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Determinants of Backwardation in Oil Futures

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ABSTRACT

The paper examines the impact of oil price volatility, the behavior of the Organization of Petroleum Exporting Countries (OPEC), and the volatility of the US Dollar exchange rate on the backwardation of crude oil futures during 1995 and 2006. During the sample period, oil has witnessed strong backwardation 57% of the time and weak backwardation 67% of the time. Our empirical results of weak backwardation show that OPEC production quota and OPEC overproduction have a negative significant effect on oil backwardation, whereas the volatility of the US Dollar against the Euro has a positive significant effect on oil backwardation. As a robustness check, we repeat the regression analysis on strong backwardation and the results do not change qualitatively. The practical implication of our results is that market participants need to consider the role of OPEC and the uncertainty in US Dollar exchange rate in determining and understanding oil backwardation.

JEL Classifications: *C10, D43, G12, G13, G14*

Keywords: *oil futures; backwardation; OPEC; exchange rate volatility; oil inventory*

I. INTRODUCTION

Backwardation is a market condition in which futures prices is lower than the spot price for a certain commodity. Many studies have noted that crude oil is often backwardated; for example, Litzenberger and Rabinowitz (1995) observed that oil futures prices are often backwardated during their sample period February 1984 to April 1992; specifically, they found that strong backwardation, futures price less than the spot price, occurs 77% of the time in oil futures markets, while weak backwardation, discounted oil futures price less than the spot price, occurs 94% in the same time period. Knetsch (2007) also showed that the oil market is weakly backwardated in most cases during the period from 1992 to 2006.

Tracking backwardation is an important topic for market participants, economists and policy makers as the degree of backwardation varies over time and sometimes the reverse situation, contango, occurs;[1] thus, understanding oil backwardation is arguably relevant since it adds another source of risk for traders, consumers and producers.

Previous studies offer different explanations for oil backwardation, for example Litzenberger and Rabinowitz (1995) offered an explanation based on the option pricing theory.[2] They argued that backwardation of crude oil prices is a necessary condition for crude oil production and that the greater the uncertainty of future crude oil prices the stronger the backwardation. Other related studies on backwardation analyzed the notion of convenience yield (e.g., Kaldor, 1939; Working, 1948) and the supply/demand imbalances (e.g., Alquist and Kilian, 2010; Milonas and Henker, 2001) as potential explanations for backwardation in futures prices of storable commodities. In sum, previous studies are inexorably tied to the relationship between backwardation and volatility as well as convenience yield. Of particular interest are other potential variables that may play a role in oil backwardation such as OPEC's behavior and the US Dollar exchange rate volatility.

Horan, Peterson, and Mahar (2004) examined the behavior of crude oil implied volatility surrounding OPEC meetings, and their results showed that volatility drifts upward as the meeting approaches. On the reverse, an appreciation of the US Dollar and signs of worldwide economic slowdown led to a sharp decrease in oil price toward the end of 2008.[3] Furthermore, the US Dollar exchange rate is a key determinant of the world oil markets because most oil trades are conducted in Dollars; a stronger Dollar pushes up world oil prices measured in local currencies, even if the Dollar price is unchanged. Conversely, when the Dollar falls, OPEC members receive smaller revenues in terms of their domestic currencies, causing substantial cuts in their purchasing power.

The theory of storage suggests that the return from holding a commodity should depend on the level of physical inventories, so the oil price movement could push oil to backwardation or a contango. Symeonidis, Prokopczuk, Brooks, and Lazar (2012) studied different commodities, including crude oil and showed that low (high) inventory is associated with forward curves in backwardation (contango), as the theory of storage predicts, and that price volatility is a decreasing function of crude oil inventory and is more pronounced in backwardated markets.

In this paper, we examine the impact of oil price volatility, the behavior of the OPEC, the US Dollar exchange rate volatility, and oil inventories on the extent of weak and strong backwardation of crude oil futures during January 1995 and December 2006. These factors are believed to be important factors affecting oil backwardation; thus we hypothesize that these factors also affect the relationship between the spot and oil futures prices, since the volatility of Dollar exchange rate, OPEC policies (and deviations from them), and the level of oil inventories increase the uncertainties about future supply/demand, thus altering the connection between spot and futures prices. Studying these factors can improve our understanding of the spot-futures relation. To the authors' knowledge, there is no similar study that incorporates these factors as potential explanations for backwardation in the oil market.

The remainder of this paper is organized as follows. In Section II, we provide a more detailed review of the related literature. Section III describes the data. Section IV discusses and presents the empirical results of the potential role of oil price volatility, OPEC behavior, US Dollar exchange rate volatility, and oil inventories on the backwardation of crude oil futures. Section V concludes the analysis.

II. RELATED LITERATURE

In this section, we review the previous literatures that provide different explanations for the backwardation phenomenon in futures markets: option pricing theory, convenience yield, and supply and demand imbalances.

There are two well-known theories on the relationship between futures and spot prices; the theory of storage and the theory of normal backwardation. The theory of storage was initially developed by Kaldor (1939) and Working (1949). According to the theory of storage, the spread between contemporaneous spot and futures prices can be explained by the following factors: interest rate, cost of storage, and the convenience yield, where they used the convenience yield to explain the backwardation in futures prices. Based on the theory of storage, they argued that the relationship between the level of inventories and the net convenience yield is inversely related. Fama and French (1987) tested the theory of storage by using the data for 21 commodities (metals, agricultural, and wood products). They found that convenience yield increases for a wide variety of metals prices (e.g., aluminum, copper, and lead) during periods of increasing volatility and risk. Recently, Symeonidis, Prokopczuk, Brooks, and Lazar (2012) studied 21 different commodities traded on the major US commodity exchanges and the London Metal Exchange for the period between December 31st, 1992 and December 31st, 2011. Their analysis showed a negative relationship between inventory and the slope of the forward curve and a negative relationship between the level of inventory and the commodity price volatility, in line with the implications of the theory of storage.

Another theory for backwardation builds on the view that backwardation includes two components: the risk premium and the expected appreciation or depreciation of the future spot price. This theory views futures markets as a risk transfer mechanism between investors who are risk-averse and the commodity producers who want to hedge. Specifically, the commodity producers (i.e., the hedgers) offer a risk premium to risk-averse investors for bearing future spot risk. Kolb (1992) argued that the spread between the futures prices and the expected spot prices stem from risk premium which arises if long and/or short traders are more risk-averse than their counterparts. For example, if long hedgers are more risk averse than their counterparts, futures prices will exceed the future spot price (i.e., contango) and the long hedgers would pay the premium. On the other hand, if sellers are more risk averse than their counterparts, futures prices would lie below the expected future spot price (i.e., backwardation) and the short hedger would pay the premium.

Backwardation in crude oil prices is inconsistent with Hotelling's (1931) theory. Hotelling's rule states that under certainty the net price (i.e., price minus marginal extraction cost) of an exhaustible resource has to grow over time at the rate of interest. More specifically, the growth rate of extraction cost should be lower than that of the interest rate to have a weak backwardation. On the other hand, the model of Litzenberger and Rabinowitz (1995) counts for weak and strong backwardation even if the extraction cost grows at the rate of interest. Prior to Litzenberger and Rabinowitz (1995) theory, no model had predicted any link between backwardation and volatility. They developed a model for backwardation based on the option pricing theory. In their model, oil reserve is viewed as a call option on oil, and its call value is greater the greater the oil price volatility. They viewed backwardation as the price to pay to the producers to refrain from keeping oil in the ground and that backwardation of crude oil prices is a necessary condition for crude oil production and that the greater the uncertainty of future crude oil prices the stronger the backwardation since greater uncertainty means higher value of oil reserve (i.e., greater tendency to keep oil in the ground). To test their model, they used data for US oil production, US oil reserves, West Texas Intermediate crude oil futures, and oil options over the period from December 1986 to December 1991 and found a positive association between backwardation and implied volatility and a negative association between production and backwardation.

Carlson, Khokher, and Titman (2007) developed a general equilibrium model of the exhaustible resource market. In their model, they added the supply adjustment cost to explain backwardation observed in resource markets because they argued that uncertainty assumption alone is not enough to explain the observed price behavior of oil (i.e., backwardation). As predicted by their model, the volatility of price changes for oil and natural gas commodities is higher when the slopes of the forward curves are both downward and upward. They also showed that the volatility of price changes for these commodities is related to the amount of backwardation and contango in prices.

Using the convenience yield argument, Brennan and Schwartz (1985) as well as Gibson and Schwartz (1990) argued that the backwardation is linked to the marginal convenience yield of oil inventories. They also argued that backwardation is equal to the present value of the marginal convenience yield of the commodity inventory. Gibson and Schwartz (1990) developed a pricing model for financial and real assets contingent on the oil price based on the assumption that the convenience yield and the spot price of oil follow a joint stochastic process. They used weekly oil futures price between January 1984 and November 1988 to determine the value of the instantaneous convenience yield. They found that the marginal convenience yield is mean-reverting.

Taking into consideration the work done by Brennan and Schwartz (1985), Gibson and Schwartz (1990), and Litzenberger and Rabinowitz (1995), Considine and Larson (2001) built a model of inventory and production in which equilibrium value includes both convenience yield and option value. Their empirical results on crude oil suggest that both convenience yield and risk premium are determinant factors of crude oil backwardation. Milonas and Henker (2001) found that crude oil price spreads are affected by convenience yields and that oil spreads and convenience yields are positively related in the near-maturity contracts. They also showed that the convenience yields behave like call option.

Using the supply/demand argument, backwardation occurs when unexpected supply shortage appears, causing a short-term upward price movement. In this case, consumers pay a premium to take delivery of commodities right away to ensure a security level for the commodity thus raising the spot price directly by shifting the demand curve upward. In a recent study, Alquist and Kilian (2010) showed that the fluctuations of oil futures spread are linked to the presence of a marginal convenience yield of oil inventories. They also indicated that oil futures spread (i.e., oil futures backwardation) is directly linked to supply and demand imbalance. They showed that the fluctuations in the oil futures spread are due to the shifts in the market expectations about future oil supply shortfalls. It is also shown that, under specific assumptions, oil futures spread will decline, as the precautionary demand component of the real spot price of crude oil increases.

Another important supply side factor is the behavior of OPEC countries. OPEC uses several instruments to control the oil market. Since 1983 OPEC has announced the production quota of all its member countries in an effort to stabilize crude oil prices by controlling oil production.[4] OPEC uses eight criteria, that are oil related factors and socioeconomic, for allocating quotas.[5] Moebert (2007) found a modest influence of OPEC's capacity utilization on crude oil. His findings imply that the upward trend in the spot market can be explained by an increasing crude oil demand of emerging markets rather than OPEC's market power. In fact, he viewed OPEC as a passive observer than a price maker. The findings of Moebert (2007) were unlike Kaufmann, Dees, Karadeloglou, and Sánchez (2004) who examined the influence of OPEC's ability on the real oil prices. Their regression analysis of the real oil prices on OPEC quota (defined as the quantity of oil to be produced by OPEC members), OPEC overproduction (the quantity of oil produced minus the OPEC quota), and capacity utilization during the period of 1986-2000 showed that OPEC has an important role in determining real oil prices. Horan, Peterson, and Mahar (2004) examined the implied volatility on crude oil futures around OPEC meetings; their results showed that volatility drifts upward as the meeting approaches. Similarly, Wang, Wu, and Yang (2008) showed that realized oil futures volatility also increases in the weeks before OPEC events recommending price increases.

Another important link to consider is the exchange rate. Studies found that cointegration exists between oil prices and exchange rates, where variations in the US Dollar exchange rate are caused by the variations in oil prices (e.g., Amano and van Norden, 1998; Chaudhuri and Daniel, 1998). Other studies found the opposite to be true. Yousefi and Wirjanto (2004) examined the price reactions of OPEC member countries to changes in the exchange rate of the US dollar against other major currencies and prices of other members. They found that the increases in nominal price of oil result from a depreciation in the US Dollar.

III. DATA AND METHODOLOGY

A. Data Description

The study uses West Texas International (WTI) light, sweet crude oil futures traded on New York Mercantile Exchange (refer to contract specification; Appendix 1) to analyze the impact of oil volatility, OPEC behavior, the US Dollar exchange rate volatility, and oil inventories on oil backwardation during the period from January 1995 to December 2006. The selection of the sample period is to use more complete OPEC data that has become available starting from 1995.

Monthly data for the four shortest maturity contracts months of the West Texas International (WTI) light, sweet crude oil futures are obtained from the US Energy Information Administration website. Each contract expires on the third business day prior to the 25th calendar day of the month proceeding the delivery month. If the 25th calendar day of the month is a non-business day, trading ceases on the third business day prior to the business day proceeding the 25th calendar day. The 1-month futures contract is the nearest to maturity contract and it's time to expiration ranges from one day to thirty one days. The 2-month contract has one additional month to expiration. The 3-month has two additional months, etc. Monthly data[6] for Cushing, Oklahoma WTI spot price in Dollars per barrel and OECD commercial crude oil inventory (end of period) in million barrels are also obtained from the US Energy Information Administration.

Table 1 provides summary statistics of the of the 1-month, 2-month, 3-month, and 4-month West Texas Intermediate (WTI) light, sweet crude oil monthly futures price series from January 1995 to December 2006. It can be seen that the mean value for the futures price decreases as the month of maturity increased. Stated differently, futures prices tend to be backwardated; being higher for the far month's futures than the nearby contracts.

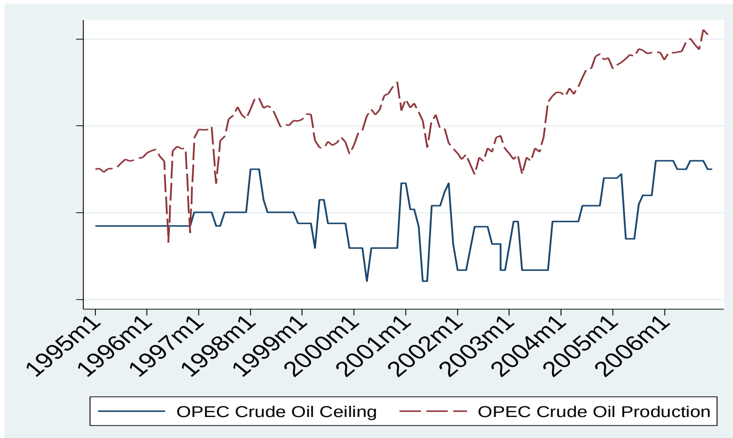
The monthly data for OPEC crude oil production ceiling allocations (quota) for its member and OPEC crude oil production in 1,000 barrel per day are all compiled from OPEC annual statistical bulletins for the years 1999-2006. Figure 1 shows that the actual OPEC monthly oil production vs. OPEC agreed quota. It can be clearly seen that OPEC oil production always exceeds the agreed production ceiling allocation. On average, the overproduction (the difference between the actual oil production and the quota) is around 3 million barrels per day, which is 12% above the average quota. We can argue that this deviation discourages current oil production and result in greater backwardation levels; this is in line with Litzenberger and Rabinowitz (1995) findings of a negative association between production and backwardation.

Table 1
Summary statistics of futures prices

	FUT(1)	FUT(2)	FUT(3)	FUT(4)
Mean	31.01	30.95	30.84	30.69
Variance	249.13	259.73	267.43	273.02
Minimum	11.31	11.64	11.95	12.23
Maximum	74.46	75.71	76.44	76.95
Skewness	1.21	1.27	1.32	1.36
Kurtosis	3.43	3.52	3.60	3.68

The table provides descriptive statistics for the 1-month, 2-month, 3-month, and 4-month West Texas Intermediate (WTI) light, sweet crude oil futures price series from January 1995 to December 2006.

Figure 1
OPEC crude oil production and quota



The figure shows the monthly crude oil production by the Organization of Petroleum Exporting Countries (OPEC), measured in 1,000 barrel/day and OPEC crude oil production ceiling, measured in 1,000 barrel/day, during the period from January 1995 to December 2006

The monthly interest rate of the three-month Treasury bill is obtained from the Board of Governors of the Federal Reserve System database.[7] The monthly exchange rate for the US Dollar against the Euro is obtained from OANDA historical database for exchange rate.[8] Appendix 2 provides a description of our variables and their data source.

B. Measuring Volatility

We use the GARCH (1,1)[9] model to measure the volatility (σ_n^2) of the WTI futures prices, in which σ_n^2 is calculated from a long-run average variance rate, V_L, σ_{n-1}, and u_{n-1}. The GARCH (1,1) model can be represented as follows

$$\sigma_n^2 = \gamma V_L + \alpha u_{n-1}^2 + \beta \sigma_{n-1}^2 \tag{1}$$

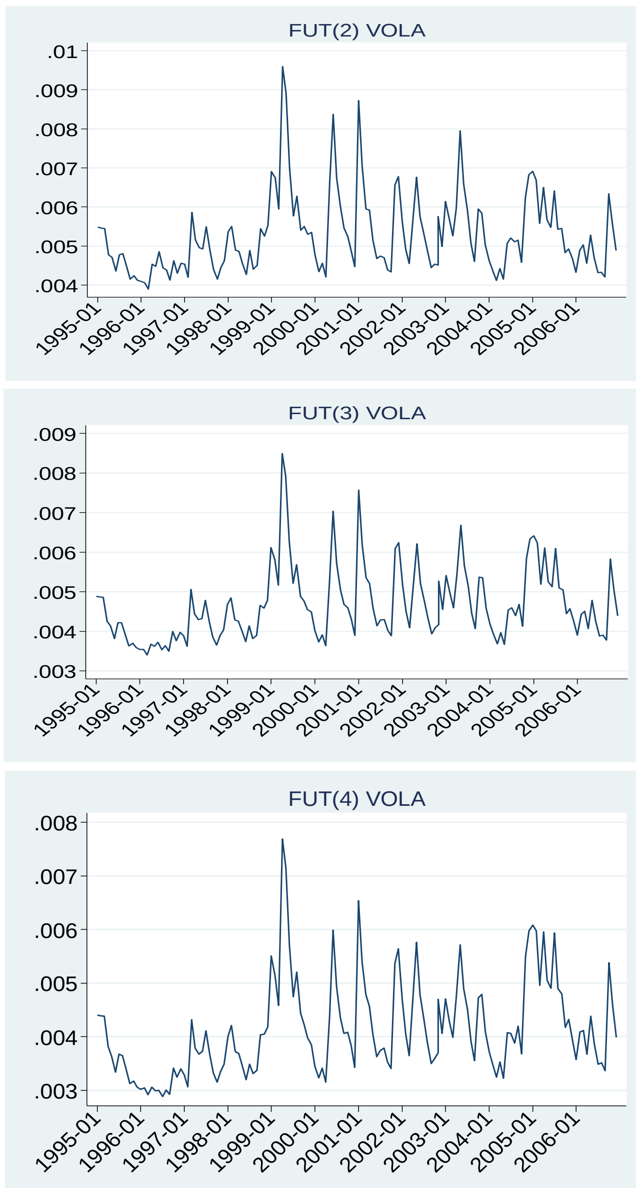
where γ is the weight assigned to V_L, α is the weight assigned to u_{n-1}^2, and β is the weight assigned to σ_{n-1}^2, such that $\gamma+\alpha+\beta=1$. In fact, the EWMA model is a particular case of GARCH(1,1) where $\gamma=0$, $\alpha=1-\lambda$, and $\beta=\lambda$. The GARCH(1,1) model also can be written as
\

$$\begin{aligned} \Delta P_t &= \kappa + \theta \Delta P_{t-1} + u_t \\ \sigma_n^2 &= \omega + \alpha u_{n-1}^2 + \beta \sigma_{n-1}^2 \end{aligned} \tag{2}$$

where $\omega=\gamma V_L$ and $\alpha+\beta<1$, to ensure the long variance is positive.

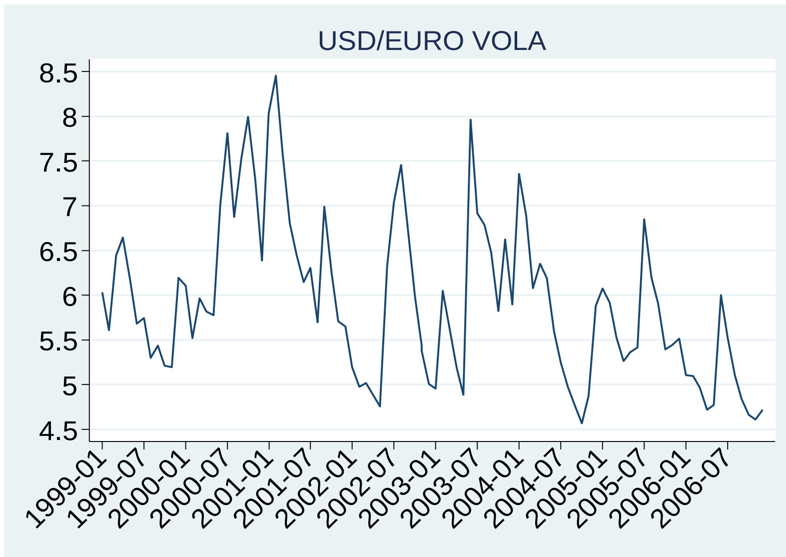
The monthly GARCH (1, 1) volatility of the 2-, 3-, and 4- month futures contracts are calculated using the daily 2-, 3-, and 4- month futures prices obtained from the US Energy Information Administration. The monthly volatilities for all the contracts are shown in Figure 2.

Figure 2
The GARCH (1, 1) volatility of the 2-, 3-, and 4- month futures contracts from January 1995 to December 2006



We also use GARCH approach to estimate the monthly volatility for the Dollar exchange rate against Euro using the daily exchange rates. Figure 3 shows the estimated monthly currency volatility for the US Dollar exchange rate against Euro.

Figure 3
Currency volatility for the US Dollar exchange rate against Euro from January 1995 to December 2006



C. Regression Analysis

To study the factors that affect the oil backwardation, we use monthly regression with standard errors adjusted using Newey-West approach, where the dependent variable is the weak backwardation in the n-month WTI futures contract and the independent variables include: WTI futures price volatility, OPEC quota and their overproduction above the production quota, US Dollar exchange rate volatility, and oil inventory levels. Specifically, the following regression[10] analysis is applied:

$$WB(n)_t = \alpha_0 + \alpha_1 VOLA(n)_t + \alpha_2 QUOTA_t + \alpha_3 OVER_t + \alpha_4 USD/EURO_t + \alpha_5 INVT_t + \varepsilon_t, \quad n = 2, 3, \text{and } 4 \tag{3}$$

where $WB(n)_t$ is weak backwardation defined as the spot price being higher than the discounted futures price as: $WB(n)_t = SPOT_t - e^{-r_t n} FUT(n)_t$ where $SPOT_t$ is the price of the 1-month futures contract (which is used as a proxy for the spot price), $FUT(n)_t$ is the price of the n-th month futures contract, r is the 3-month Treasury bill, n refers to the n-th month futures contract and t is the time frequency in the time series model.

As for the independent variables: $VOLA(n)_t$ is the standardized volatility of the n-th month futures contract measured using GARCH (1,1), $QUOTA_t$ is OPEC crude oil production allocation to its members, $OVER_t$ is OPEC overproduction rate by its members as actual production minus $QUOTA_t$. Both $OVER_t$ and $QUOTA_t$ are used to study the effect of OPEC on oil backwardation. $USD/EURO_t$ is the volatility of the US Dollar exchange rate against Euro measured using GARCH(1,1), and $INVT_t$ is OECD commercial crude oil inventory (end of period).

Table 2 shows the descriptive summary of oil backwardation for the 2-month, 3-month, and 4-month futures contract. It can be seen that backwardation is higher for the far month's futures contracts than that of the nearby futures contracts. This is applicable for both weak and strong backwardation. For example, the level of strong backwardation of 2-month futures contract is $0.06, while the strong backwardation level for the 3-month and 4-month futures are $0.17 and $0.31, respectively. Similarly, the values of weak backwardation are $0.25, $0.45, and $0.69 for the 2-month, 3-month, and 4-month futures contracts, respectively. The table also shows that oil futures contracts are, on average, strongly backwardated 57% of the time and weakly backwardated 67% of the time during the period from January 1995 to December 2006.

Table 2
Summary statistics of oil backwardation

	FUT(2)	FUT(3)	FUT(4)
Strong backwardation ($)			
Mean	0.06	0.17	0.31
Variance	0.45	1.34	2.37
Minimum	-1.78	-3.02	-3.97
Maximum	2.08	3.31	4.04
Skewness	-0.24	-0.31	-0.36
Kurtosis	3.48	3.24	3.08
Weak backwardation ($)			
Mean	0.25	0.45	0.69
Variance	0.38	1.13	1.98
Minimum	-1.28	-2.25	-2.94
Maximum	2.25	3.56	4.36
Skewness	0.18	0.05	-0.01
Kurtosis	3.36	3.06	2.85
Fraction of the Time in Backwardation (in%)			
SB	54.86	54.94	61.81
WB	65.28	66.67	69.44

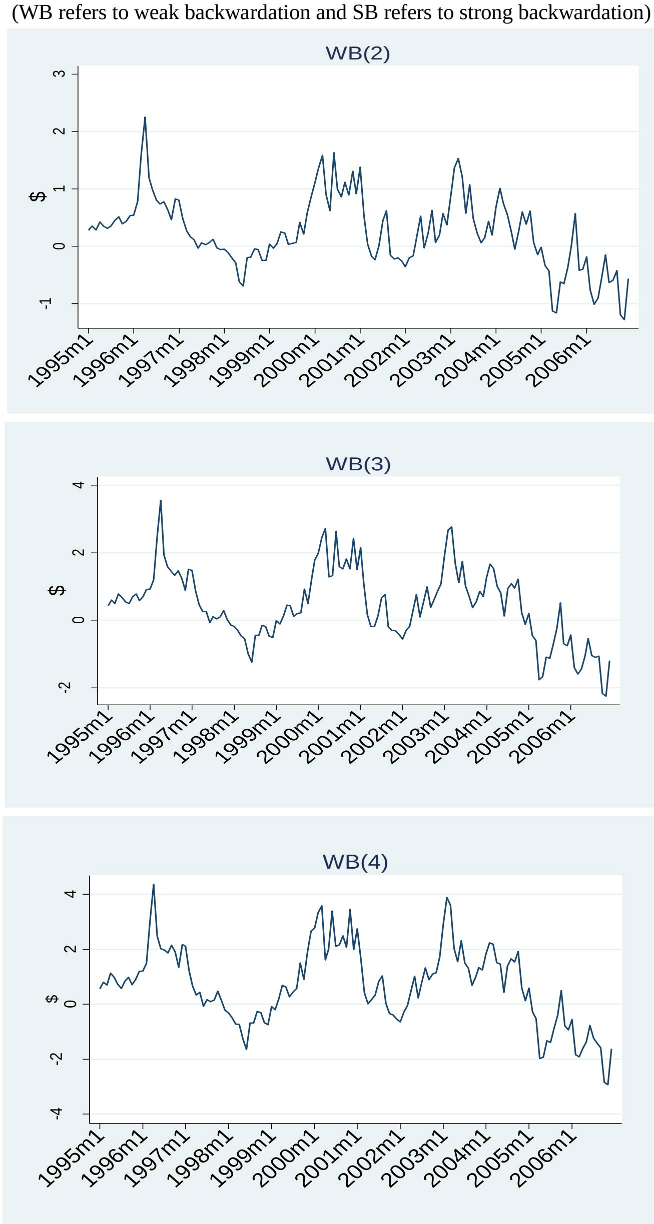
The table reports a summary statistics of the strong and weak backwardation of the 2-month, 3-month, and 4-month West Texas Intermediate (WTI) light, sweet crude oil futures price series from January 1995 to December 2006. Strong backwardation (SB) is defined as the difference between the spot price and the futures price, $SB(n)_t = SPOT_t - FUT(n)_t$, where $SPOT_t$ is the price of the 1-month futures contract, used as a proxy for the spot price, $FUT(n)$ is the price of the n-th month futures contract. Weak backwardation (WB) is defined as the spot price being higher than the discounted futures price as: $WB(n)_t = S_t - e^{-r_t n} FUT(n)_t$, where r is the 3-month Treasury bill.

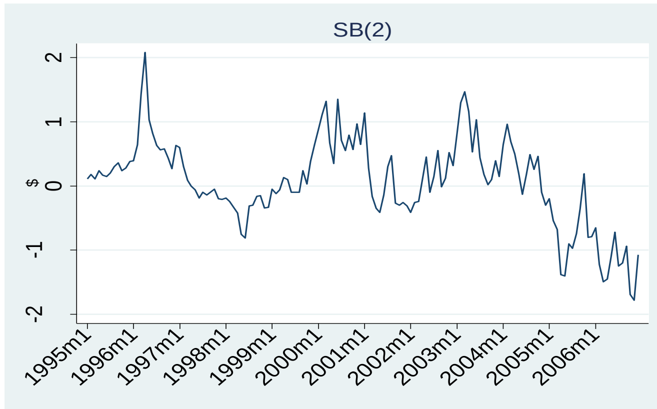
Figure 4 displays the weak backwardation of the 2-, 3- and 4-month WTI futures contracts. As shown from the figure, the market experiences backwardation between 1995 and 2006. However, there were two periods in which oil futures did experience some long duration of contango during the sample study period. The first period lasted

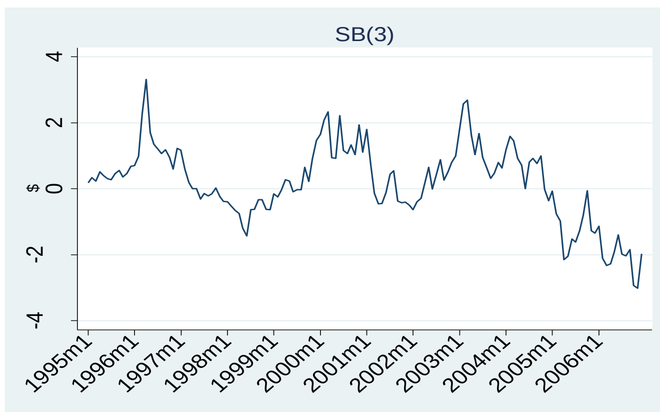
Figure 4

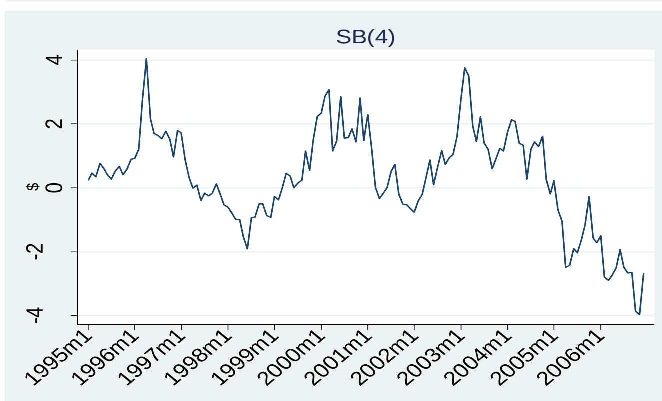
Weak and strong backwardation in the 2, 3 and 4 month WTI futures

(WB refers to weak backwardation and SB refers to strong backwardation)









around 12 months in 1998 and was associated with a declining trend of crude oil prices, which is consistent with the conventional wisdom that in periods of contango, oil producers accumulate inventories which would result in pushing the price of oil for immediate delivery to go down. The second period was after February 2005 and was associated with an upward trend in oil prices despite of the rise of inventories.

IV. RESULTS AND DISCUSSIONS

A. Regression Analysis of Weak and Strong Backwardation

The correlation matrix among the weak backwardation for the 2-month, 3-month and 4-month futures and oil price volatility, OPEC quota, OPEC overproduction, US Dollar exchange rate volatility, and oil inventories is reported in Table 3. The correlation matrix shows that all pairs of control variables do not raise concerns for multicollinearity in the multiple regression analysis as the highest correlation coefficient between the explanatory variables is 0.34.[11]

Table 3
Correlation matrix for the weak backwardation

	WB(2)	VOLA(2)	QUOTA	OVER	USD/EURO	INVT
WB(2)	1.00					
VOLA(2)	-0.03	1.00				
QUOTA	-0.45[a]	-0.06	1.00			
OVER	-0.21[a]	0.11	-0.15[c]	1.00		
USD/EURO	0.38[a]	0.15[c]	-0.26[a]	-0.04	1.00	
INVT	-0.71[a]	0.12	0.34[a]	0.09	-0.18[b]	1.00
	WB(3)	VOLA(3)	QUOTA	OVER	USD/EURO	INVT
WB(3)	1.00					
VOLA(3)	-0.11	1.00				
QUOTA	-0.49[a]	-0.01	1.00			
OVER	-0.19[b]	0.16[c]	-0.15[c]	1.00		
USD/EURO	0.37[a]	0.10	-0.26[a]	-0.04	1.00	
INVT	-0.74[a]	0.18[b]	0.34[a]	0.09	-0.18[b]	1.00
	WB(4)	VOLA(4)	QUOTA	OVER	USD/EURO	INVT
WB(4)	1.00					
VOLA(4)	-0.18[b]	1.00				
QUOTA	-0.50[a]	0.05	1.00			
OVER	-0.16[c]	0.22[b]	-0.15[c]	1.00		
USD/EURO	0.37[a]	0.05	-0.26[a]	-0.04	1.00	
INVT	-0.75[a]	0.22[a]	0.34[a]	0.09	-0.18[b]	1.00

The table reports the correlation matrix between the dependent variables: the monthly weak backwardation for n-th month of the WTI futures contract, WB(n) and the independent variables: the GARCH volatility of the n-th month futures contract, VOLA(n), OPEC crude oil production allocation to its members, QUOTA, OPEC overproduction rate by its members, OVER, the volatility of the US Dollar exchange rate against Euro, USD/EURO, and the OECD commercial crude oil inventory, INVT. More variable details are available in Appendix 2. The monthly data are from January 1995 through December 2006. The notations a, b and c refer to significance at 1, 5 and 10% level, respectively.

The regression results of monthly weak backwardation for the 2-month, 3-month and 4-month futures on oil price volatility, OPEC quota, OPEC overproduction, US Dollar exchange rate volatility, and oil inventories are displayed in Table 4. The extent of weak backwardation is used as a dependent variable in a regression analysis since weak backwardation occurs more frequently than strong backwardation (see Table 2).

The regressions of weak backwardation for the 2-month, 3-month and 4-month futures generally produce qualitatively similar results. It can be seen, the coefficient of $VOLA_t$ is positive yet not significant in the 2-month regression. The positive association between weak backwardation and volatility is consistent with the prediction of Litzenberger and Rabinowitz (1995) theory.

Table 4
Regression analysis of weak backwardation

	WB(2)			WB(3)			WB(4)		
VOLA	11.05			0.80			-13.27		
	(0.32)			(0.01)			(-0.14)		
QUOTA	-0.08[a]	-0.08[a]	-0.10[a]	-0.16[a]	-0.16[a]	-0.19[a]	-0.22[a]	-0.22[a]	-0.25[a]
	(-3.69)	(-3.73)	(-3.50)	(-4.50)	(-4.51)	(-4.01)	(-4.63)	(-4.67)	(-4.15)
OVER	-0.06[b]	-0.06[b]	-0.06[b]	-0.09[c]	-0.09[c]	-0.10[c]	-0.09	-0.09	-0.10
	(-2.04)	(-2.00)	(-1.98)	(-1.86)	(-1.83)	(-1.83)	(-1.49)	(-1.48)	(-1.51)
USD/EURO	0.017[b]	0.18[b]		0.28[b]	0.28[b]		0.36[b]	0.36[b]	
	(2.48)	(2.52)		(2.40)	(2.43)		(2.33)	(2.35)	
INVT	-0.40[a]	-0.40[a]	-0.41[a]	-0.72[a]	-0.72[a]	-0.74[a]	-0.97[a]	-0.98[a]	-1.00[a]
	(-8.54)	(-8.74)	(-8.76)	(-9.76)	(-9.93)	(-9.88)	(-10.30)	(-10.32)	(-10.26)
CONS	12.00[a]	11.99[a]	13.86[a]	22.00[a]	21.99[a]	24.97[a]	29.82[a]	29.87[a]	33.65[a]
	(9.65)	(9.68)	(12.52)	(11.40)	(11.47)	(14.71)	(11.88)	(12.00)	(15.20)
R^2 ADJ(%)	61.21	61.45	57.62	66.01	66.31	63.02	67.29	67.52	64.49

The table reports the regression results adjusted to Newey-West. The dependent variables WB(n) are the monthly weak backwardation for n-th month of the WTI futures contract. The independent variables include: the GARCH volatility of the n-th month futures contract, VOLA(n), OPEC crude oil production allocation to its members, QUOTA, OPEC overproduction rate by its members, OVER, the volatility of the US Dollar exchange rate against Euro, USD/EURO, and the OECD commercial crude oil inventory, INVT. More variable details are available in Appendix 2. The monthly data are from January 1995 through December 2006. The t-values are given in parentheses. The notations a, b and c refer to significance at 1, 5 and 10% level, respectively.

The coefficients of $QUOTA_t$ are negatively significant for all contracts. This suggests that the greater the level of OPEC quota the lower the level of backwardation as an increase in the quota variable tends to reduce oil price. In other words, an increase in the quota tends to put a downward pressure on prices. As for the effect of OPEC on oil backwardation, the coefficients of OPEC overproduction are negative for all contracts and significant for 2-month and 3-month contracts. This suggests that the greater the level of OPEC overproduction the lower the level of backwardation as an increase in the OPEC overproduction tends to reduce oil price. This result is consistent with the fundamentals of the supply/demand balance. Put differently, the increased uncertainty about the future supply of OPEC members due to the deviation from the allocated production ceiling results in a lower backwardation level.

As for the US Dollar exchange volatility, we expect that the extent of backwardation is greater the greater the Dollar exchange volatility. As can be seen from Table 4, the USD/EURO coefficients are positively significant at 5% in all specifications and for all futures contracts. That is to say, as the volatility of the US Dollar against the Euro increases, the level of weak backwardation increases too.

As for oil inventories; the theory of storage suggests that high volumes of inventory lowers the level of backwardation and even sustain a deep contango. As can be seen from Table 4, the oil inventory coefficients are negative and significant for all contracts. This finding is also consistent with the prior work by Fort and Quirk (1988) who stated that "one possible explanation for backwardation is the high correlation between cash and futures prices when inventories of a commodity are large". The results are robust, as different regression specifications produce virtually the same results.

As a robustness check, we repeat the analysis by analyzing the effect of oil volatility, OPEC quota, OPEC overproduction, the volatility of US Dollar exchange rate, inventory level, and spot price changes on the extent of strong backwardation.

$$\begin{aligned} SB(n)_t &= \alpha_0 + \alpha_1 VOLA(n)_t + \alpha_2 QUOTA_t + \alpha_3 OVER_t + \alpha_4 USD/EURO_t \\ &+ \alpha_5 INVT_t + \varepsilon_t, \quad n = 2, 3, \text{ and } 4 \end{aligned} \tag{4}$$

where $SB(n)_t$ is strong backwardation defined as the spot price being higher than the futures price as:

$$SB(n)_t = SPOT_t - FUT(n)_t > 0$$

where $SPOT_t$ is the price of the 1-month futures contract (which is used as a proxy for the spot price) and $FUT(n)_t$ is the price of the n-th month futures contract.

The results do not change qualitatively implying that the results are robust. The coefficients of OPEC overproduction, OPEC Quota, and inventory are significantly negative for all contracts and for all specifications. Further, the coefficients of US Dollar against the Euro are significantly positive.

Table 5
Regression analysis of strong backwardation

	SB(2)			SB(3)			SB(4)		
VOLA	21.30			24.49			20.19		
	(0.69)			(0.41)			(0.22)		
QUOTA	-0.13[a]	-0.13[a]	-0.15[a]	-0.23[a]	-0.23[a]	-0.26[a]	-0.31[a]	-0.31[a]	-0.35[a]
	(-5.30)	(-5.29)	(-4.53)	(-5.71)	(-5.69)	(-4.79)	(-5.72)	(-5.73)	(-4.85)
OVER	-0.08[a]	-0.08[a]	-0.09[b]	-0.13[b]	-0.12[b]	-0.13[b]	-0.14[b]	-0.14[b]	-0.15[b]
	(-2.73)	(-2.68)	(-2.63)	(-2.45)	(-2.40)	(-2.37)	(-2.11)	(-2.06)	(-2.06)
USD/EURO	0.18[a]	0.19[a]		0.29[b]	0.30[b]		0.38[b]	0.38[b]	
	(2.53)	(2.64)		(2.43)	(2.50)		(2.35)	(2.40)	
INVT	-0.40[a]	-0.40[a]	-0.41[a]	-0.72[a]	-0.72[a]	-0.74[a]	-0.98[a]	-0.97[a]	-1.00[a]
	(-8.16)	(-8.23)	(-8.12)	(-9.10)	(-9.12)	(-8.97)	(-9.49)	(-9.35)	(-9.20)
CONS	12.89[a]	12.88[a]	14.85[a]	23.47[a]	23.43[a]	26.57[a]	31.94[a]	31.88[a]	35.90[a]
	(10.42)	(10.40)	(12.57)	(11.75)	(11.71)	(13.97)	(12.04)	(11.98)	(14.05)
R^2 ADJ(%)	65.67	65.82	62.22	68.88	69.01	65.90	69.52	69.73	66.86

The table reports the regression results adjusted to Newey-West. The dependent variables SB(n) are the monthly strong backwardation for n-th month of the WTI futures contract. The independent variables include: the GARCH volatility of the n-th month futures contract, VOLA(n), the OPEC crude oil production allocation to its members, QUOTA, the OPEC overproduction rate by its members, OVER, the volatility of the US Dollar exchange rate against Euro, USD/EURO, and the OECD commercial crude oil inventory, INVT. More variable details are available in Appendix 2. The monthly data are from January 1995 through December 2006. The t-values are given in parentheses. The notations a, b and c refer to significance at 1, 5 and 10% level, respectively.

V. CONCLUSION

Understanding oil backwardation arguably is relevant since the varying degree of backwardation adds another source of risk for traders, consumers and producers. This paper shows that oil futures generally exhibit backwardation. Specifically, it shows that oil futures are strongly and weakly backwardated 57% and 67% of the time, respectively, during the period from January 1995 to December 2006. The paper also finds that the level of backwardation is higher for the far-month-futures contracts than that of the nearby futures contracts.

We further examine the influence of oil price volatility, the behavior of OPEC, the volatility of US Dollar exchange rate, and oil inventories on the extent of weak and strong backwardation of crude oil futures during January 1995 - December 2006. Both

OPEC behavior and the volatility of the Dollar exchange rate are believed to be important factors affecting oil backwardation. The regression results show that OPEC behavior significantly affects the relation between spot and futures prices of oil. More specifically, the paper finds that OPEC production quota imposed on its members has a significant negative effect on weak and strong backwardation. It also finds that OPEC member's overproduction has a negative significant effect on oil backwardation. Put differently, the increased uncertainty about the future supply of OPEC members due to the deviation from the allocated production ceiling, which often results in a decline of oil prices, leads to lowering the backwardation level.

The weak and strong backwardation regression results show that the coefficient of the volatility of US Dollar exchange rate against the Euro is positively significant. The regression analysis shows negative association between weak backwardation and oil inventories in all specifications which is consistent with the theory of storage.

The practical implication of our analysis is that market participants, economists and policy makers need to consider the role of OPEC behavior and uncertainty in US Dollar exchange rate in determining and understanding oil backwardation.

ENDNOTES

1. The period from late 2006 to 2013 witnessed a contango; the opposite of backwardation as it occurred 70% of the time in oil futures markets during that period. Since then it returned to backwardation.
2. The earliest option pricing model that derives a closed-form solution for option is the Black and Scholes (1973).
3. For example, in 1997, when the world economy was already in a recession, OPEC failed to predict oil demand correctly and increased its production levels that resulted in a huge decrease in oil prices. In June-July 2008, a combination of supply uncertainties in oil producing countries and a falling US Dollar caused an unprecedented oil price spike.
4. Over the years, the OPEC quota system has essentially never worked for different reasons; 1) OPEC has no way to enforce compliance by its members; 2) There were always member's dissatisfied with their assigned quotas; and 3) Oil production by OPEC members generally exceeded the production ceiling.
5. These factors include: oil reserves, production capacity, historical production share, domestic oil consumption, population, dependence on oil exports, and external debt.
6. Data on total inventory level in the world is not available at the monthly level. OPEC only reports crude oil inventory at the end of the year. It should be also noted that OPEC crude oil reserves as percentage of the total world crude oil reserves was 77% on average during the sample period.
7. Refer to: http://www.federalreserve.gov
8. The monthly futures return and US Dollar exchange rate against the Euro return are computed as: $R_t = \ln(P_t / P_{t-1})$, where P_t is the futures price/exchange rate price at time t, P_{t-1} is the price at time t-1.
9. Hansen and Lunde (2005) found no evidence that a GARCH (1,1) model is outperformed by more sophisticated models (330 ARCH-type models) in their analysis of exchange rates.

10. To check for balanced regression, we perform Augmented Dickey Fuller (ADF) test and we find that the dependent variable and all the independent variables are stationary. Thus a balanced regression is satisfied.
11. Pallant (2007) indicated that any correlation above 0.7 definitely indicates problems with multicollinearity.

APPENDIX 1

WTI futures contract specifications

Trading hour	Monday – Friday 9:00 AM to 2:30 PM (8:00 AM to 1:30 PM CT)
Contract Unit	1,000 barrels
Price Quotation	U.S. Dollars and Cents per barrel
Price Fluctuation	Minimum: $0.01per barrel Maximum Daily Price: Initial Price Fluctuation Limits for All Contract Months. At the commencement of each trading day, there shall be price fluctuation limits in effect for each contract month of this futures contract of $10.00 per barrel above or below the previous day's settlement price for such contract month.
Listed Contracts	Crude oil futures are listed nine years forward
Settlement Type	Physical
Delivery	Delivery shall be made free-on-board ("F.O.B.") at any pipeline or storage facility in Cushing, Oklahoma with pipeline access to Enterprise, Cushing storage or Enbridge, Cushing storage.

Source: CME Group web site: http://www.cmegroup.com/trading/energy/crude-o

APPENDIX 2

Variable description

Variable	Description	Unit	Data Source
FUT(1) FUT(2) FUT(3) FUT (4)	four shortest maturity contracts months of the West Texas International (WTI) light, sweet crude oil futures traded on New York Mercantile Exchange (NYMEX)	$	US Energy Information Administration
INVT	OECD crude oil inventories (at the end of the period)	Million barrels	US Energy Information Administration
QUOTA	OPEC crude oil production ceiling allocations	1,000 barrel per day	OPEC annual statistical bulletins
OVER	The difference between OPEC crude production and OPEC crude oil production ceiling allocations	1,000 barrel per day	
WB(2) (3) (4)	The difference between spot price and the discounted futures price	$	
SB(2) (3) (4)	The difference between spot price and the futures price	$	
USD/EURO	The volatility of exchange rate of US Dollar against the Euro		OANDA
VOL (2) (3) (4)	The volatility of the 2-, 3- and 4-month maturity WTI futures contract using GARCH(1,1)		
TBM3	The 3-month Treasury Bill	%	Federal Reserve Bank database

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