Maturity Structure of Commodity Roll Strategies: Evidence from the Energy Futures

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Abstract

We investigate the maturity-structure of roll strategy returns in the energy futures markets. Our innovation is to report and analyze the risk/return profile, the Sharpe ratio, and the asset pricing loadings of rollover strategies based on futures contracts of the same underlying commodity but with maturities between two and 12 months. We find that a conditional rollover strategy, which takes a long position in backwardation and a short position in contango, delivers the highest Sharpe ratio for all commodities. While we don't observe a significant difference in terms of asset pricing beta for different roll positions, the Sharpe ratio tends to be higher for contracts with a shorter time to maturity. We also report some distinct patterns of maturity-structure across energy commodities. Findings of the paper have implications for managing commodity-based investments.

Keywords: Futures Contracts,, Roll Strategies, Roll Yield, Maturity-Structure, Energy Futures

1. Introduction

Commodities have become an important and popular asset class, thanks to their potential for inflation-hedging, portfolio diversification, leverage investment, and a reasonable return with a low loading on known risk factors (including the market factor). Asset managers interested in commodity investment can follow a diverse set of active and passive investment

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strategies, including the popular rollover strategy.

The rollover (or roll) strategy includes entering a futures contract with a given time-to-maturity, holding the futures contracts for a certain time period (typically for one month), and then closing the position to realize the return generated by changes in the price of the underlying futures contract. The investor then opens a new futures contract position (with the same time-to-maturity as before) and repeats the strategy. For a review on the summary of existing literature on this topic see Miffre (2015).

The main contribution of the current paper is to examine the performance of rollover strategies defined on futures contracts with different time-to-maturity or what we call *maturity structure* of roll yields. By allowing the investment strategy to enter and exit futures contracts beyond the front month and to hold the contract for a time shorter than its maturity, we construct the maturity structure and discuss its properties for the five selected commodities.

Allowing for investment strategies with a constant one-month holding period but based on longer maturity futures contracts creates a new dimension in the investment strategy space. This proposed strategy generates a *vector* of rollover return time-series for a single commodity (as opposed to a single time-series) and enables us to look into the behavior of returns associated with different futures contracts for the same commodity. The asset manager not only picks the best portfolio of commodities for her rollover strategy, but also chooses the best investment horizon associated with each commodity.

There is a theoretical motivation behind our research. We rely on the fact that the prices of futures contracts with different time-to-maturity potentially have different sensitivities to macroeconomic as well as idiosyncratic shocks. Returns of futures contracts with a short time-to-maturity (e.g., one- or two-month contracts) contain short-term news of the underlying commodity, such as sudden changes in the current supply or inventories (e.g., a terrorist attack on an oil pipeline), and are very volatile. This is known as the Samuelson Effect in the commodity finance literature.

On the other hand, longer maturity futures mainly react to fundamental and long-term shocks, such as macro productivity shocks, changes in the GDP growth rates, discovery of new reserves, drilling activities, new regulations, and fundamental technological developments. See Kogan et al. (2009) and Carlson et al. (2007) as examples of structural models in this area.

Obviously, if the commodity is storable and there are active storage markets, futures prices over all maturities will be linked (Williams and Wright (2005)); still, these prices will not be perfectly correlated with each other, which makes it possible for them to have different loadings on short-term and long-term factors. Therefore, while we expect to see a high correlation between roll yields over different maturities, it is also expected to see different risk/return profiles and differences in loading on asset pricing factors. As an example, we expect that a roll strategy on a nearby contract (e.g., a two-month) exposes the investor to a high level of commodity-specific (idiosyncratic) risks than a one-month rolling using a 12-month or a 24-month contract.

The theoretical motivation of our research is not new. However, to the best of our knowledge, not much empirical research has been done to quantify it. Empirical examination of heterogeneities in roll yields is a relevant and important exercise. If roll yields across different maturities show similar risk/return patterns, investment managers will be indifferent between possible futures contracts at various maturities (and will mainly consider other factors, such the picking the most liquid, with lower margin requirement, or the most underpriced contracts). However, if the maturity horizon of the futures contract plays a significant role in the returns dynamics, then one needs to select the optimal future contract (in terms of the time to maturity) for each commodity. Depending on the investment manager?s objective, the optimal futures horizon(s) should deliver the highest Sharpe ratio for an acceptable level of volatility. Given that not all commodities have the same exposure to short-term and long-term factors, the next logical question would be: Do the maturity-structures of rollover returns vary across different underlying commodities?

Our research question is valid for almost all commodities, including base metals, precious metals, and agriculture. However, this paper only focuses on energy commodities because of the certain favorable characteristics of the energy futures markets. First, energy contracts are offered and traded in regular and non-sparse maturities (up to the maximum maturity); whereas, some commodities (e.g., agriculture products) have gaps in their maturity structure (i.e. futures contracts are not available for certain months of the year). Second, energy futures contracts are popular instruments, ranking very high in terms of trading volume and liquidity[1], and have a reasonable long history of trade. Finally, energy commodities are heavily exposed to both idiosyncratic and macroeconomic factors.

We contribute to the literature by studying maturity effect in roll yield. Our research builds on results reported by other papers, including Ma et al. (1992),Mouakhar and Roberge (2010), Carchano and Pardo (2009), and Taylor et al. (2015). Erb and Harvey (2006) and Gorton and Rouwenhorst (2006) report the performance of rollover strategies for a wide range of commodities. Daskalaki et al. (2014) review the performance of risk-factor models in explaining cross-sectional differences in commodity returns. However, to the best of our knowledge, all these papers run their tests using a fixed roll horizon and focus on cross-sectional aspects of the problem. The novelty of our research is to introduce the concept of maturity structure to the literature of roll yield.

We document a monotonic relationship between the length of futures contracts and three key measures: the average return, the volatility of returns, and the Sharpe ratio. The results are robust for all commodities. The average return and volatility curves all decline with the length of the futures contract. However, the slope of the Sharpe ratio curve depends on the

[1]For our research design, illiquidity is a major issue. We should make sure that all futures contracts used in the estimation are liquid enough and the returns patterns are not mainly driven by infrequent trades.

investment strategy chosen. For unconditional investment strategies the slope is positive, meaning that the further into the future the maturity date of the futures contracts, the higher is the Sharpe ratio. The relationship gets reversed when the investment position is conditioned on the slope of the forward curve.

The results show that the maximum Sharpe ratio, among all investment strategies and maturity horizons, is attained with a conditional strategy on two-month futures contracts. This is a robust result across all commodities. We show that the performance of a three-factor CAPM model changes monotonically relative to horizon.

To summarize, this paper offers the following contributions. First, we show noticeable differences in performance of investment strategies using different futures horizons but similar underlying commodities. Second, we find out that there is not a strong maturity structure effect in the asset pricing tests of rollover strategies. Finally, we show how the maturity structure of the rollover returns diverges across different energy commodities.

The remainder of the paper is organized as follows. In Section 2 we introduce the basic theoretical concepts. Section 3 introduces data and explains the empirical strategy of the paper. Results of the empirical estimations are presented in Section 4. Finally, we discuss our findings and propose directions for future research in Section 5.

2. Model Setup

2.1. Mathematics of Roll Strategy

The fundamental entity of the model is $F_{t,T}$, which is the price of the futures contract at time t, maturing T periods later. For example, a 12-month futures contract will be denoted by $F_{t,12}$. After a month has passed and the time to maturity has become 11 months, the same contract will be represented by $F_{t+1,11}$. Note that in our notation T refers to the time-to-maturity of the contract at time t (and not a calendar date). T is a most building block of our research because it represents the time-to-maturity of the rolling contracts at the time the investor enters a new position. The futures contract is held for H periods. At the closing, time to maturity is equal to $T - H$ [2].

The excess (or net) return at time t is defined as the percentage change from buying a futures contact H months ago and selling it at time t net the risk-free rate.

$$\mathrm{r}_t^{H,T} = \frac{F_{t,T-H} - F_{t-H,T}}{F_{t-H,T}} - R_t^f \tag{1}$$

where $\mathrm{r}_{t+H}^{H,T}$ is the *realized* excess return at time t associated with a rolling strategy with a holding period H and a time-to-maturity T, R_t^f is the risk-free rate at time t. For example, if the investor enters a 12-month futures contract of crude oil, holds it for four months and closes the position at time t, $H = 4$ and $T = 12$. In this case, Excess $\text{Return}_t^{4,12} = \frac{F_{t,8} - F_{t-4,12}}{F_{t-4,12}} - R_t^f$

The typical strategy discussed in the literature is associated with $H = 1$ and $T = 1$. In this special case, the futures contract matures when the position is closed and the selling price becomes equal to the sport price.

$$\mathrm{r}_t^{1,1} = \frac{F_{t,0} - F_{t-1,1}}{F_{t-1,1}} - R_t^f = \frac{S_t - F_{t-1,1}}{F_{t-1,1}} - R_t^f \tag{2}$$

Throughout the paper we refer to the time-to-maturity (T) when the investors opens a position as the *roll position* . For example, if the investment strategy is to enter seven-month futures contract and close it a month later, the roll position will be seven months. Our research is dealing with a set or roll positions in the range of 2-12 months for energy commodities (2-8 months for gasoline.)

In this research we have chosen a fixed holding period of one month. Thus, $H = 1$ for all strategies. What differ across strategies is T. R_t, the vector of roll returns at time t includes

[2]Some other papers use the notation of $F_{t,T}$ to refer to the time t price of a futures contract expiring at the calendar data T. There is a one-to-one mapping from our formulation and the other formulation. If we want to represent our $F_{t,12}$ contract in the other notation it will be $F_{t,t+12}$. Alternatively, $F_{t,T}$ in the other notation, will be $F_{t,T-H}$ in our convention.

$r_t^{K,1}, K \in \{2, ..., T_{max}\}$, where T_{max} is the largest time-to-maturity.

2.2. Investment Strategies

The investor can follow a naive unconditional continuous roll strategy, or alternatively, condition her strategy on the slope of the forward curve. A conditional strategy would mean that the investor takes long or short positions on the underlying contract depending on the futures curve being in contango or backwardation. The slope of the term structure of commodity futures prices is among popular signals used to choose a short or long position (Fuertes et al. (2014)). This approach gives us four separate investment strategies, and we report the performance results for all four.

Unconditional Long. This strategies includes long positions on futures contracts, independent of the slope of the futures curve. We label this strategy as "unconditional".

Conditional Long/Short. The slope of forward curve can provide information about the direction of price changes in future periods (Chinn and Coibion (2013)). Thus, one can exploit the observable sign of slope to form a conditional investment strategy. The conditional strategy switches between long and short positions depending on the slope. When the forward curve is in contango (i.e., positive slope) the strategy goes *short* and when the curve is in backwardation the position is *long*.

Contango Short Only. This strategy takes a *short* position when the curve is in contango. When the curve is in backwardation, the capital is invested in risk-free assets and a zero excess return is recorded.

Backwardation Long Only. This is the opposite of the contango short strategy. The investor takes long positions when the curve is backwardation. The strategy refrains from investing when the curve is in contango (and again earns zero excess return).

2.3. Asset Pricing Tests

After generating time-series of returns for each investment strategy, we run the following regression of excess returns (the term r^f in the regression) on three major Fama-French asset pricing factors of the market return, small-big (SMB), and high-low (HML).

$$r_t^s = r_t^f + \beta_m r_t^m + \beta_{\mathrm{SMB}} r_t^{\mathrm{SMB}} + \beta_{\mathrm{HML}} r_t^{\mathrm{HML}} + \epsilon_t \tag{3}$$

We refer to the three coefficients, $\beta_m, \beta_{\mathrm{SMB}}, \beta_{\mathrm{HML}}$, as the loading of roll returns on asset pricing factors. We also report the R^2 of the regression to examine the percentage of variance explained by known asset pricing factors.

3. Empirical Setup

3.1. Data

The basket of commodities studied in this paper includes WTI crude oil, Brent crude oil, natural gas, gasoline, and heating oil.

All futures price dates are obtained from Bloomberg. Asset pricing factors (market return, SMB, and HML) are downloaded from Keneth French's website. The short-tern risk-free rates are obtained from Fred.

Sample Selection Criteria. The starting date of sample for each commodity is chosen in a way to ensure the existence of liquid prices over selected horizons. We choose a maximum 12-month futures contract, because in the historical data trading activity (thus the liquidity) declines significantly with maturities beyond 12-month. This pattern has been changed in recent years as there are several commodities (including crude oil) with liquid contracts well beyond 12-month time to maturity. However, to have a long enough sample we decided to limit the time-to-maturity to a maximum of 12 months and work with futures contracts with a maturity of 2 to 12 months. To pick the sample's start date we apply two conditions.

First, we make sure that there are substantial open interests and volume across *all* futures contracts within the sample. Second, we calculate roll yields and limit sample to a range that produce market activity (i.e. positive price change) for all maturities in all months. Using the two criteria (and requiring that both criteria being met) we cut the sample of available data to make sure the final sample represent a liquid market for maturities between 2-12 months (with the exception of maturities 2-8 months for gasoline.)

Although the starting dates of series vary across commodities, the sample is balanced for each commodity. In other words, for each commodity we have full observations for all maturities within the selected sample period. Table 1 presents some basic information regarding the selected commodities.

Commodity	Ticker	Start Date	End Date	Futures Horizon	Number of Observations	Percentage of Backwardation (%)
WTI Crude Oil	CL	April 1991	Feb 2016	12 Months	298	52.2
Brent Crude Oil	BR	May 1998	Feb 2016	12 Months	213	56.6
Gasoline	HU/RB	May 1987	Feb 2016	8 Month	345	60.5
Heating Oil	HO	July 1986	Feb 2016	12 Month	355	43.5
Natural Gas	NG	June 1990	Feb 2016	12 Months	308	31.6

Table 1: List of Commodities

Being in contango (positive slope of the forward curve) or backwardation (negative slope of the forward curve) is an import state variable of a commodity market and also a critical input to our investment strategies. We report the percentage of backwardtion for each commodity in Table 1.

3.2. Implementation

Psudo Algoritm. For each underlying commodity we create a continuous vector of monthly returns generated by the four different investment strategies. Unlike other studies, which work with a single-time series for each underlying commodity, our universe of returns includes the vectors of time-series (i.e., a matrix of returns) for each commodity.

Transaction Costs. We don't explicitly account for transaction costs. Our key assumption is that transaction costs are more or less the same for all liquid futures contracts of *the same energy commodity* . Since our major goal is to compare the performance of futures of the same commodity (and not the performance across different commodities), not accounting for trading costs should not have a major effect on results because it cancels out in the comparison.

4. Results

The in-the-sample results of the roll strategies are reported in this section. First, the time-series behavior of returns for two representative futures contracts are reported. Then, we report the average return, volatility, and Sharpe ratio of returns associated with each futures position. Finally, we show how the asset pricing factor loadings changes across different futures positions.

4.1. Time-Series of Returns

Before reporting the moments of roll returns Figure 1 shows the time-series dynamics of returns for positions involving two-month and 12-month (eight-month in the case of gasoline) futures contracts. Both roll positions are held for one month and the investor rolls to the next futures contract after a month. We observe a strong correlation between returns of short and long maturity roll strategies. The direction of movements is almost identical for both strategies. However, as expected, the returns of the short maturity position are more volatile and experience more frequent extreme values. In a sense, the investment strategy involving the long maturity position can be considered a more conservative version of the short-maturity strategy.

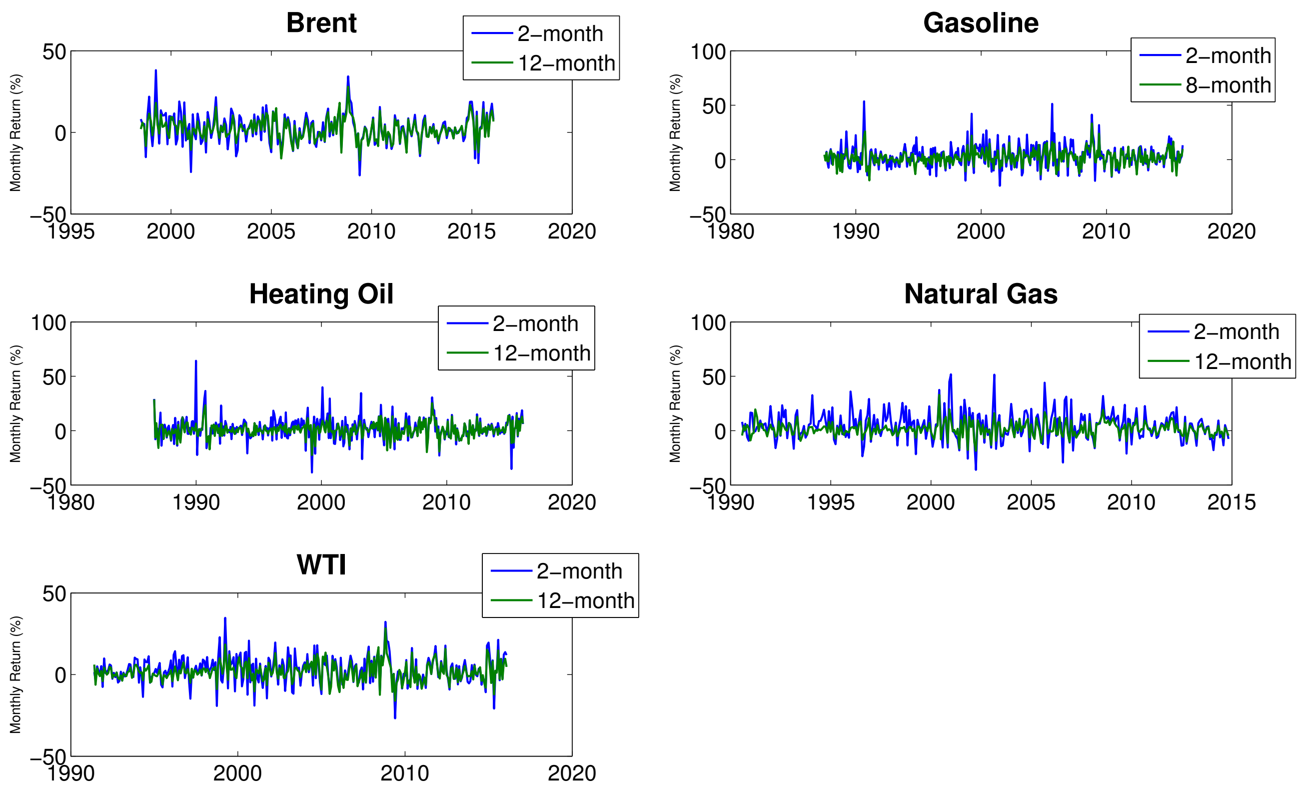

Figure 1: Time Series of Returns for the Shortest and Longest Maturity. The plots show the time-series of returns for roll yields using two futures contracts and a one-month holding period.

4.2. Statistical Behavior of Returns

The summary results of the rollover strategies for the five commodities are reported in Tables 2 - 5. The tables contain the average excess return, the volatility of excess returns, and the Sharpe ratio of different roll strategies for all five commodities. We report the results of the conditional, unconditional, contango short, and backwardation long strategies in separate tables.

To better visualize the maturity structure of returns, Figures 7 - 6 exhibit the average return, volatility, Sharpe ratio, and skewness of returns for each commodity separately. Except for natural gas, we observe a smooth maturity structure over the three major metrics (average return, volatility, and the Sharpe ratio).

Commodity	Return Measure	Horizon										
		2	3	4	5	6	7	8	9	10	11	12
Brent	$E(r)$	2.68	2.62	2.55	2.49	2.40	2.34	2.24	2.17	2.11	2.06	1.98
	$\sigma(r)$	9.23	8.72	8.38	8.07	7.82	7.57	7.36	7.18	7.01	6.84	6.74
	Sharpe Ratio	0.29	0.30	0.30	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.29
WTI	$E(r)$	2.89	2.69	2.53	2.39	2.26	2.15	2.04	1.95	1.87	1.79	1.72
	$\sigma(r)$	8.35	7.90	7.53	7.20	6.92	6.67	6.45	6.26	6.09	5.94	5.80
	Sharpe Ratio	0.35	0.34	0.34	0.33	0.33	0.32	0.32	0.31	0.31	0.30	0.30
HO	$E(r)$	2.00	1.77	1.63	1.47	1.34	1.23	1.13	1.06	1.02	0.87	0.88
	$\sigma(r)$	10.28	8.88	8.38	8.05	7.74	7.47	7.23	7.03	6.91	6.76	6.56
	Sharpe Ratio	0.19	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.15	0.13	0.13
Gasoline	$E(r)$	3.35	2.87	2.59	2.37	2.21	2.05	1.89	-	-	-	-
	$\sigma(r)$	10.22	8.96	8.15	7.62	7.26	6.96	6.80	-	-	-	-
	Sharpe Ratio	0.33	0.32	0.32	0.31	0.30	0.29	0.28	-	-	-	-
NG	$E(r)$	4.53	3.74	2.99	2.52	2.24	1.99	1.74	1.63	1.52	1.49	1.46
	$\sigma(r)$	13.21	11.44	9.97	9.07	8.50	7.96	7.47	7.01	6.79	6.55	6.51
	Sharpe Ratio	0.34	0.33	0.30	0.28	0.26	0.25	0.23	0.23	0.22	0.23	0.22

Table 2: Performance of the Conditional Strategy

4.3. Asset Pricing Behavior

A puzzling feature of commodity returns is their low and insignificant loadings on typical risk factors (including market returns) despite a reasonably high Sharpe ratio. The issue has been discussed in several papers. Ghoddusi (2012) suggests that a loading on long-run risks component is responsible for the return. Yang (2013) relates the return to shocks to the

Commodity	Return Measure	Horizon										
		2	3	4	5	6	7	8	9	10	11	12
Brent	$E(r)$	0.68	0.65	0.72	0.75	0.77	0.76	0.76	0.75	0.76	0.74	0.76
	$\sigma(r)$	9.61	9.11	8.75	8.43	8.16	7.91	7.67	7.48	7.30	7.12	7.00
	Sharpe Ratio	0.07	0.07	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.11
WTI	$E(r)$	0.23	0.35	0.42	0.44	0.45	0.46	0.46	0.44	0.42	0.40	0.40
	$\sigma(r)$	8.88	8.38	7.97	7.62	7.31	7.03	6.79	6.58	6.39	6.22	6.07
	Sharpe Ratio	0.03	0.04	0.05	0.06	0.06	0.07	0.07	0.07	0.07	0.06	0.07
HO	$E(r)$	0.93	0.45	0.45	0.49	0.50	0.48	0.46	0.46	0.50	0.41	0.45
	$\sigma(r)$	10.45	9.07	8.55	8.19	7.85	7.57	7.31	7.10	6.97	6.80	6.61
	Sharpe Ratio	0.09	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.06	0.07
Gasoline	$E(r)$	1.49	0.97	0.77	0.79	0.76	0.69	0.66	-	-	-	-
	$\sigma(r)$	10.68	9.40	8.56	7.98	7.59	7.26	7.06	-	-	-	-
	Sharpe Ratio	0.14	0.10	0.09	0.10	0.10	0.10	0.09	-	-	-	-
NG	$E(r)$	-0.70	-0.31	-0.08	-0.05	-0.11	-0.09	-0.09	-0.02	0.13	0.21	0.17
	$\sigma(r)$	14.20	12.15	10.48	9.47	8.84	8.25	7.72	7.24	6.99	6.75	6.70
	Sharpe Ratio	-0.05	-0.03	-0.01	-0.01	-0.01	-0.01	-0.01	-0.00	0.02	0.03	0.03

Table 3: Performance of the Unconditional Strategies

Commodity	Return Measure	Horizon										
		2	3	4	5	6	7	8	9	10	11	12
Brent	$E(r)$	1.06	1.05	0.98	0.94	0.88	0.86	0.81	0.78	0.74	0.73	0.68
	$\sigma(r)$	6.54	6.31	6.13	5.96	5.83	5.68	5.55	5.43	5.32	5.21	5.17
	Sharpe Ratio	0.16	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13
WTI	$E(r)$	1.41	1.25	1.14	1.06	0.99	0.92	0.87	0.83	0.80	0.77	0.74
	$\sigma(r)$	6.05	5.74	5.52	5.33	5.17	5.03	4.90	4.78	4.67	4.58	4.48
	Sharpe Ratio	0.23	0.22	0.21	0.20	0.19	0.18	0.18	0.17	0.17	0.17	0.17
HO	$E(r)$	0.64	0.77	0.70	0.60	0.52	0.48	0.44	0.41	0.37	0.34	0.32
	$\sigma(r)$	6.76	6.24	5.99	5.77	5.60	5.45	5.31	5.19	5.07	5.01	4.86
	Sharpe Ratio	0.10	0.12	0.12	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07
Gasoline	$E(r)$	1.01	1.04	0.99	0.87	0.81	0.76	0.70	-	-	-	-
	$\sigma(r)$	6.04	5.47	5.09	4.84	4.70	4.53	4.47	-	-	-	-
	Sharpe Ratio	0.17	0.19	0.20	0.18	0.17	0.17	0.16	-	-	-	-
NG	$E(r)$	2.68	2.12	1.65	1.41	1.30	1.16	1.04	0.95	0.82	0.77	0.77
	$\sigma(r)$	9.80	8.51	7.58	6.97	6.61	6.22	5.90	5.44	5.16	4.94	4.97
	Sharpe Ratio	0.27	0.25	0.22	0.20	0.20	0.19	0.18	0.17	0.16	0.16	0.16

Table 4: Performance of the Contango Short Strategies

Commodity	Return Measure	Horizon										
		2	3	4	5	6	7	8	9	10	11	12
Brent	$E(r)$	1.74	1.70	1.70	1.68	1.65	1.62	1.57	1.53	1.50	1.46	1.44
	$\sigma(r)$	6.77	6.29	5.98	5.70	5.46	5.24	5.05	4.90	4.76	4.63	4.51
	Sharpe Ratio	0.26	0.27	0.28	0.30	0.30	0.31	0.31	0.31	0.31	0.32	0.32
WTI	$E(r)$	1.64	1.60	1.55	1.49	1.44	1.39	1.33	1.28	1.23	1.18	1.14
	$\sigma(r)$	6.13	5.77	5.44	5.14	4.88	4.65	4.45	4.27	4.12	3.99	3.88
	Sharpe Ratio	0.27	0.28	0.29	0.29	0.29	0.30	0.30	0.30	0.30	0.29	0.29
HO	$E(r)$	1.57	1.22	1.15	1.08	1.03	0.96	0.90	0.87	0.87	0.75	0.77
	$\sigma(r)$	7.84	6.44	5.97	5.69	5.40	5.16	4.93	4.78	4.72	4.54	4.42
	Sharpe Ratio	0.20	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.16	0.17
Gasoline	$E(r)$	2.50	2.00	1.76	1.66	1.57	1.46	1.36	-	-	-	-
	$\sigma(r)$	8.51	7.37	6.62	6.11	5.74	5.48	5.28	-	-	-	-
	Sharpe Ratio	0.29	0.27	0.27	0.27	0.27	0.27	0.26	-	-	-	-
NG	$E(r)$	2.11	1.87	1.60	1.37	1.20	1.08	0.96	0.94	0.96	0.98	0.95
	$\sigma(r)$	9.49	8.15	6.85	6.09	5.60	5.18	4.77	4.58	4.54	4.43	4.33
	Sharpe Ratio	0.22	0.23	0.23	0.22	0.21	0.21	0.20	0.20	0.21	0.22	0.22

Table 5: Performance of the Backwardation Long Strategies

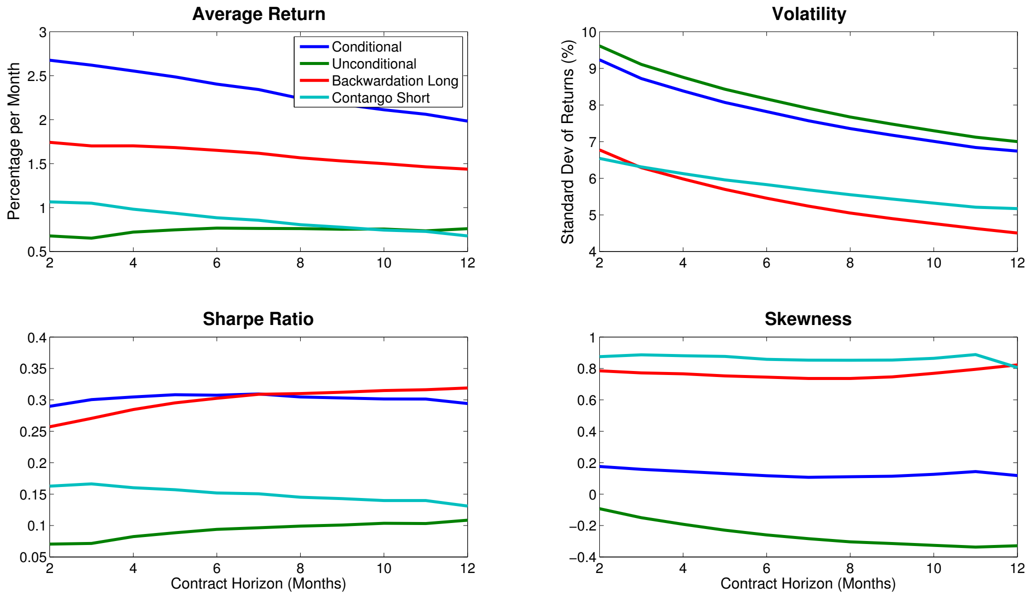

Figure 2: Maturity Structure of Brent Roll Yields

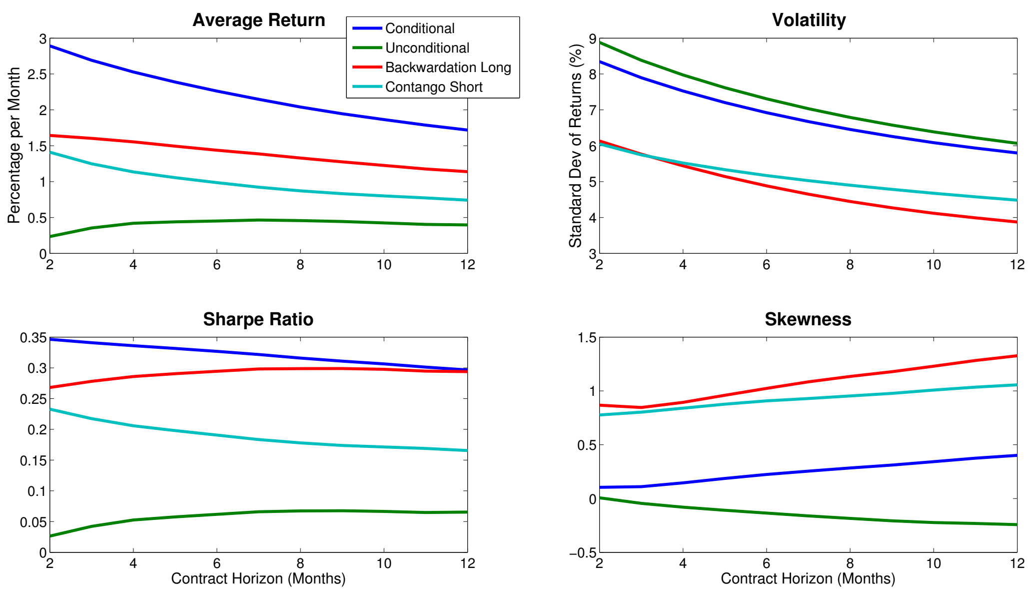

Figure 3: Maturity Structure of WTI Roll Yields

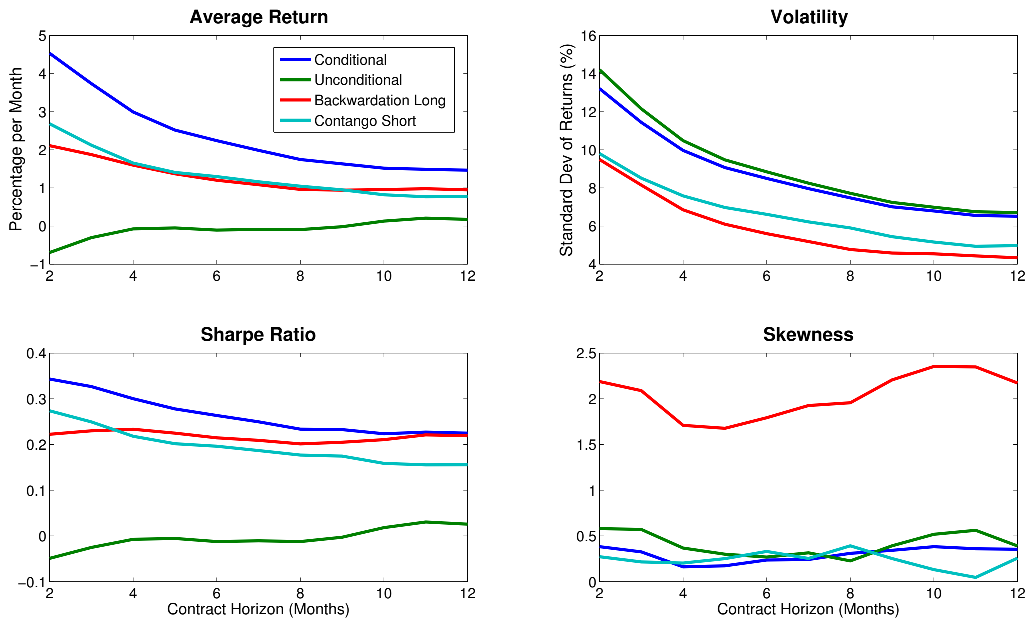

Figure 4: Maturity Structure of Natural Gas Roll Yields

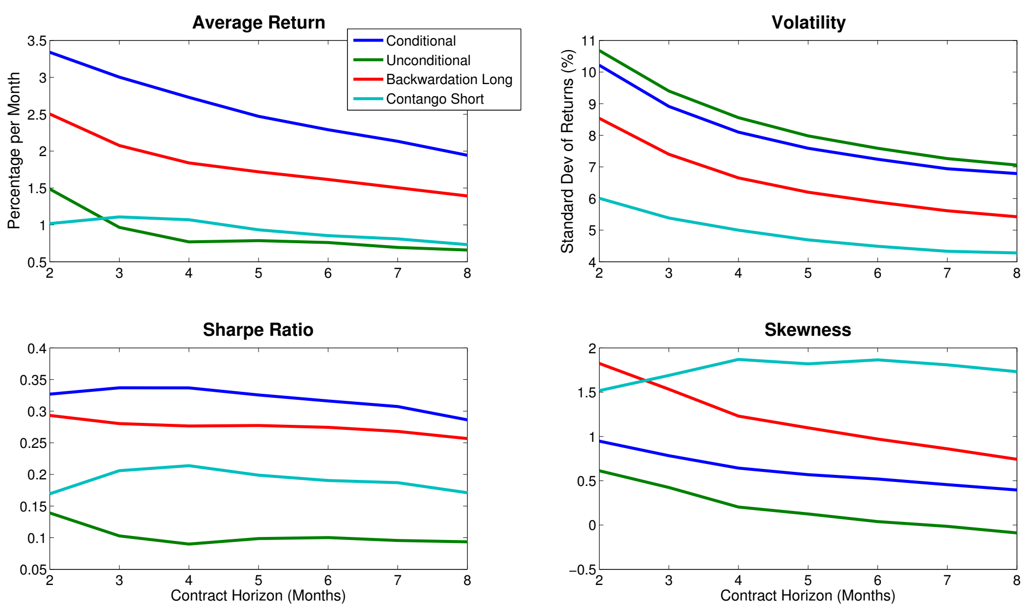

Figure 5: Maturity Structure of Gasoline Roll Yields

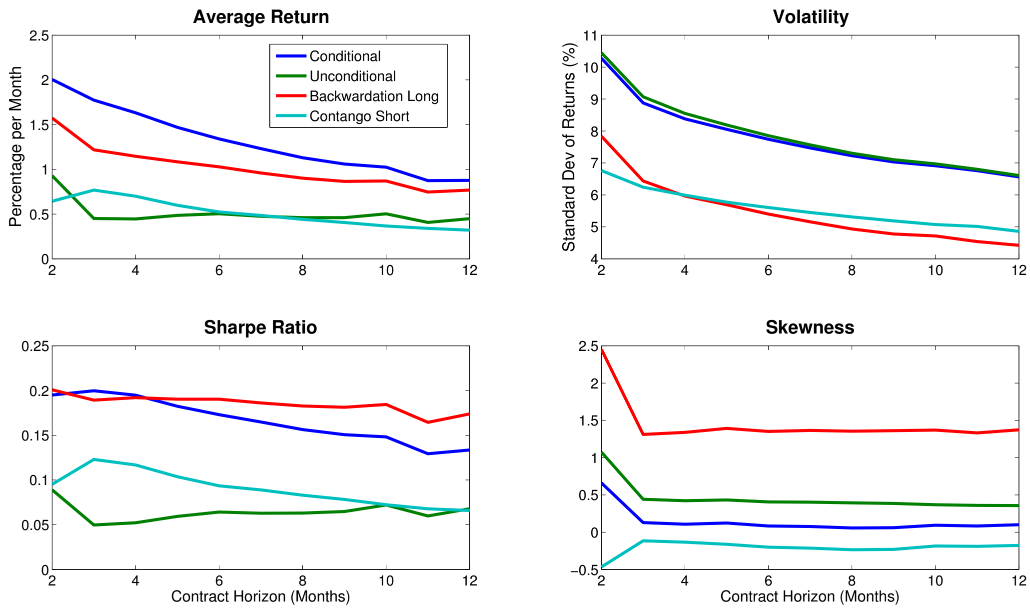

Figure 6: Maturity Structure of Heating Oil Roll Yields

relative price of investment goods. Dhume (2010) proposes adding durable to a consumption-based asset pricing model to explain cross-sectional differences.

Motived by the results in the literature, we consider the power of a three-factor CAPM model in explaining the roll returns for different horizons. Figure shows the loading of roll returns on three key Fama-French factors as well as the R^2 of returns regression. We observe that the R^2 increases with the time-to-maturity for commodities. This pattern of R^2 supports the initial conjecture that roll returns generated by investing in longer time-to-maturity futures are more connected to the macroeconomic factors.

4.4. Principle Component Analysis (PCA)

Commodity futures, even with different time horizons, are exposed to common factors. However, they are not perfectly correlated with each other. The usual practice in the commodity markets analysis is to deconstruct forward curves into a few major factors. The typical principle components are associated with the drivers of level, slope, and curvature.

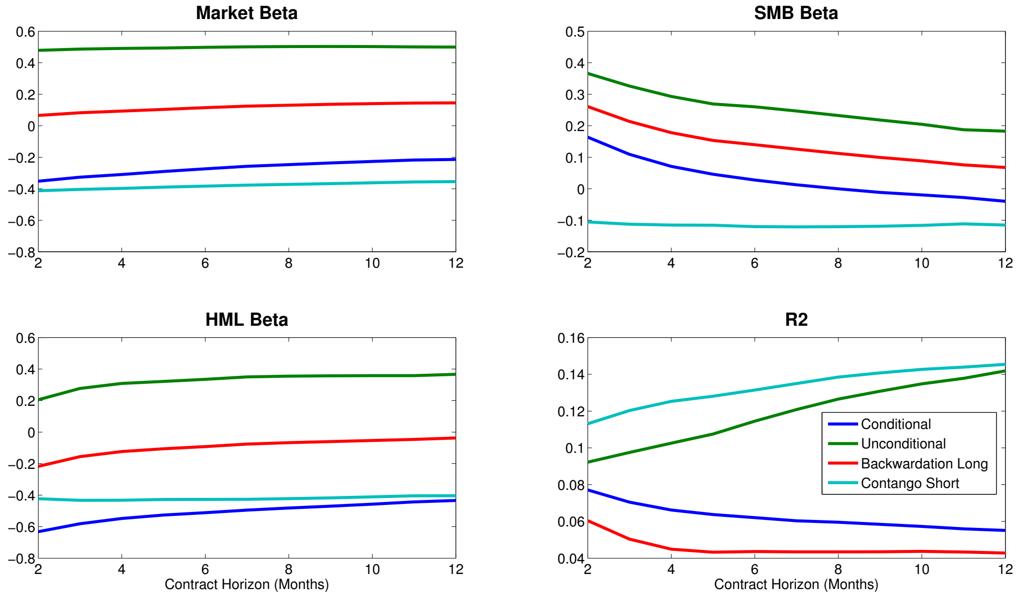

Figure 7: Factor Loadings of Brent Returns

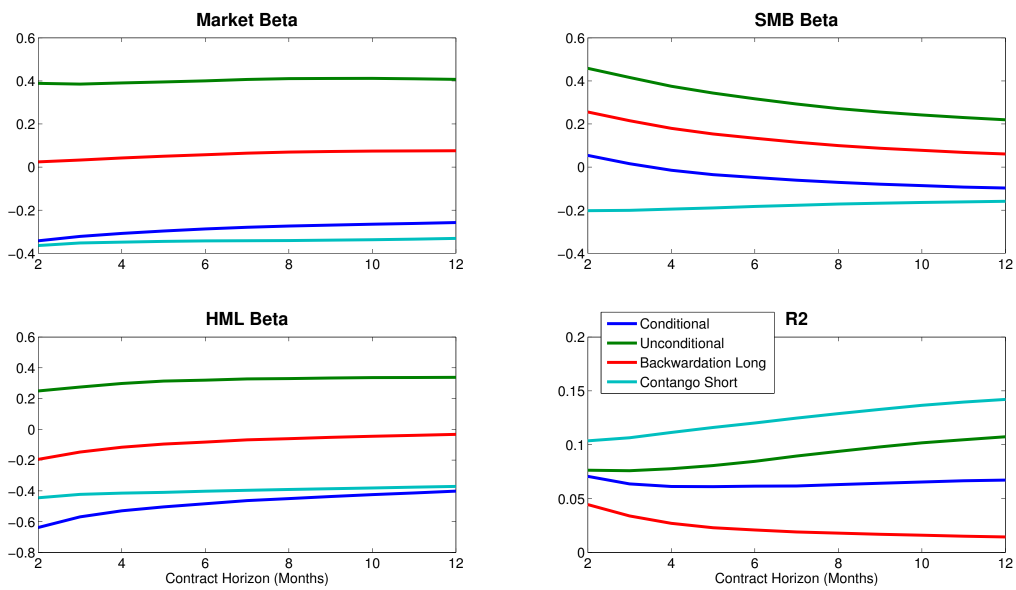

Figure 8: Factor Loadings of WTI Returns

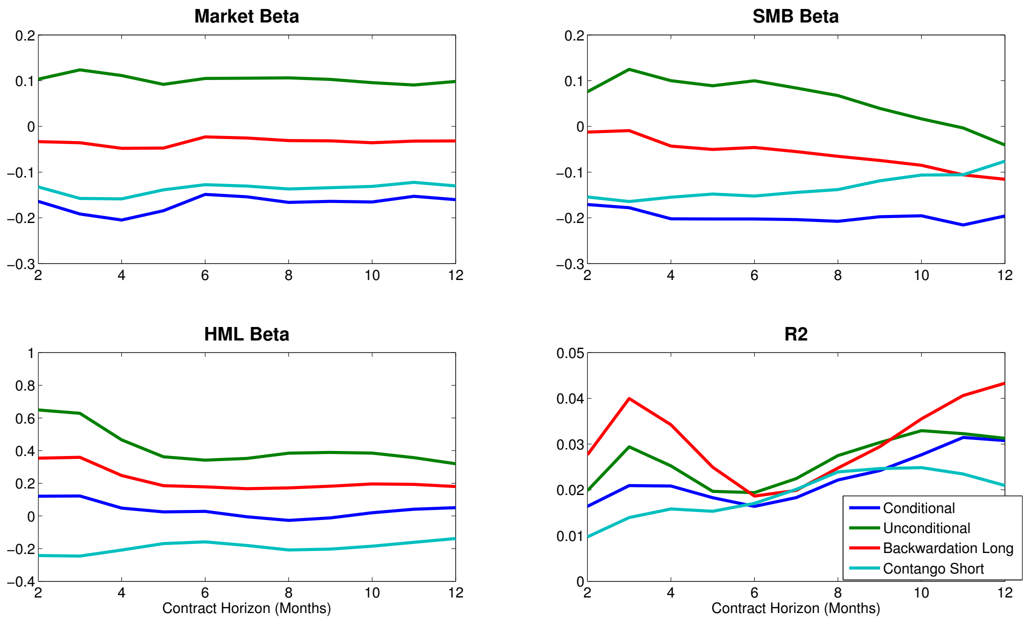

Figure 9: Factor Loadings of Natural Gas Returns

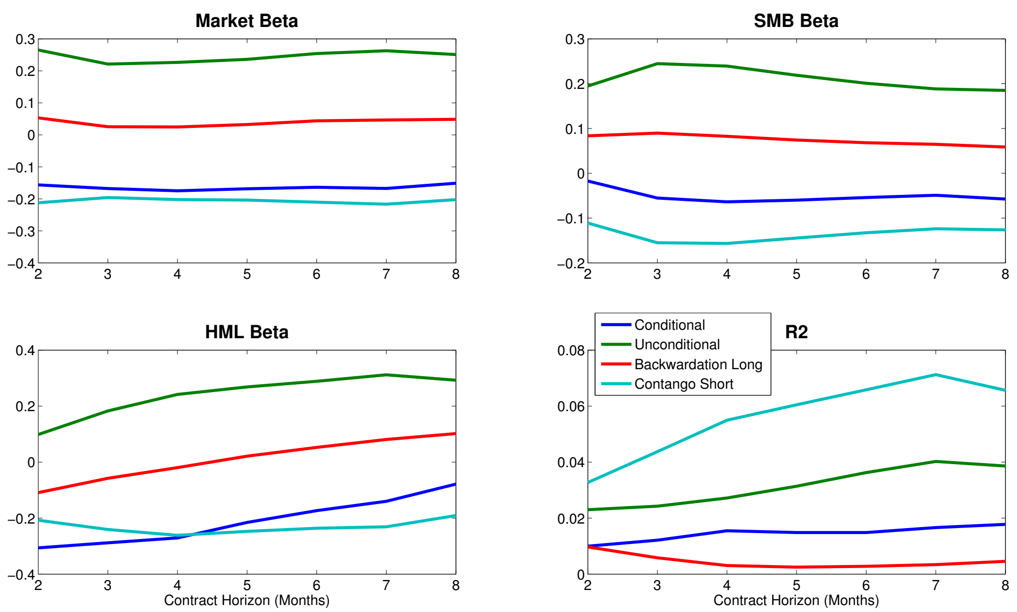

Figure 10: Factor Loadings of Gasoline Returns

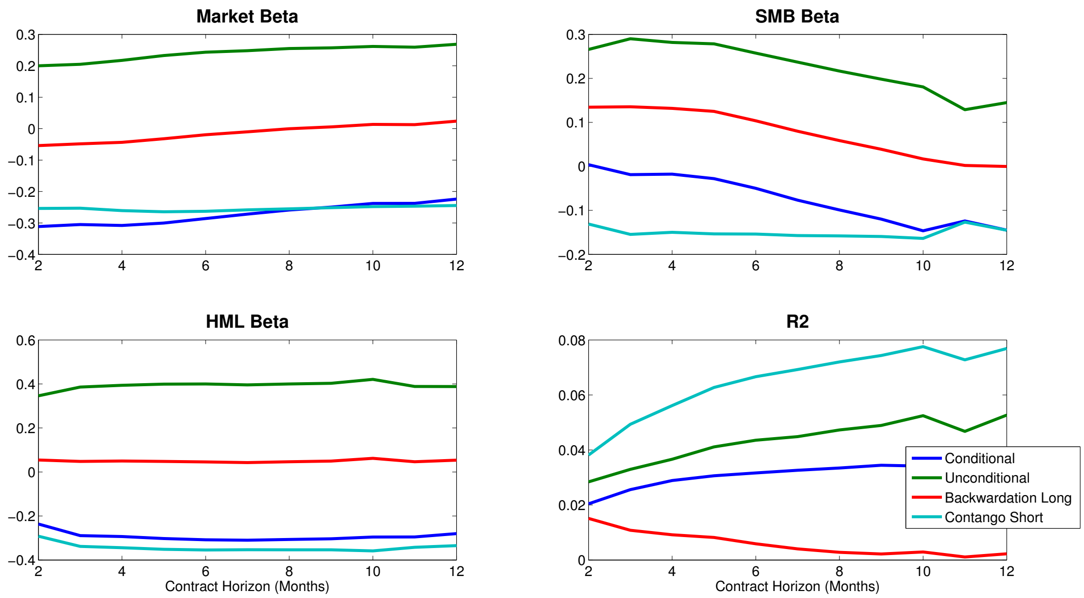

Figure 11: Factor Loadings of Heating Oil Returns

The near end of the forward curve mainly moves with the level factor; the far end of the curve is affected by all three factors of level, slope, and curvature. We will show in the principle component analysis that the level factor has the highest explanatory power in explaining variations of roll returns. However, other two factors play a role.

The PCA exercise helps us better understand the connection between roll returns over different horizons. Table 6 shows the PCA results for commodities studied in the paper. A common pattern among all commodities is that the first principle component (PC) explains a significant proportion of variation for roll returns. Except for natural gas, the first component almost entirely explains the variation.

Figure 12 shows the loadings of the first thee principle components (which together explain almost the entire variation of the maturity-structure) on each roll position. Similar to other commodity curves, the three components closely resemble the level (PC1 for all commodities), slope, and the curvature factors.

Commodity	PC1 (%)	PC2 (%)	PC3 (%)
Brent	99.0	99.9	99.9
WTI	98.5	99.9	99.9
Natural Gas	68.4	96.6	99.1
Gasoline	94.5	98.7	99.5
Heating Oil	95.5	99.2	99.8

Table 6: Principle Component Analysis (PCA) of Roll Returns. The table shows the cumulative percentage of variation explained by the first three principle components.

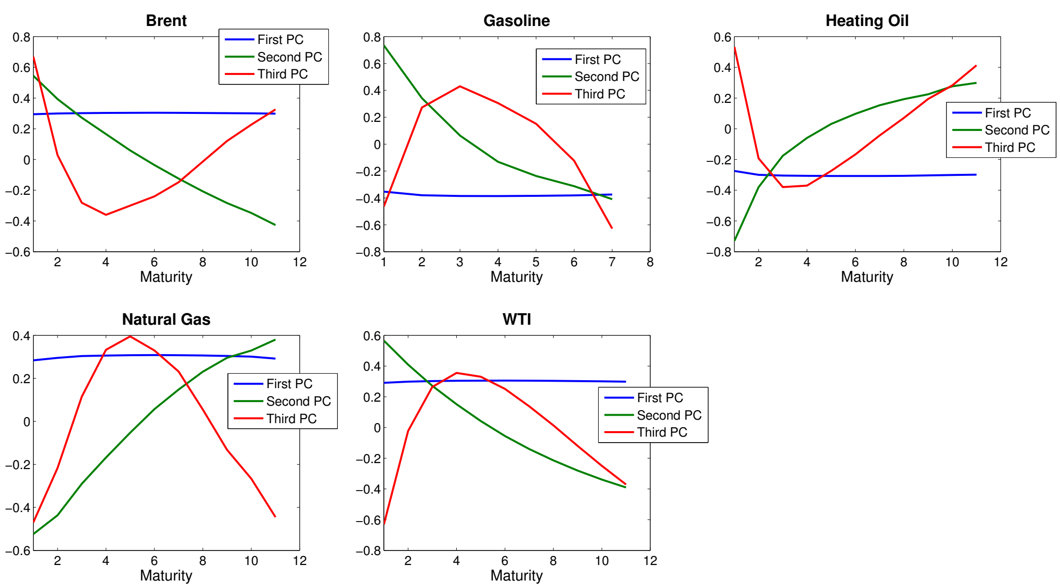

Figure 12: The Loadings of First Three Principle Components.

5. Conclusion and Future Research Directions

We report the maturity-structure of roll yields for a set of five energy commodities. The analysis of the risk/return profile and asset pricing characteristics of those roll yields suggests the following conclusions: 1) a conditional strategy, defined as taking a long position during backwardation and a short position during contango times, produces the highest Sharpe ratio; 2) near-maturity roll positions trend to deliver the highest Sharpe ratio; 3) the loading on the SMB factor decreases and loading on the HML factor increases with the time-to-maturity; 4) the volatility of roll yields smoothly decline as the time-to-maturity of the roll position increases; 5) the average Sharpe ratios associated with the five energy commodities are close to each other.

The current research can be extended in multiple directions. First, an immediate extension is to apply the framework proposed in this paper to a larger set of commodities. This extension requires a special care in the handing of the liquidity considerations for commodity markets with less liquid futures contracts. Second, the research can be replicated using higher frequency rollover strategies ? in particular rolling at the daily and weekly frequencies. A higher frequency rollover involves a higher level of transaction costs. Thus, a relevant question would be to find the optimal holding time. Third, one can examine a portfolio of roll strategies, which includes a set of rollover strategies on different commodities. The portfolio optimization problem not only considers the optimal weight of each commodity but also needs to find the *optimal roll position* for each commodity.

Since our goal in this research was to provide a big picture of the maturity structure behavior, we didn't focus on market microstructure issues. An important extension of the current work would be to consider the effect of traders' positions and trading volume on the behavior of roll strategies (see Acharya et al. (2013) and also Alizadeh and Tamvakis (2016) as a recent relevant work).

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