“Causes of market anomalies of crude oil calendar spreads: does theory of storage address the issue?”

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SECTION 2. Management in firms and organizations

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Causes of market anomalies of crude oil calendar spreads: does theory of storage address the issue?

Abstract

Beginning with the 2008 financial crisis, crude oil futures market participants began to observe situations where contango spread values exceeded carrying charge amounts many times over and lasted relatively long. The article describes these unusual occurrences on the example of the behavior of crude oil calendar spreads and analyzes the causes for such anomalies. Moreover, most researchers have focused on studying the market in a state of normal backwardation, paying much less attention to the market in contango. The recent appearance of "wild" contangos of anomalous dimensions in the futures markets shows that the theory of storage and the cost of carry model requires revision in order to align the model's theoretical foundation with the empirical observations. This article's main aim is the desire to draw attention to the need for updating the theory of storage and the cost of carry model. In addition, the article also examines the causes of the phenomenon of "wild" contangos in the futures markets.

Keywords: futures pricing, cost of carry model, theory of storage, contango, backwardation, crude oil calendar spreads.
JEL Classification: G10, G13, G15.

Introduction

The theoretical foundation for modeling the price dynamics of crude oil futures and spot markets is based on the theory of storage and the co-integration of these two markets via arbitrage. The theory of storage (Working, 1948, 1949; Brennan, 1958; Telser, 1958; Williams, 1986) has played a dominant role in explaining the pricing relationship between futures and spot markets, as well as the relationship between futures of different maturities.

The theory of storage states that the price difference between the price of purchasing the commodity today (i.e. cash) and futures (i.e. the basis) or the difference between two futures contracts (i.e. the spread) depends on three elements: (1) the cost of storage; (2) the convenience yield; and (3) the risk premium for holding inventory (Ates & Wang, 2007). The magnitude of the convenience yield depends on the level of inventory and demand shocks.

Most of the previous works (Brennan, 1958; Gray & Peck, 1981; Fama & French, 1987, 1988; Ng & Pirrong, 1994; Pindyck, 1994; Gao & Wang, 2005) applied the theory of storage to explain the intermarket dynamics of spot and futures prices and their relative volatility for non-energy storable commodities. In general, the results suggest that intermarket behavior of price dynamics and relative volatility are consistent with those implied from the theory of storage.

Different authors, including Cho and McDougall (1990), Ng and Pirrong (1996) and Susmel and Thompson (1997), have researched the application of the theory of storage for modeling price variations in energy commodities. In particular, Cho and McDougall (1990) examined the relationship between variation in the basis and the level of inventory in the crude oil, gasoline and heating oil markets.

As an integral part of the theory of storage that allows modeling price formations on futures markets could be used the cost of carry model (Hull, 2006; Moles, 2004). Theoretically, the equilibrium futures price should be equal to the spot price, plus the cost of carry, which is defined as the sum of the cost of storage, plus the interest rate (Chance, 1991). According to the cost of carry model, the basis (basis = spot price – futures price) cannot exceed the cost of carrying the physical commodity, which mainly consists of financing and storage costs. Thus, when the basis is equal to the cost of storage, the market is said to be at full carrying charges. According to the theory of storage, the futures market seldom reaches a "full carry" situation because any excess of this value will create opportunities to implement arbitrage strategies (i.e. strategies that are practically risk-free for the investor and that are based on a temporary market imbalance) (Hull, 2006). Later, we will describe in greater detail the role of arbitragers. Moreover, some researchers, including Anand (2000), argue about the impossibility of full carry markets.

In 2008, crude oil futures market participants began to observe situations where the contango spread values exceeded the carrying charge amount many times over. This lasted relatively long. This article illustrates these unusual occurrences on the example

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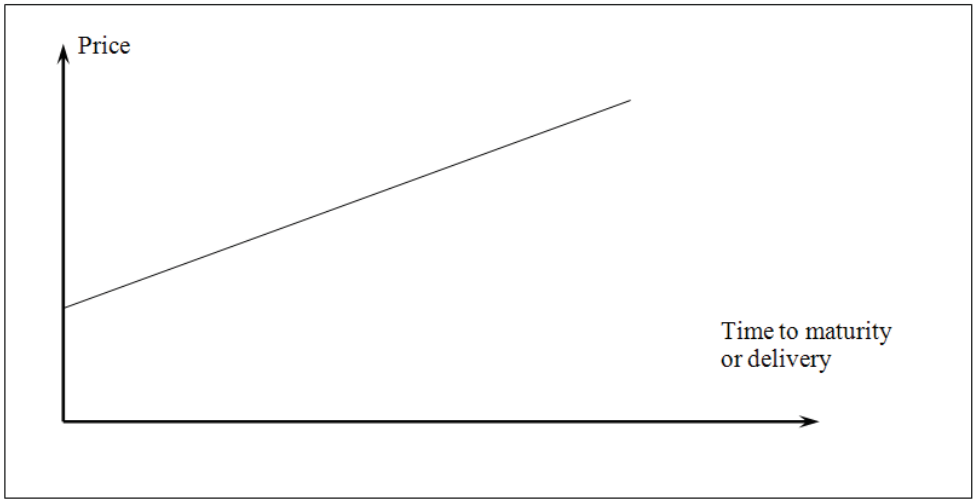
of the behavior of crude oil calendar spreads and analyzes the causes for such anomalies.

Starting with Working (1948, 1949) onwards, the majority of scholars have focused on studying the market in a state of normal backwardation (i.e. when the basis is positive), paying much less attention to the market with a negative basis, (i.e. contango). The recent appearance of "wild" contango of anomalous dimensions in the futures markets shows that the theory of storage and the above mentioned cost of carry model require a revision in order to align its theoretical foundation with empirical observations (Perchanok, 2011a; 2011c). The desire to draw attention to this issue was the main purpose of this article. In addition, the authors set the task of understanding the causes of this phenomenon.

The paper is structured as follows. Section 1 discusses the theoretical foundation of contango and backwardation concepts, as well as the role of arbitrageurs in the co-integration of futures and spot market. Section 2 concentrates on analysis of crude oil calendar spreads from the end of 2008 to mid 2010. Section 3 contains results and the final section concludes the paper.

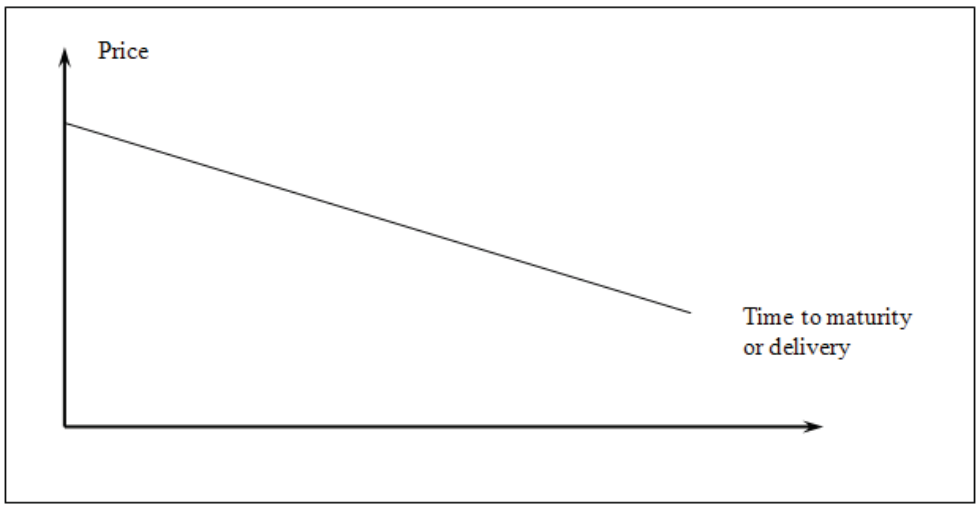
2. Market behavior: contango and backwardation

Contango is a price situation in which futures prices exceed spot prices (prices in the physical market). Accordingly, backwardation is a market condition in which spot prices exceed futures prices. So, if a market is in contango, the basis will be negative as the futures price will be higher than the spot price, while in a backwardation market the basis will be positive as the spot price will exceed the futures price (Moles, 2004; Perchanok, 2011a). Figure 1 graphically illustrates contango pricing.



Source: Perchanok (2011a).

Fig. 1. The basis is negative and the market is in contango



Source: Perchanok (2011a).

Fig. 2. The basis is positive and the market is in backwardation

To better understand this, let us refer to the futures pricing theory and, in particular, examine commodity markets. So, according to the cost of carry model for pricing futures, the relationship between the futures price and the spot price can be expressed by the following equation (Black, 1976; Hull, 2006):

$$F = S * e^{rt}, \quad (1)$$

where F is the futures price, S is the spot price, e is exponential, r is the risk-free rate, and t is time to contract maturity.

This formula reflects the futures price when no other expenses are incurred except financing costs. Since we are speaking about commodity futures, it is evident that in addition to certain financial carrying costs there will be some storage costs. Therefore, to account for these storage costs, the equation is expanded (1). As a result, we obtain the following formula:

$$F = S * e^{(r+u)*t}, \quad (2)$$

where u is the annual storage cost that is proportional to the spot price.

By using this formula we can easily compute the futures price based on the known spot price, risk-free rate, carrying costs and time between the spot price and the futures price. Thus, if the futures price is equal to the theoretical price derived from the equation (2), a market is in "full carry", i.e. the futures price fully reflects the costs of storing and financing the commodity. However, this is not always the case, and futures prices are often below "full carry". Moreover, commodity markets often become "inverted". Whereas the situation in a contango market is more or less clear, for a backwardation market, the above equation (2) seems slightly inaccurate. The formula should be expanded (2) by adding a convenience yield (Kaldor, 1939; Brennan, 1958; Telser, 1958). As a result, the formula (2) will look as follows:

$$F = S * e^{(r+u-y)*t}, \quad (3)$$

where y is the convenience yield.

The introduction of the convenience yield concept helps to understand how price formation occurs in a backwardation market. If $r + u$, i.e. storage costs plus financing costs, is greater than the convenience yield y ($r + u > y$), then the market will be in contango. If the convenience yield exceeds full carrying cost, i.e. $y > r + u$, then the market will be in backwardation.

So, what does convenience yield mean? Convenience yield is the benefit of holding physical goods in the spot market. The essence of this concept is probably easier to explain with an example. Let's assume that, in anticipation of a sharp increase in demand for heating oil, a petroleum product trader will prefer holding a physical commodity rather than futures contracts for heating oil. For instance, this may take place when unusually cold weather sets in at the end of winter, when heating oil inventories are nearly exhausted and heating oil spot prices may surge, shifting the market from contango to backwardation. Another example is a drastic rise in wheat prices caused by loss of a major part of a futures crop due to drought, heavy rains or other natural calamities. In other words, the convenience yield can be described as the benefits of holding the commodity in the spot market (Brennan, 1986; Perchanok, 2011a).

Studies based on the storage model relate the convenience yield directly to the level of inventories (Fama & French, 1988). Generally, the theory of storage suggests that the marginal convenience yield falls with inventory, but at a decreasing rate (Brennan, 1958; Telser, 1958; Fama & French, 1988). At low levels of inventory, the marginal convenience yield is larger than carrying costs and the spot – futures price spread is positive. As the level of inventories goes up, the marginal convenience yield falls towards zero and the spot – futures price spread becomes negative and converges towards the cost of carry. Pindyck (1994) suggests a convex relationship between the convenience yield and stock levels with the marginal convenience yield rising rapidly as inventories approach zero and remain close to zero over a wide range of moderate to high stocks. Some models consider a non-linear relationship with the marginal convenience yield rising at low level of inventories and then declining in a non-linear manner to zero. At sufficiently high inventory levels, the marginal storage becomes increasingly expensive as storage facilities reach full capacity levels and the marginal benefit from adding stocks becomes zero (Larson, 1994).

Note that the convenience yield only applies to commodity markets where the physical commodity can appear to be in short supply, causing a short-term rise in prices. Normally, this concept does not apply to financial markets. Take, for example, stock index futures. It is obvious that there can be no shortage or short supply (Perchanok, 2011a).

The following conclusions can be drawn about the features of the contango and backwardation markets. The carry in a contango futures market nearly covers all storage costs, encouraging market players to hold the commodity and sell it in the future rather than in the spot market. On the

contrary, the price situation in a backwardation market encourages withdrawal from storage and sale of commodities in the spot market at current prices. Empirically, this means that in a contango market players expect future prices to increase above current prices, while in a backwardation market current prices exceed possible future prices (Perchanok, 2011a).

Now that we have discussed the relationship between futures and spot prices in detail, let us briefly discuss what contango and backwardation markets mean for spreads. In a contango market, contracts for near-month delivery are cheaper than contracts for more distant months. In a backwardation market, the situation is the opposite (Schap, 2005; Perchanok, 2011a).

A description of the concept of contango and backwardation would be incomplete without mentioning the theoretical role of arbitrageurs and arbitrage strategies, through which futures and spot market co-integration occurs. Hull (2006) describes such strategies in detail.

If we turn to equation (2) and assume that U – storage cost is disproportionate to the spot price, then we obtain the following equation:

$$F = (S + U) * e^{rt}, \quad (4)$$

Consumable commodities, rather than investment assets, usually do not bring interest, but may require significant storage costs. Consider the arbitrage strategies which we use to calculate the futures prices of goods on the basis of spot prices. Assume that (4) is not satisfied and the inequality is valid

$$F > (S + U) * e^{rt}, \quad (5)$$

To take advantage of this opportunity, the arbitrageur could use the following strategy:

1. Get a loan of $S + U$ under the risk-free interest rate and buy one unit of the commodity by paying the cost of storage.
2. Conclude a forward contract to sell the commodity unit.

If we think of a futures contract as a forward, this strategy will lead through a period of time t to a profit equal to $F - (S + U) * e^{rt}$. This strategy can be easily implemented for any product. However, if the arbitrageur will do so, the price of S will grow and the price of F will fall until the inequality (5) does not change its sign. Consequently, (5) can not hold indefinitely.

Suppose further that

$$F < (S + U) * e^{rt}, \quad (6)$$

Investors tend to use many types of investment assets such as gold or silver solely for investment. In the case of the inequality (6), the arbitrageur can implement the following strategy:

1. Sell the commodity to compensate the cost of storage, and invest under a risk-free rate.
2. Conclude a forward contract to purchase the commodity.

As a result, at the contract's expiration the arbitrageur will make a profit, which is $(S + U) * e^{rt} - F$ exceeds the investor's profits who just held the stored commodity. Consequently, equation (6) can not hold indefinitely. So, because of (5) and (6) cannot happen for a long time, we conclude that $F = (S + U) * e^{rt}$.

For commodities unused for investment purposes, these arguments are unfounded. Individuals and companies storing goods in warehouses do so because of their consumer value rather than their investment attractiveness. They are reluctant to sell physical goods and avoid buying forward contracts, because they cannot spend forward contracts. Consequently, there are no barriers to inequality (6). Thus, for the consumed commodity we can assert that

$$F <= (S + U) * e^{rt}, \quad (7)$$

If the cost of storage is directly proportional to the spot price, the inequality

$$F <= S * e^{(r+u)*t}. \quad (8)$$

2. Analysis of crude oil calendar spreads from the end of 2008 to mid 2010

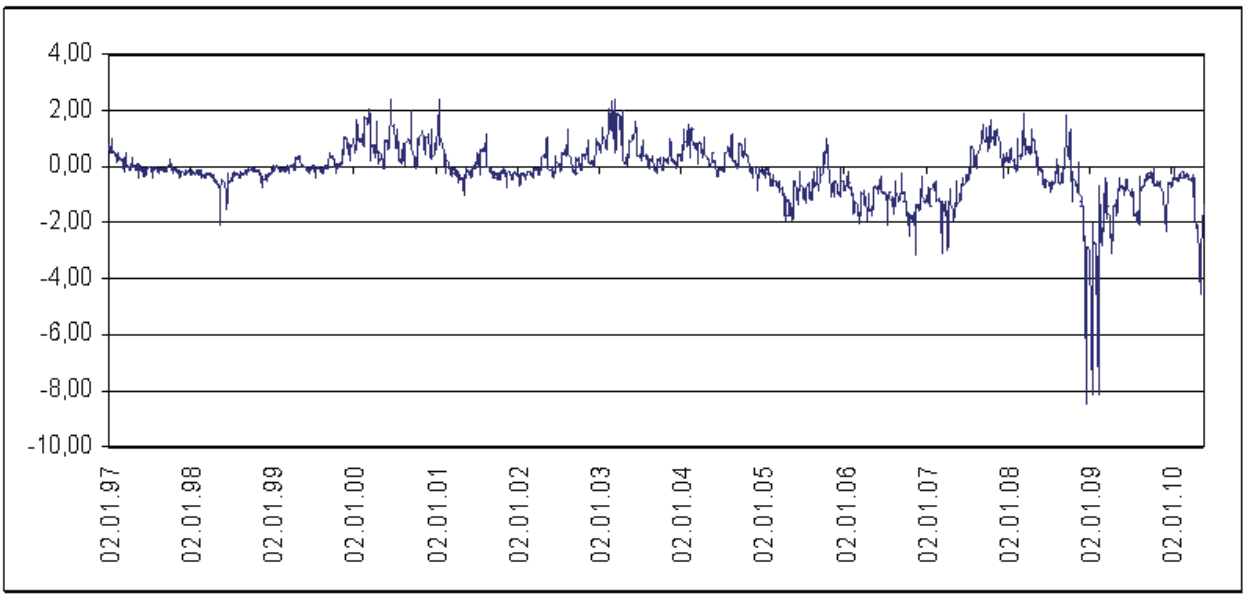
Trading in Light Sweet Crude Oil (WTI) futures takes place in New York on the NYMEX Exchange. The contract size is 1000 barrels (42000 gallons), minimum price increment: $0.01 per barrel ($10.00 per contract), ticker: CL. More detailed specifications of this contract can be found on the CME Group (2012) website.

A spread involving simultaneous buying and selling of futures contracts for the same commodity, but with different delivery months, is known as intramarket spread (Working, 1933; Kawaller et al., 2002; Schap, 2005; Perchanok, 2011b). The spread of this type is very often called a calendar spread (Schap, 2005). This is probably the most common spread type. According to the convention adopted by the CME (CME Group, 2012), the purchase of a crude oil calendar spread would mean buying a nearby contract and selling a distant contract; whereas, a spread sale would mean buying a distant month contract and selling a nearby one.

For a long time it was expected that the oil market should trade in backwardation most of the time, meaning that the price of the front month's futures contracts should be higher than the price of more remote contracts. For example, Litzenberger and Rabinowitz (1995) report that from 1984 to 1992, backwardation in the crude oil markets occurred over 70% of the time. Using futures data on crude oil, heating oil and gasoline from roughly the same period, Edwards and Canter (1995) reported that energy markets show a high frequency of backwardation.

There are several theoretical arguments for backwardation that are common in energy markets. One argument based on the theory of storage points to the role of the convenience yield (Working, 1948; Brennan, 1958). Convenience yield exists because inventories provide holders with consumption/production flexibility. Markets are in backwardation if the convenience yield, net of storage costs, exceeds the interest rate. This is likely to happen when the supply level is low and thus, spot energy prices are high (Charupat & Deaves, 2003).

From the perspective of the theory of storage argument, energy markets have characteristics that make them prone to short supply and thus, backwardation. A shortage of storage facilities, an uncertainty in OPEC production decisions and, especially for heating oil and gasoline, seasonal spikes in demand, all contribute to the markets generally being in short supply. Therefore, it is reasonable to expect backwardation to be the norm in energy markets. Figure 3 shows a chart of crude oil two-month spread over the period from 1997 to 2010.

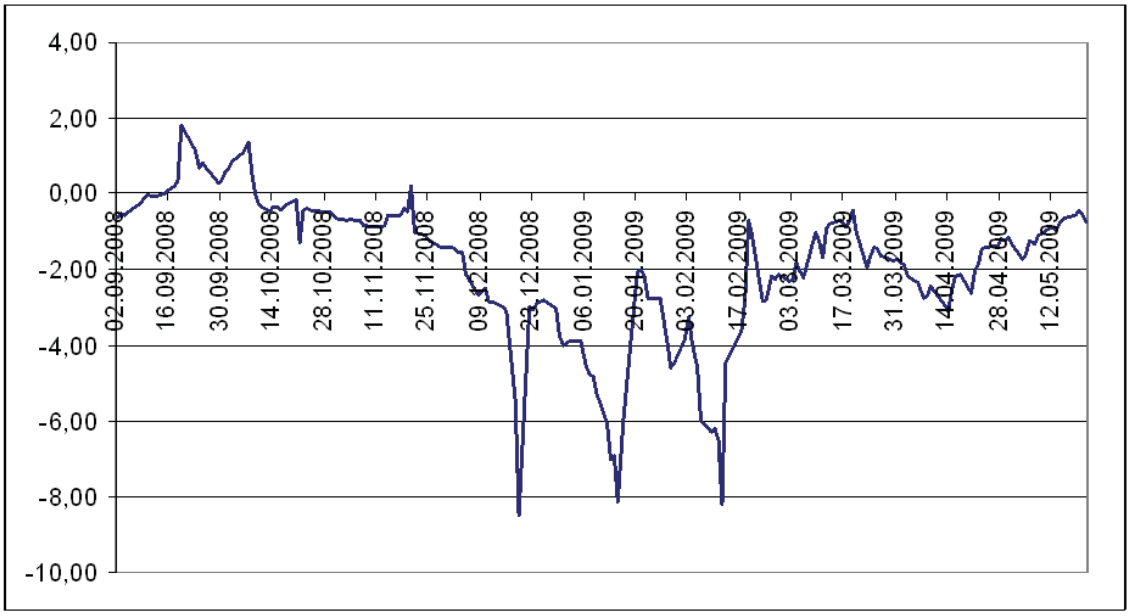


Source: U.S. Energy Information Administration (2012a).

Fig. 3. Chart of crude oil calendar spread between two consecutive months

The above chart illustrates that the spread values were both positive and negative during this period; in fact, the market actually alternated between contango and backwardation. Moreover, the market was in contango more than 50% of the time. Another interesting fact is that between 1997 and 2008, the average value of this spread was close to zero and the spread represented a fairly stable price structure, fluctuating within a range of max +2 and min -2, with long contango periods giving way to equally long periods of backwardation.

In the second half of 2008, the market went into contango, and beginning from mid-October 2008, we could see a sharp widening of the spread, which reached a peak on December 19, when the spread between the front month and the next one future contracts was $-8 per barrel. During several days preceding the expiry date of the nearest month futures contract, the spread narrowed dramatically to almost $-3. Towards the end of December 2008, and the beginning of January 2009, we could again see the spread sharply widen to $-8 and reach the peak on January 15 (see Figure 4).



Source: U.S. Energy Information Administration (2012a).

Fig. 4. Chart of crude oil calendar spread between two consecutive months over the period from September 2008 to May 2009

Then, we see an abrupt return to the initial position over a short time before the expiry of the nearby contract. This scenario repeats itself once again in February 2009. The spread spent all of 2009 in contango. In December 2008, and at the beginning of 2009, the spread sharply widens on the back of aggressive reductions in oil prices (see Figure 5).



Source: eSignal.

Fig. 5. Chart of oil prices between 1994 and 2010

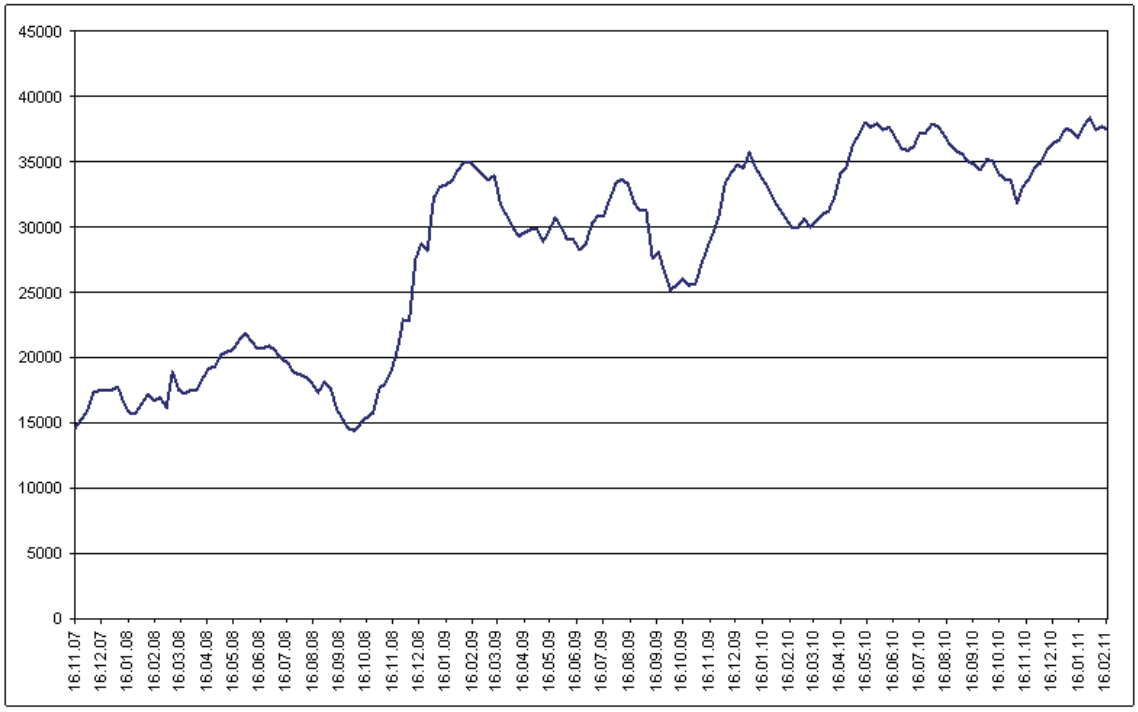
As mentioned in the introduction, in the accordance with the cost of carry model, the basis (*basis = spot price – futures price*) cannot exceed the cost of carrying the physical commodity, which mainly consists of financing and storage costs (Hull, 2006). Thus, when the basis is equal to the cost of storage, the market is at full carrying charges. According to the theory of storage (e.g. cost-of-carry model), the futures market seldom reaches a "full carry" situation because any excess of this value will create opportunities to implement arbitrage strategies (arbitrage strategies are defined as strategies that are practically risk-free for the investor and that are based on a temporary market imbalance). Therefore, the situation which occurred between December 2008, and February 2009, was, in fact, such an imbalance. According to the existing theory of storage, arbitrageurs should have quickly erased the discre-

pancy by actively purchasing nearby futures and selling distant ones simultaneously. Thus, the arbitrageur accepts delivery under the purchased contract, pays all storage and financing costs, and makes delivery under the back month expiration contract (Perchanok, 2011a, 2011c).

Arbitrage profit is equal to the difference between the value of two futures contracts and the actual cost of storage. Theoretically, it constitutes a risk-free profit. The presence of arbitrage opportunities should also limit the upside of contango, both in volume and in time. Despite the theoretical model, we observe a market imbalance, whereby the spread value exceeds full costs by several times. This situation lasted a few months in 2008, 2009 and 2010, which is not at all characteristic for arbitrage models. We tried to find an explanation for this phenomenon in several different sources.

Many authors (Cho & McDougall, 1990; Ng & Pirrong, 1996; Susmel & Thompson, 1997) refer to the base theory, analyzing the correlation between an increase in oil inventories, the difference between spot prices and futures contracts, and spread between various futures contracts. What this research study basically reveals is that an increase in oil inventories leads to reduced oil prices, and pushes the market into contango.

Developing this logic, we can assert that in a contango situation, futures prices cover storage costs, thus stimulating future increases in inventories in storage, which, in turn, deepen the contango. In fact, we observed this process when Cushing crude oil inventtories swelled from approximately 14.4 million barrels in October 2008 to 35 million barrels by the middle of February 2009 (see Figure 6).



Source: U.S. Energy Information Administration (2012b).

Fig. 6. Weekly cushing, OK ending stocks excluding SPR of crude oil (thousand barrels)

There is also a theoretical possibility that contango will continue to widen until some macro changes occur, which will lead to a decrease in inventories. Such macro changes can include, for example, a sharp growth in the consumption or a significant reduction in the supply of crude oil. In this case, a reduction in supplies caused by OPEC's decision to curtail production occurred. A collapse of prices on the global oil market dictated this decision (BBC News, 2008; Mouawad, 2008). It finally led to a gradual decrease in Cushing oil inventories. As a result, spreads returned to a more or less normal level in March 2009 (see Figures 3 and 4). This raises the question, "Why hadn't the arbitrage model "worked" in that particular situation?" A possible explanation may be that the volume of full costs for storing oil could have rocketed suddenly as Cushing storage had reached its limits. This implies that an increase in storage costs tends to increase the "full carry" ceiling value and deepen the contango even further. However, total capacity at Cushing was about 50 million barrels at the end of 2008. Therefore, it is unlikely that this situation could be explained by a lack of further possibilities for storing oil supplies.

Accordingly, it is hard to suppose that storage costs had risen sharply in this context, thereby pushing up the alleged ceiling of full carrying chargers.

Another possible explanation could be the crisis in global financial markets, which was accompanied by a decrease in liquidity. What happens if at some point in time a decrease of liquidity comes and, consequently, an increase in the risk-free rate at which a market participant may take the money? If the appeal to (1) and (2), the futures price should rise significantly, increasing the basis and widening the contango between the price on the spot market and the futures price. The same scenario can play out for spreads, when the difference between the price of futures with earlier expiry dates and the price of futures with later expiry will increase, thus deepening the existing contango.

However, we do not agree with such an explanation. It is true that we saw a significant reduction in liquidity on the markets, which probably contributed to the fact that different players on the spot and futures oil markets began to experience certain difficulties in attracting financial resources, or else the cost of these financial resources had increased. However, we can recall that practically all large central banks of the world massively lowered discount rates at that time, actively inflating the market by additional liquidity and stimulating the banks to extend credits (Banking News & Directory, 2012). Therefore, it is doubtful that the problems in attracting financial resources constituted a reason for such a significant market imbalance.

Now let us take a look at how the market developed further. In 2009, we see a sharp (in percentage terms) increase in oil prices, when prices virtually double from their minimum values. All spreads return to their normal levels from the beginning of March 2009, maintaining the contango price structure, but not moving beyond full carrying charges. All these processes were accompanied by the gradual recovery of the global economy and stock market, stabilization of the bond market and consumer demand.

However, what do we see in December 2009? Once again, future spreads sharply widen. They do not reach the values that we observed almost one year ago, but they also move beyond reasonable theoretical values. We must say that the market reached a balance in this situation fairly quickly, having moved the spreads back to their maximum theoretical values. Spreads remained in the fore-mentioned situation until mid-February 2010. Then the situation changed and the spreads began to narrow quite sharply. Many spreads almost approached zero, promising to shift to backwardation in the very near future. As a minimum, this process seemed unusual and strange if we refer to previous explanations of some of the authors (Cho & McDougall, 1990; Susmel & Thompson, 1997). They connect the substantial widening of spreads with the large growth of inventories, in our case – at Cushing. In fact, from January 2010, oil inventories began to grow week after week (U.S. Energy Information Administration, 2012a), reaching almost record values (see Figure 6). Proceeding from this logic, spreads should widen; whereas we see them narrowing. Analysts stated that this process was connected with prevailing optimism about strengthening of the global economy and a continuing increase in the demand for crude oil (Habiby, 2010).

At the beginning of April 2010, spreads began to widen sharply again, reminding us of the processes which occurred between December 2008 and February 2009. Perchanok (2011a, p. 107) suggests that "in a few days, spreads exceeded the ceiling value of full carrying charges many times, and continued to widen dramatically. The main difference between the current widening and preceding ones was that spreads did not return within their normal boundaries, even when there was a technical "impetus" connected with the expiry of the front futures contract."

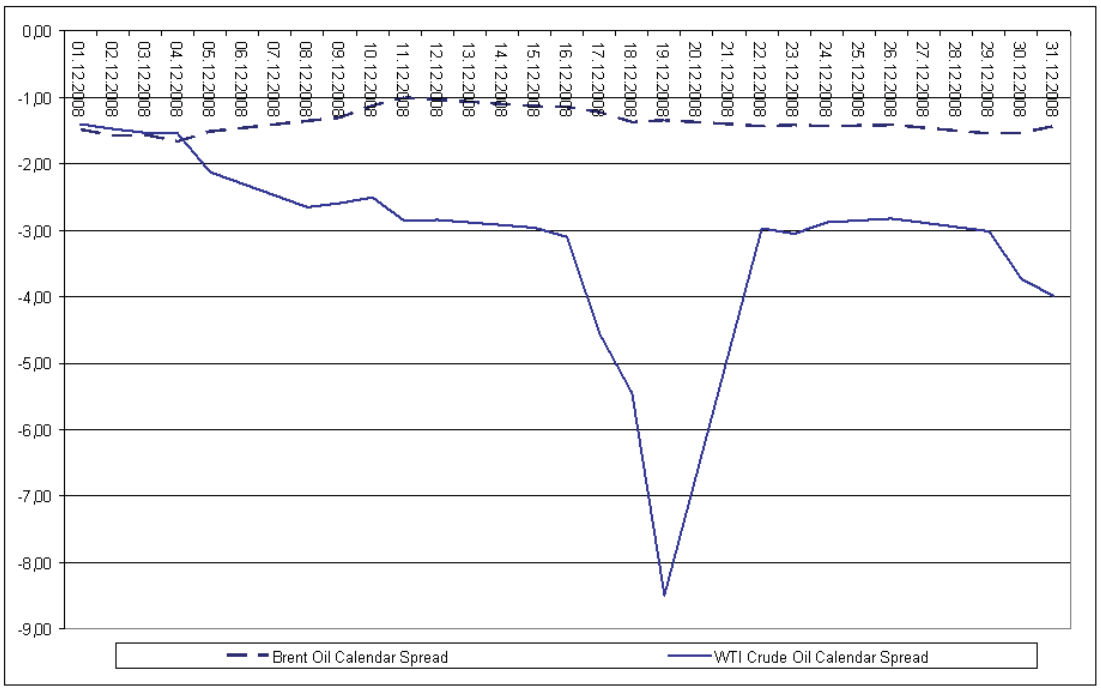
This raises the following question: If the widening of spreads is connected directly with the increase in crude oil inventories at Cushing, and this seems to be the fundamental factor, then why did we see such a sharp narrowing of spreads in the situation of a record increase in inventories, which proceeded to grow for 11 consecutive weeks? An alternative question – What caused such an aggressive widening of spreads starting from April 2010? None of the phenomena which occurred during the crisis period, namely, huge declines in oil prices and lack of liquidity on the market, have been present. Moreover, in the second half of April 2010, on the one hand, oil prices reached local maximums of $87 per barrel (see Figure 5), and on the other hand, the market was filled with cheap and available liquidity. Such questions raise doubts about prevailing explanations, which are based on the current theory of storage and arbitrage model, and on the significant correlation between spread values and size of oil inventories.

3. Possible explanation

In our opinion, the following dynamics are taking place: (a) It seems that in order to find an explanation, we should look at the very essence of the Light Sweet Crude Oil (WTI) futures contract

quoted on the NYMEX. Theoretically, there should be a physical delivery of the commodity to Cushing when this futures contract expires (CME Group, 2012). That is, futures prices and spread values actually reflect the situation at the Cushing facility rather than the general balance between supply and demand in the U.S. We can often see that crude oil inventories in the United States, in general, do not experience such sharp increases in percentage terms as in Cushing (Perchanok, 2011a). Moreover, this facility contains no more than 10% of total U.S. inventories (excluding strategic reserves) (U.S. Energy Information Administration, 2012b). That is, when futures are linked tightly to a concrete local site, this effectively tempts speculators to manipulate futures prices, creating "bubbles". In this case we are dealing with a "contango bubble". Earlier, we dealt with an antifundamental spread narrowing which occurred in February and March 2010.

We can support this idea by the fact that many major market players have come to realize this disadvantage of WTI oil futures (Perchanok, 2011c). In particular, during the "wild contango" period which lasted from December 2008 to February 2009, Saudi Arabia raised the question of abandoning the WTI as a crude oil benchmark (Blas, 2009). In fact, more than half of the world oil trading is actually tied up to Brent. Brent oil futures are listed on both the ICE and the NYMEX Exchange. There are two basic differences between these two oil benchmarks. First, Brent and Brent oil futures are not linked to a specific territory. Second, physical deliveries are not foreseen under Brent futures contract. Settlements are made in cash at the ICE Brent Index Price at the contract expiry date (ICE, 2012). These factors make Brent the most universal benchmark for oil prices in the world. Brent futures prices and spreads between futures reflect the global balance between crude oil supply and demand much more clearly. Therefore, we do not observe these phenomena with Brent futures. Although Brent futures are also in contango, we do not see such drastic speculative manipulations ("bubbles") (see Figure 7).



Source: QuoteCenter.

Fig. 7. Comparative chart of WTI oil calendar spread and Brent oil calendar spreads for the period from December 2, 2008 to Decemver 31, 2008 based on two consecutive months futures

In addition, we can confirm the argument that everything that happens with WTI futures seems speculative in nature, and not at all connected with fundamental reality by the fact that in all those situations during the period of "enormous contango", there were abrupt jerks towards narrowing of spreads which speculative short position technical closures of the expiring month contract caused. At the same time, one of the arbitrage model hypotheses states that there are arbitrage players in the market who will take delivery under an expiring contract, provide storage and further delivery against distant futures, thereby contributing to a gradual narrowing of the spread (Hull, 2006).

However, what happens when only 2% of the total number of contracts ends up in the physical delivery (as is common with the ripe futures markets)? This implies that, at the very least, it would be difficult to apply arbitrage models to this situation. In other words, in this situation it is necessary to develop an alternative model which would reflect today's increased volatility on the WTI futures market (and in the markets in general).

The 2008 crisis led to changes in financial markets which were unobservable previously. In particular, we are talking about the fact that the world's largest banks have lowered interest rates to almost 0 (Banking News & Directory, 2012). Additionally, the Fed has brought rates to a value of 0.25%, which remained for three years (2009-2012) and, as stated at the recent Federal Open Market Committee (FOMC) meetings, will remain so until 2014 (Board of Governors of the Federal Reserve System, 2012). The financial world is facing a new reality, which is called "zero risk-free rate".

The impact of this factor on theoretical finance is difficult to overestimate. One such example is that of Capital Asset Pricing Models (CAPMs) which come in various form such as single-factor, multi-factor, the consumption-based CAPM (Sharpe, 1964; Lintner, 1965; Sharpe et al., 1999) as well as Arbitrage Pricing Theory (APT) and other multi-dimensional modes which assume that risk exists in more than one dimension (Ross, 1976), imply that the risk-free rate is not zero. The same is true for the described cost of carry model. If to insert the value of $r = 0$ in the formula (1), the futures price will be equal to the spot price, that is, markets can not be in contango.

Moreover, since the summer of 2011, analysts have started to observe a situation where short-term U.S. and German bonds traded at a negative yield. Following this logic, a negative risk-free rate should lead to a permanent presence in the backwardation commodity markets, regardless of the situation with fundamental supply and demand balance. Otherwise, arbitrageurs would open the possibility of a risk-free profit. However, despite that the WTI crude oil market was in contango for a long time, the precious metals markets are in contango. Base metals markets switch periodically between contango and backwardation.

This situation points to the fact that many financial models must be adapted to the current state of affairs. Although many researchers hold that the simple form of CAPM model cannot be regarded as adequate explanation for stock pricing (Ross, 1976; Fama and French, 1992; 2004; Andrikopoulos, 2011) this is not the case in this particular context. If we ignore the theoretical models, and pay attention to which implications for financial markets have a zero risk-free rate on a practical level, we will find an interesting picture. In particular, the great number of investors, including institutional ones, have been focused for decades on obtaining nominal and real risk-free income. Since 2008, the situation has changed drastically and the real risk-free rate of return has become negative. This leads to the fact that traditional investors are attempting to adapt themselves to new situations by trying to find other ways of investing. This includes new approaches: discovering other markets, such as commodities and narrowing the investment horizon, thereby trying to reduce exposure to long-term risks. The emergence of larger speculative capital in the markets leads to higher volatility and appearance of values of financial instruments which are disconnected from the fundamental situation and lack any logic (Perchanok, 2011c, 2012).

Further development of computer technology has led to the fact that trading machines start to play a significant role. Perchanok (2012, p. 1) suggests that "Although in earlier times the volume of these machine operations represented only an insignificant market share, currently their actions are a major factor in defining the direction and speed of movement of various financial assets' prices. Of course, even before the appearance of trading programs, sudden speculative price spikes or slumps occurred that were in conflict with fundamental factors. However, there were quite a number of arbitrageurs, investors, and commercial players who, by their actions, quickly restored the status quo in the market, returning prices to normal ranges." Now, it is becoming increasingly apparent that fundamental analysis and a focus on fundamentals have ceased to play any significant role in trading decisions. Such changes suggest that algorithmic trading programs, not people are making most of these decisions (Perchanok, 2012).

Widely regarded as one of the main tools of technical analysis is the concept of a trend and it can be most easily incorporated into algorithms of trading machines. Perchanok (2011a) states that spread trends are expressed much more strongly than in the case of simple outright positions. Therefore, the actions of trading machines, focused on trend following increase the trending move, bringing the size of spreads to absurd values. These values contradict with fundamental logic and theoretical models, which should explain spread values (e.g. the cost of carry model).

Discussion about the need to supplement the theory of storage and the cost of carry model would not be complete without mentioning a particular school of thought, best represented by the work of Anand (2000) who finds it impossible for the market to be in a full-carry condition for a long time because of arbitrage opportunities. Anand (2000, p. 32) suggests that "We use the cost-of carry model to show that no-arbitrage conditions rule out the possibility of the convenience yield being zero, or, equivalently, the possibility of markets being at full carry. We show that an option component to the convenience yield exists, and this option has value when the market is at full carry. The spread is analyzed for option-like properties to establish the existence of the option. Further, cointegration tests are used to show the existence of the option in the cost-of-carry relationship." Anand (2000, p. 35) further suggests that "When the convenience yield equals zero (at full carry), this creates an arbitrage opportunity for the cash and carry trader. As is generally understood, an arbitrage implies a position that is costless, with a zero probability of a negative payoff, and a positive probability of a positive payoff. The position has the structure of a call option on a convenience yield, which is in the money when the market moves away from full carry". Additionally, Anand (2000, p. 36) explains: "Therefore, as stated earlier, a market at full carry provides a free option to the cash and carry trader. Given a positive probability of the option payoff being positive and the assumption that this option is priced into the futures contract, the market *can never be at full carry*".

While the authors agree with the possibility of reaching the state of full-carry market, although not mentioning the possibility of exceeding these levels, they argue that the persistence of this condition is impossible for a long time due to arbitrageurs. However, the real situation on the market is in conflict with the authors' work and with other researchers who support this concept. As Perchanok (2011a) mentioned, the arbitrageurs' activity does not play as active a role as previously due to the increased role of speculative capital, which limits the effect of the actions which arbitrageurs take. Thus, the arbitrageurs' premise of quickly liquidating the market discrepancy is not quite true in the present market situation. Tokic (2011) expresses a similar idea. In his article he examines how the interaction of different participants in the crude oil futures markets affects the crude oil price efficiency. Tokic (2011, p. 2051) states that "normally, the commercial market participants, such as oil producers and oil consumers, act as arbitrageurs and ensure that the price of crude oil remains within the fundamental value range. However, institutional investors that invest in crude oil to diversify their portfolios and/or hedge inflation can destabilize the interaction among commercial participants and liquidity-providing speculators. We argue that institutional investors can impose limits to arbitrage, particularly during the financial crisis when the investment demand for commodities is particularly strong".

So, if a significant effect from arbitrage activity cannot be counted on, it is possible to assume the appearance of abnormal market situations which are inexplicable in terms of existing models.

Conclusion

This article had two aims: to find a possible explanation for the occurrence of "wild" contango on the WTI crude oil futures market and to draw attention to the need for updating the theory of storage and the cost of carry model. Achieving these, the author makes the following conclusions:

Already in 2007, there was an opinion that the WTI Crude Oil Benchmark pricing does not adequately reflect the situation on the international oil market (Habiby, 2007). The events of years 2008-2010 showed a further decrease in the status of this benchmark as a determinant of world oil prices. Tight binding of a futures contract to the physical delivery into Cushing Hub makes WTI very much locally-oriented. This opens opportunities for excessive speculative influence not only on the outright prices, but also on the calendar spreads.

The theory of storage is a fundamental theory which was created by Working (1948, 1949) and popularized by later authors. This theory reflected the situation when the futures markets were not excessively occupied by the speculators and abundant speculative capital. By that time markets players based their decisions on the fundamental balance between demand and supply. Therefore, the theory of storage brought up a theoretical foundation under the observed market processes. It addressed very well the existence of steep backwardation because this market condition is based upon purely fundamental factors. However, enormous contangos did not exist at that time and appeared only recently. Giant speculative presence, excessive liquidity, rising efficiency of the ripe futures markets, appearance of round the clock trading and algorithmic trading machines strengthened the divergence between fundamentally explainable from a theoretical point of view values of contangos and values of observed ones. There is an urgent need for further research in order to effectively amend and adapt the theory of storage in a timely manner in line with the latest market situation.

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