.6270	0.0000	-0.2896	0.9999	-0.9532
Std Dev	10.39%	5.59%	11.62%	9.48%	4.58%	10.19%	8.39%	4.65%	9.71%	7.19%	5.00%	8.74%
Sharpe R	19.22%	-22.34%	24.70%	7.02%	-9.08%	9.39%	1.24%	3.13%	0.00%	-1.45%	4.99%	-4.76%
Panel D: ranking period of 12 months												
Mean	1.37%	0.00%	1.62%	0.50%	0.08%	0.37%	0.10%	0.40%	-0.21%	-0.21%	0.55%	-0.73%
t-stat	2.7339	0.0000	2.9380	1.1071	0.3588	0.7404	0.2536	1.7528	-0.4477	-0.6270	1.9121	-1.7590
Std Dev	10.06%	4.81%	11.06%	9.03%	4.64%	10.13%	8.21%	4.51%	9.30%	6.64%	5.77%	8.29%
Sharpe R	13.65%	0.00%	14.67%	5.53%	1.79%	3.70%	1.27%	8.75%	-2.24%	-3.13%	9.55%	-8.78%

MMT refers to momentum. Mean and standard deviation are annualized by multiplying by 26 and $\sqrt{26}$ respectively.

*****, ** and * are indicates significance at the 1% level, 5% level and 10% level, respectively.**

Table 11: Regression results of momentum trading returns with the 1st-nearby futures on convenience yield, net hedging pressure and monthly dummies, bi-weekly data; p-values in parentheses

	Holding period of 1 month		Holding period of 3 month		Holding period of 6 month		Holding period of 12 month	
	Long Winner	Short Loser	Long Winner	Short Loser	Long Winner	Short Loser	Long Winner	Short Loser
Panel A: ranking period of 1 month								
Variable								
Intercept	0.0190	0.0543	0.0311	0.0807	0.0490	0.0595	0.0753	0.0533
	(0.1253)	(<.0001)***	(0.1391)	(<.0001)***	(0.1135)	(0.0249)**	(0.0748)*	(0.1296)
CY3MONTH	0.4123	0.4727	0.5175	0.3895	0.9506	-0.1883	1.3192	-0.4617
	(0.0225)**	(<.0001)***	(0.0906)*	(0.0248)**	(0.0348)**	(0.4733)	(0.032)**	(0.1857)
HP	0.0440	-0.0964	0.1434	-0.1359	0.1469	-0.1329	0.1550	-0.1396
	(0.014)**	(<.0001)***	(<.0001)***	(<.0001)***	(<.0001)***	(0.0004)***	(0.011)**	(0.0049)***
Panel B: ranking period of 3 months								
Variable								
Intercept	0.0016	0.0501	-0.0106	0.0402	-0.0044	0.0218	0.0077	0.0083
	(0.9007)	(<.0001)***	(0.6505)	(0.0308)**	(0.8903)	(0.3963)	(0.8573)	(0.8093)
CY3MONTH	0.4717	0.4158	1.4735	0.3379	2.2020	0.3270	1.4925	-0.5818
	(0.0153)**	(0.0002)	(<.0001)***	(0.0553)*	(<.0001)***	(0.1799)	(0.0202)**	(0.073)*
HP	0.0339	-0.0724	0.0891	-0.1543	0.1101	-0.1665	-0.0456	-0.0991
	(0.0625)*	(<.0001)***	(0.0066)***	(<.0001)***	(0.015)**	(<.0001)***	(0.4482)	(0.047)**
Panel C: ranking period of 6 months								
Variable								
Intercept	-0.0228	0.0219	-0.0385	0.0311	-0.0040	0.0167	-0.0671	-0.0771
	(0.1168)	(0.0378)**	(0.1125)	(0.0593)*	(0.9065)	(0.4569)	(0.1081)	(0.0175)**
CY3MONTH	0.4152	0.0426	0.9454	0.1601	2.0764	0.1193	2.7722	-0.6207
	(0.048)**	(0.7499)	(0.0071)***	(0.443)	(<.0001)***	(0.6754)	(<.0001)***	(0.1309)
HP	0.0446	-0.0853	0.0929	-0.1680	0.1111	-0.1795	0.0066	-0.1803
	(0.0286)**	(<.0001)***	(0.0063)***	(<.0001)***	(0.0193)**	(<.0001)***	(0.9105)	(0.0003)***
Panel D: ranking period of 12 months								
Variable								
Intercept	-0.0034	0.0177	0.0058	0.0369	-0.0026	-0.0102	-0.0689	-0.1035
	(0.7949)	(0.0973)*	(0.7972)	(0.0368)**	(0.9361)	(0.6611)	(0.0905)*	(0.0007)***
CY3MONTH	0.0043	0.0068	0.5904	-0.8578	1.8458	-0.3157	2.6517	-0.8330
	(0.9817)	(0.9754)	(0.0654)*	(0.0185)**	(<.0001)***	(0.51)	(<.0001)***	(0.1804)
HP	0.0581	-0.0749	0.0610	-0.1024	0.0097	-0.1993	-0.1332	-0.3999
	(0.0015)***	(<.0001)***	(0.0505)*	(0.0004)***	(0.8272)	(<.0001)***	(0.018)**	(<.0001)***

Numbers in parentheses are *p-value*. Coefficients with *p-value* highlighted by ***, ** and * are significant at 1%, 5% and 10% levels, respectively.

Table 12: Regression results of momentum trading returns of calendar spread that longs the 1st-nearby futures and shorts the 12-month futures on convenience yield, net hedging pressure and monthly dummies, bi-weekly data; p-values in parentheses

	Holding period of 1 month		Holding period of 3 month		Holding period of 6 month		Holding period of 12 month	
	Long Winner	Short Loser	Long Winner	Short Loser	Long Winner	Short Loser	Long Winner	Short Loser
Panel A: ranking period of 1 month								
Variable								
Intercept	-0.0054	0.0464	0.0264	0.0451	0.0538	0.0384	0.0967	-0.0278
	(0.68)	(0.0002)***	(0.3105)	(0.0085)***	(0.0619)*	(0.1531)	(0.0081)***	(0.0003)***
CY12MONTH	0.2963	-0.0041	0.3342	0.0112	0.5377	-0.1554	0.8795	-0.0857
	(<.0001)***	(0.9167)	(<.0001)***	(0.8321)	(<.0001)***	(0.0611)*	(<.0001)***	(<.0001)***
HP	-0.0045	-0.0282	0.0670	-0.0458	0.1658	-0.0350	0.0740	-0.0398
	(0.8194)	(0.1166)	(0.0862)*	(0.0619)*	(0.0001)***	(0.3626)	(0.1747)	(<.0001)***
Panel B: ranking period of 3 months								
Variable								
Intercept	-0.0283	0.0218	-0.0295	0.0260	-0.0046	-0.0139	-0.0359	0.0335
	(0.0534)*	(0.0494)**	(0.2549)	(0.0072)***	(0.8798)	(0.5777)	(0.3506)	(0.2052)
CY12MONTH	0.2707	0.0287	0.7154	-0.0997	0.6557	-0.2415	0.8850	-0.2696
	(<.0001)***	(0.4737)	(<.0001)***	(0.0044)***	(<.0001)***	(0.0078)***	(<.0001)***	(0.005)***
HP	0.0020	-0.0373	0.0185	-0.0377	0.0800	-0.0907	-0.0344	-0.1523
	(0.9235)	(0.0182)**	(0.6193)	(0.0061)***	(0.0645)*	(0.0111)**	(0.5327)	(<.0001)***
Panel C: ranking period of 6 months								
Variable								
Intercept	-0.0302	0.0213	-0.0438	0.0221	-0.0333	-0.0016	-0.1412	-0.0189
	(0.0791)*	(0.0126)**	(0.0928)*	(0.0631)*	(0.2959)	(0.9266)	(0.0004)***	(0.4739)
CY12MONTH	0.1752	0.0040	0.4544	-0.0427	0.6743	-0.1091	0.8035	-0.2653
	(0.0002)***	(0.9182)	(<.0001)***	(0.4328)	(<.0001)***	(0.1697)	(<.0001)***	(0.0285)**
HP	0.0469	-0.0314	0.0990	-0.0761	0.1081	-0.0865	-0.0402	-0.1108
	(0.0481)**	(0.0105)**	(0.0061)***	(<.0001)***	(0.0141)**	(0.0006)***	(0.459)	(0.0037)***
Panel D: ranking period of 12 months								
Variable								
Intercept	-0.0147	0.0182	0.0220	0.0386	-0.0411	-0.0172	-0.1429	-0.0956
	(0.3658)	(0.0106)**	(0.3707)	(0.0009)***	(0.1867)	(0.3004)	(<.0001)***	(0.0015)***
CY12MONTH	0.1468	-0.1738	0.3579	-0.3807	0.5946	-0.4400	0.8284	-0.3626
	(0.0022)***	(<.0001)***	(<.0001)***	(<.0001)***	(<.0001)***	(<.0001)***	(<.0001)***	(0.0458)**
HP	0.0418	-0.0226	0.0041	-0.0451	-0.0459	-0.0014	-0.2335	-0.2400
	(0.0883)*	(0.0434)**	(0.9116)	(0.014)**	(0.3301)	(0.9573)	(<.0001)***	(<.0001)***