Implications of changing correlations between WTI and other commodities, asset classes, and implied volatility

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October 2012

Summary

- Correlations among changes in the prices of commodities, and between the prices of commodities and other asset classes, generally increased from 2007 until 2012. One reason often cited for the increase in the correlation of commodity and asset price movements has been increasing economic growth in emerging market economies.

- When correlations of crude oil prices with prices of multiple commodities decline, it usually implies that a supply side issue is affecting the crude oil market. When the correlation of crude oil price movements with the price movements for a specific commodity falls while remaining strong with other commodity prices, it implies that the other commodity is being affected by its own market-specific supply side issues.

- Macroeconomic conditions and expectations have led to higher positive correlations between WTI prices and the S&P 500, and larger negative correlations between WTI prices and exchange rates and bonds prices.

- The relationship between WTI prices and implied volatility provides insights into whether crude oil prices are being affected by demand expectations or supply side issues. In general, if the correlation between price and implied volatility is negative, then expectations for future economic growth are the main drivers of crude oil prices. If the correlation is positive, then news events relating to supply side issues tend to dominate.

Introduction

Crude oil price movements are constantly changing as the market reacts to new information regarding current production, consumption and inventory levels of crude oil and petroleum products. Oil prices are also affected by changes in the market's expectations of the future supply and demand balance. Depending on market conditions and sentiment, different time periods can have news and events related to either supply or demand issues as the dominant factors dictating price movements. The analysis presented here attempts to identify time periods when crude oil prices are responding more to either supply or demand, relative to the other, by examining the magnitude and sign of the correlation of crude oil prices against other commodities and asset classes.

Academic researchers have examined the reasons behind the elevated correlation between movements in the prices of commodities and other asset classes that began in the latter half of the decade from 2000 to 2010. The impact of index trading, where investors purchase shares of funds designed to track a basket of commodities, has been explored as one possible cause (Xiong). Researchers have also studied how trading by hedge funds, which typically trade across multiple asset classes, has contributed to increased correlations (Robe). EIA has also examined the recent stronger correlations between movements in crude oil prices and the prices of other commodities and asset classes in our What Drives Crude Oil Prices? website as part of our Energy and Financial Market Initiative. This paper looks beyond the identification of factors behind the shifts in these correlations. Instead, it focuses on what the changes in correlations may imply concerning the relative importance of supply or demand factors to price formation.

Methodology

Correlations are calculated on a quarterly basis between the prices of WTI crude oil and other commodities, asset classes, and the implied volatility derived from the prices of options traded on WTI crude oil contracts. The data used in the quarterly correlation calculation is from the daily percent returns of the front month futures contract for WTI crude oil against the daily percent changes of the front month futures contracts for copper, wheat, corn, soybeans, gold, silver, and natural gas. The WTI crude oil price is also correlated with the daily percent changes in the S&P 500 equity index, the spot value for the U.S. dollar index (a weighted basket of exchange rates of the U.S. dollar against six other major currencies), and changes in the yields of 30-year U.S. treasury bonds. Finally, the correlation of the daily percent changes of the front month WTI contract price with the percent changes of implied volatility for the same front month contract is also calculated. Correlations are performed on all of the trading days in a given quarter, each containing 59 to 63 observations.

Additionally, tests of statistical significance are performed to determine if the level of correlation is different from quarter to quarter. A two tailed test of the difference between two correlations drawn from a sample is used to check if the correlation for one quarter is statistically different from the previous quarter, an indication of a change in the relationship between crude oil and other markets. It should be noted that some of the assumptions for this test will be violated. For example, testing if the correlation of two sets of observations is different requires that the observations within each sample be independent and normally distributed. This is not necessarily true for returns on futures prices, which can show dependence on previous price movement over short time periods of time. Also noted in

previous academic research, the historical distribution of returns on futures prices does not precisely fit a normal distribution, most notably exhibiting leptokurtosis, or an increase in the probability of extreme downside movements than would otherwise be expected in a normal distribution. For these reasons, the tests of significance are suggestive, but not definitive.

Results

Other Commodities

In 2006 and 2007, daily price movements in the front month WTI crude oil contract price became more strongly correlated with the daily price movements in the front month futures contract prices for other commodities. The correlations were all positive and generally increased in magnitude from 2006 through 2009 (Figures 1 through 6). The magnitudes of the correlations from 2009 to present have not been as strong as in 2009, but they remain above pre-2006 levels.

One reason often cited for the increase in the correlation of price movements has been increasing economic growth, particularly from emerging market economies. As these economies grew, more crude oil would be refined into gasoline or diesel fuel to transport goods and services. Similarly, more industrial metals, such as copper, would be used in construction or building additional power lines to expand electricity grids. The economic growth would also lead to higher incomes for residents of emerging market economies and they would be able to afford more nutritious diets, increasing their demand for agricultural products, like corn, wheat or soybeans. They would also have higher disposable income to spend on discretionary items like jewelry, further increasing the demand for precious metal commodities like gold and silver.

The general trend over the last decade has been increasing correlation between movements in WTI crude oil prices and the prices of other commodities. But what does it tell us when the correlation between crude oil prices and the prices of these commodities decreases significantly in a quarter? When this occurs, it suggests that another factor specific to crude oil markets or the other commodity market is overshadowing the changes in expectations for macro-economic growth that typically link the two markets. Generally, this occurs when news and events related to current or future supply in a particular commodity market would cause changes in its price to differ from changes in the prices of other commodities. The day to day price movements would be dictated by developments surrounding these supply side issues and the correlation with other commodity prices movements would fall. The case of a broad based drop in the correlation of crude oil prices with the prices of multiple commodities would be indicative of a major supply related event in the crude oil market. Alternatively, a drop in the correlation of crude oil prices with the prices of one particular commodity, with correlations remaining strong with other commodity prices, suggests a supply related issue or other major event in the other market.

An example of this very scenario occurred in the first quarter of 2011, when civil unrest in Libya caused a large drop in the amount of crude oil exported from the country. Since Libya did not export any other raw commodities in significant quantities, the supply disruption was unique to the crude oil market. As shown in Figures 1 through 4, the correlation of crude oil price movements with other commodity prices

fell in the first quarter of 2011. The drops in the correlation with copper prices, from .59 to .11, and with wheat prices, from .49 to .12, were both statistically significant. There were also drops in the correlation from .39 to .17 and .42 to .18 for corn and soybean prices, respectively, even though the changes were not statistically significant.

There are also several examples of large drops in correlation between crude oil and an individual commodity prices while the correlations of crude oil against other commodity prices remained strong. In the third quarter of 2009, the correlation of crude oil and wheat was .05, a significant decline from the .60 correlation recorded in the second quarter of 2009 (Figure 2). The correlation of crude oil against all other commodities remained fairly constant from the second to the third quarter of 2009, suggesting that wheat prices were being strongly influenced by a supply side event specific to wheat markets in that quarter. In fact, wheat prices spiked in the first half of the quarter on fears that weather would reduce the yield in that year's crop, but then declined sharply in the second half of the quarter when the harvest was better than expected.
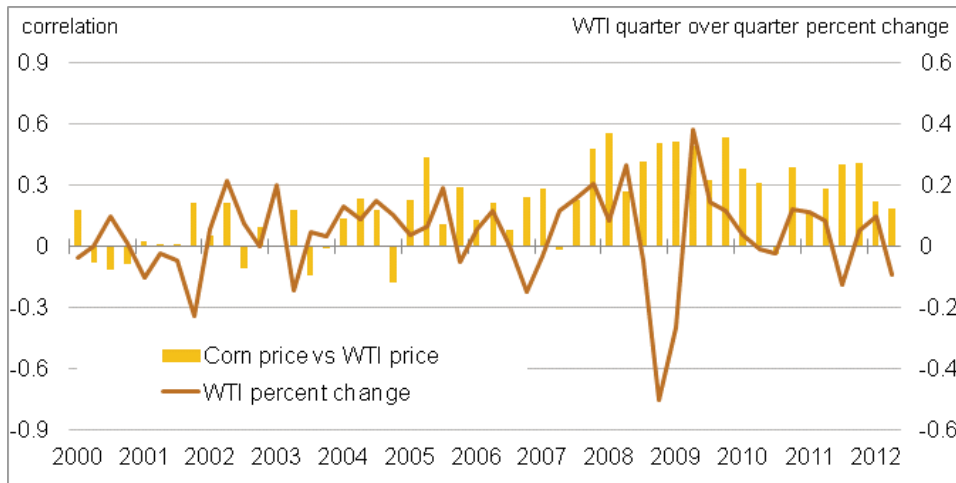
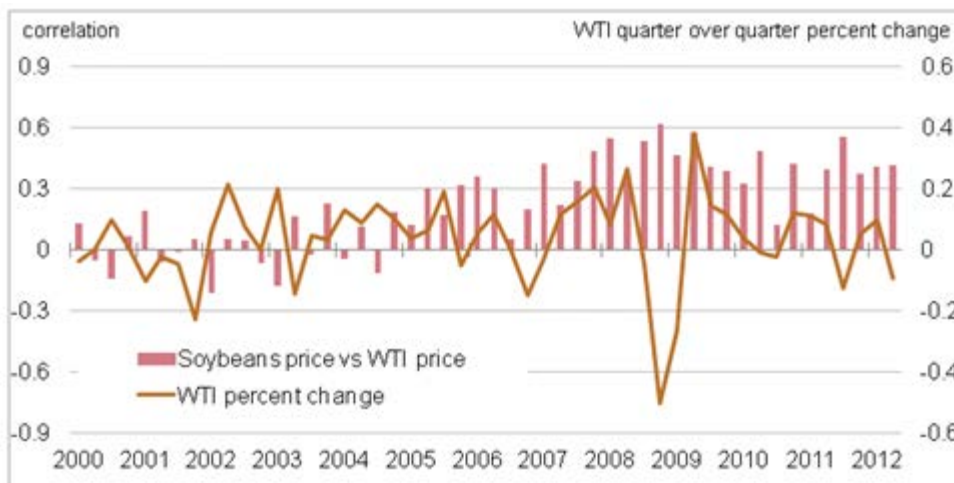**Figure 1. Quarterly correlations of copper and WTI crude oil prices**
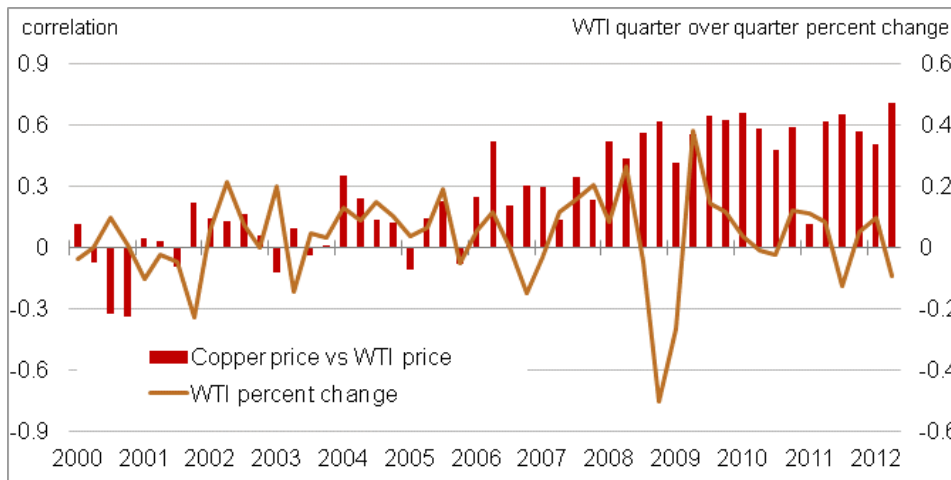
Figure 2. Quarterly correlation of corn and WTI crude oil prices
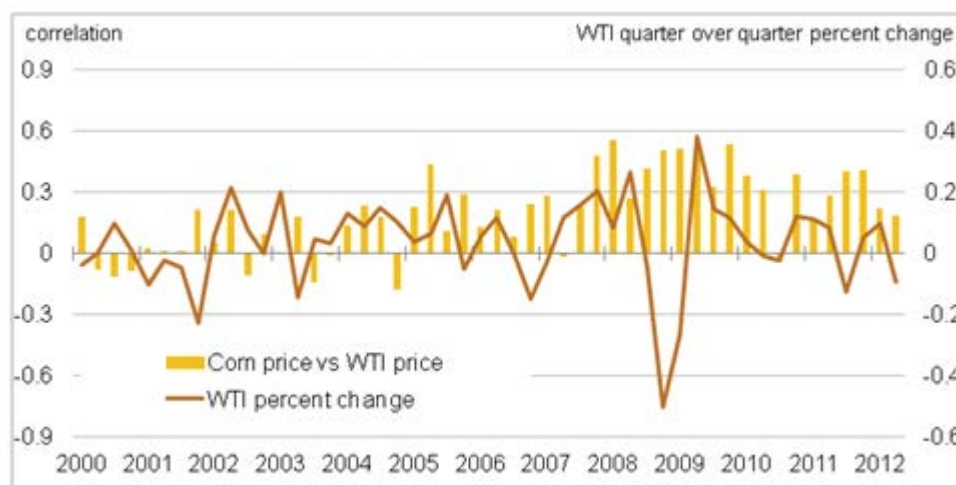
Figure 3. Quarterly correlation of corn and WTI crude oil prices

Figure 4. Quarterly correlation of soybeans and WTI crude oil prices

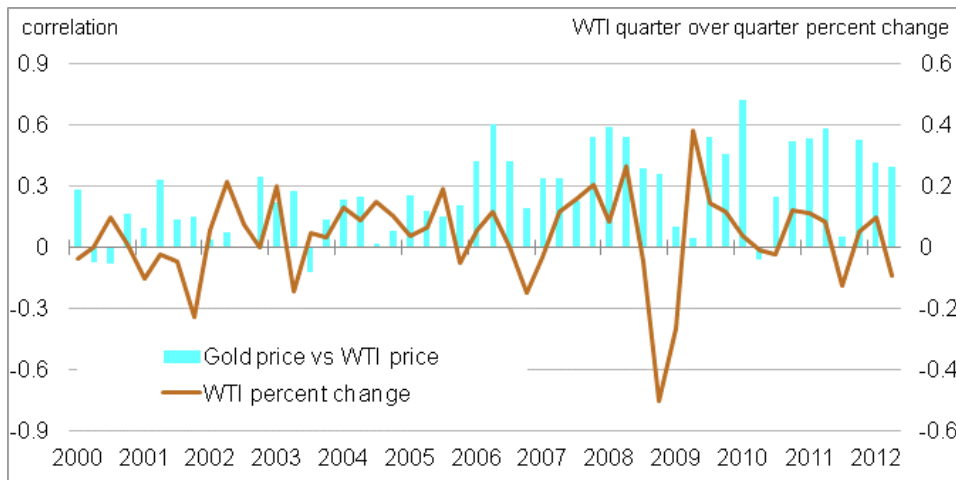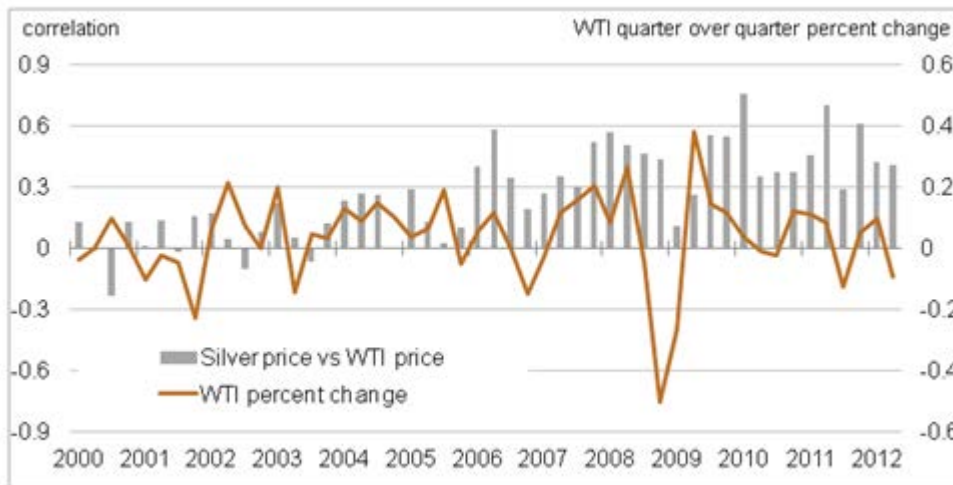**Figure 5: Quarterly correlation of gold and WTI crude oil prices**

Figure 6. Quarterly correlation of silver and WTI crude oil prices

Prior to 2006, the U.S. Henry Hub natural gas price was the only commodity price to show a consistently strong correlation with WTI crude oil prices. However, since the second quarter of 2009, U.S. natural gas prices have not shown significant correlation with crude oil prices, or any other commodity prices. This is another example of a market where price movements are being strongly influenced by factors unique to one commodity (Figure 7). With the increased production of natural gas from tight formations, price movements have been caused by both supply side developments and weather, which tends to be random and have less of an impact on other commodities. Additionally, unlike the other commodities listed, natural gas is subject to more regional pricing as shipping natural gas across oceans is much more expensive than shipping other commodities and liquid spot markets are not prevalent. Since the front month futures price for U.S. natural gas is for delivery of the commodity to Henry Hub in Louisiana, it tends not to be affected by increased economic growth in emerging market economies.

Figure 7. Quarterly correlation of natural gas and WTI crude oil prices
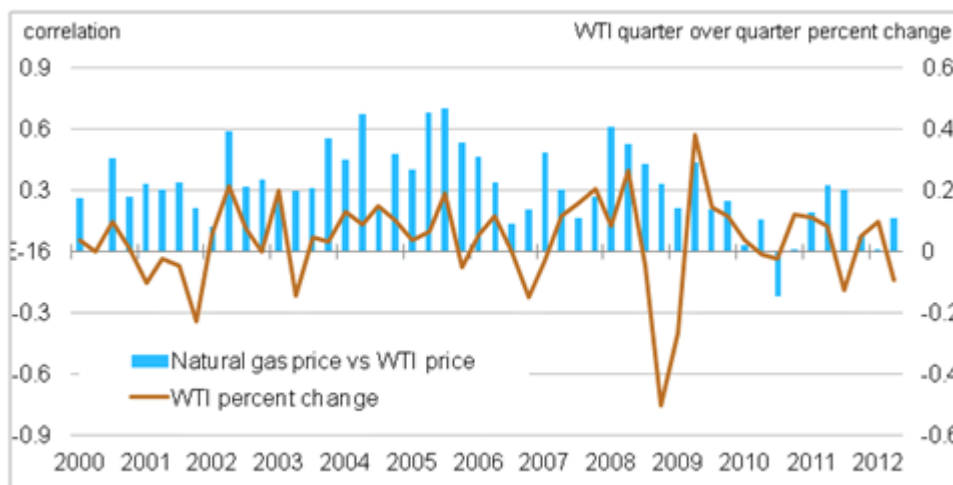
Other financial markets

In addition to other commodities, the relationship between daily price movements of crude oil and other asset markets can also yield information about the motivations of crude oil price movements. Beginning in 2008, crude oil price movements began showing higher correlations with the movements in the S&P 500 and yields on 30-year U.S. treasury bonds. Correlations of higher magnitude between oil prices and the value of the U.S. dollar began earlier, in 2007. In normal market conditions, each asset class has shown either positive or negative relationship with crude oil prices but they can deviate at different points in time depending on developments in crude oil or financial markets.

The value of any company depends on its potential future revenues and the stock price for that company is the market's interpretation of the value of those potential future revenues. The value of a large group of stocks, like the S&P 500, will depend heavily on expectations for future economic growth. Since expectations for future economic growth also impact demand for crude oil, it is expected that there would be a positive relationship between the price of oil and the value of the S&P 500. In fact, there has been a statistically significant positive correlation between daily percent changes of the WTI futures contract and daily returns on the S&P 500 U.S. equity index in 14 out of 15 quarters since 2008 (Figure 8). The highest correlation of .73 occurred recently in the second quarter of 2012. Much like the other commodities mentioned above, the correlation of crude oil against the S&P 500 dropped significantly during the first quarter of 2011 with the Libya oil supply disruption.

Figure 8. Quarterly correlation of the S&P 500 and WTI crude oil prices
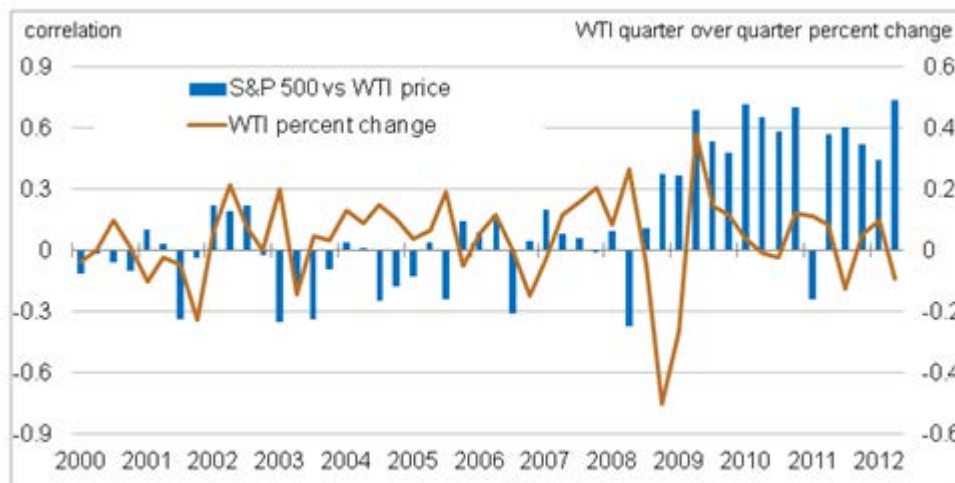

U.S. treasury bonds serve as a safe haven investment and generally increase in price during times of market turmoil and economic stress. Bond yields move inversely to price, so the opposite of the change in 30-year Treasury bond yields was used to calculate the correlation of bond prices with crude oil price movements. Since 2008, most quarters have seen the expected negative correlation between bond prices and crude oil prices, indicating that changes in economic growth were strongly influencing price movements. As expectations for economic growth improve, investors will want to take on more risk, sell U.S. treasuries, and buy assets that could have a higher rate of return, such as stocks or commodities. In the fourth quarter of

2010, the U.S. Federal Reserve Board of Governors began a second round of long term asset purchases (quantitative easing) with the intent to increase bond prices (push down yields) and encourage investors to buy other asset classes. Evidence of this occurred in the fourth quarter of 2010, when the correlation between U.S. treasury bond yields movements and crude oil prices was .06, a statistically significant decline in magnitude from the previous quarter where the correlation was -.41. This was the only asset class or commodity that showed a statistically significant decline in the correlation with crude oil prices from the third to the fourth quarter of 2010.

Figure 9. Quarterly correlation of U.S. 30 year treasury bond prices and WTI crude oil prices
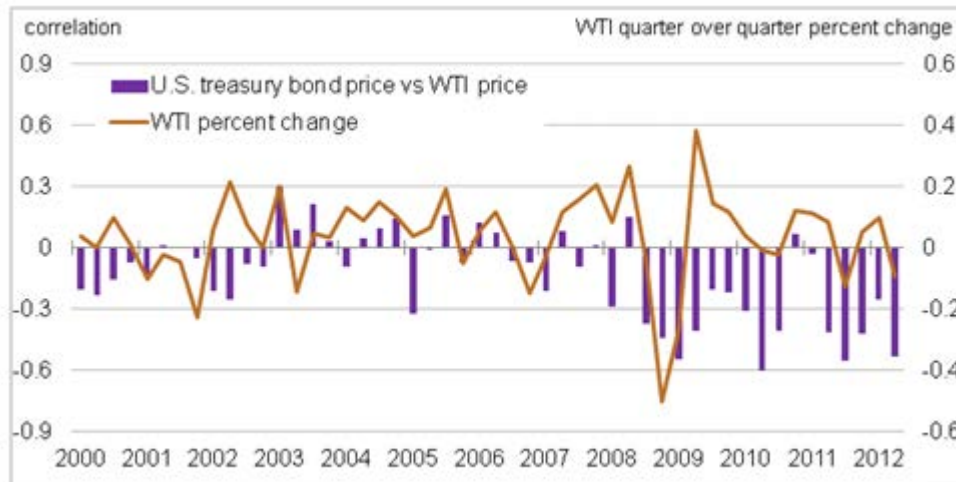
The correlation of WTI crude oil against the spot value of the U.S. Dollar Index, an index that tracks the value of the U.S. dollar against a basket of currencies, has been elevated since the fourth quarter of 2007. The only exceptions to this were in the first quarter of 2009 and 2011, during the height of the financial crisis and the Libyan supply disruption. There are two reasons that crude oil would have a negative correlation with the value of the U.S. dollar. The first is simply that because oil benchmarks are traditionally priced in U.S. dollars, a depreciation of the dollar increases the number of dollars required to buy a barrel of oil overseas. A second reason is that the risk aversion of investors could play a role in the negative correlation of WTI crude oil prices and the U.S. dollar. Since a higher proportion of safe haven assets are denominated in U.S. dollars, during times of market uncertainty investors will sell riskier assets and buy safer ones, which will require the net purchase of U.S. dollars. The same uncertainty usually provides downward pressure on crude oil prices.

Figure 10. Quarterly correlation of the U.S. dollar index and WTI crude oil prices
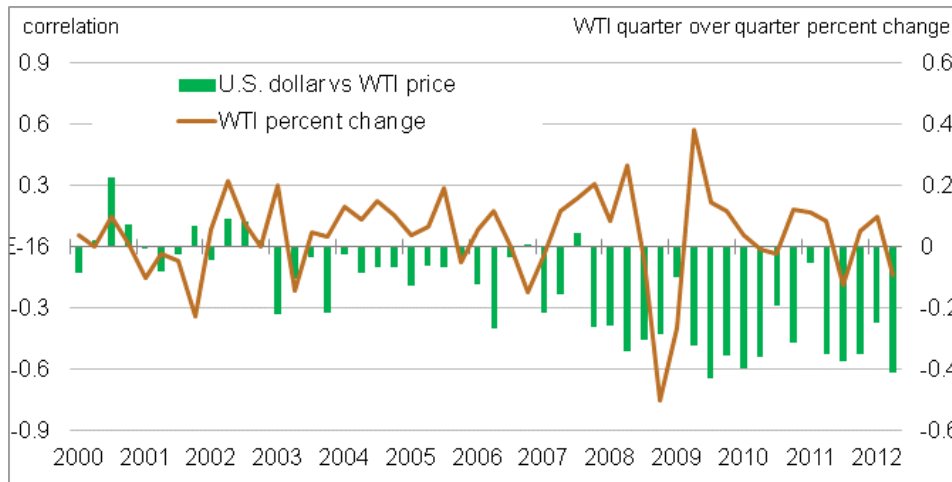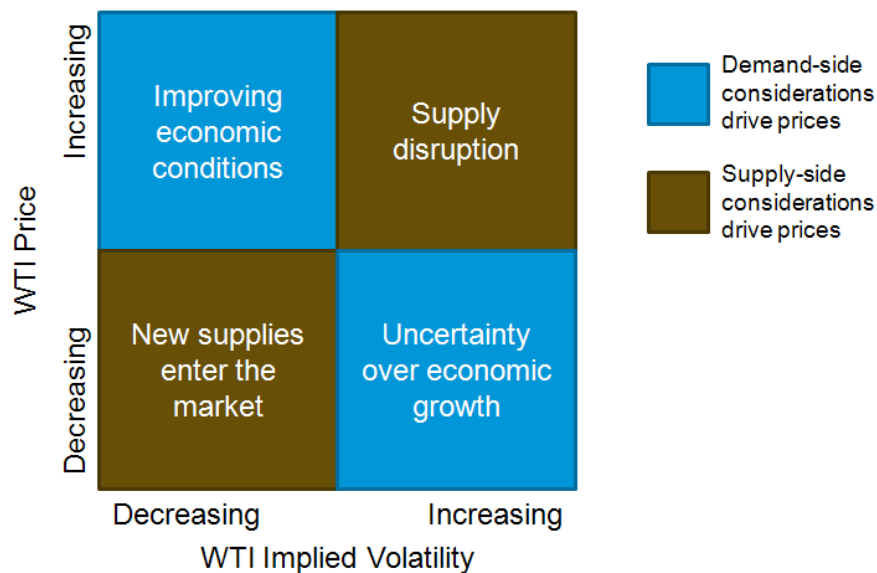

WTI implied volatility

Implied volatility is derived from the prices of options traded on WTI crude oil futures contracts. Much like a futures price, implied volatility is determined in real time through a market process. Much like the relationships between crude oil and other commodities, equities, bonds and the U.S. dollar, the correlation between the WTI price and its implied volatility increased in magnitude starting in 2009. There are four different market conditions that can be identified based on whether or not crude oil prices are moving up or down and if the correlation between price and implied volatility is either positive or negative (Figure 11).

- Negative correlation: price moves down, implied volatility moves up. This is consistent with the market's increased uncertainty over economic growth (higher probability of lower growth negatively impacting demand) and price moves lower. We saw this during the fourth quarter of 2008, the first quarter of 2009, the third quarter of 2011, and the second quarter of 2012.
- Negative correlation: price moves up, implied volatility moves down. The conditions for this behavior imply a market sentiment of improving economic conditions (increased future demand for crude oil) and prices moving higher over a potentially tighter market. This occurred in the second quarter of 2009 through the first quarter of 2010 when the fear of a global depression alleviated as conditions surrounding the financial crisis eased. The same relationship can be also observed in the fourth quarter of 2010 when the Fed initiated its second round of treasury purchases, also known as quantitative easing.
- Positive correlation: price moves up, implied volatility moves up. Quarters where you see these kinds of movements often contain a supply disruption. An increase in the uncertainty over future supply because of a disruption will also cause prices to increase. We see this in the third quarter of 2005 (hurricanes), the first quarter of 2011 (Libya) and to a lesser extent, the first quarter of 2003 (beginning of the Iraq war). Alternatively, there may have been one unique instance where a demand side shock caused prices to move higher and increased implied volatility. In the second and third quarters of 2004, oil prices and implied volatility moved higher

while being positively correlated without a significant loss of oil supplies. There are anecdotal reports that China was filling its strategic petroleum reserve at the time, creating increased demand while the uncertainty of how much or how long they would be adding strategic stocks increased uncertainty and price volatility. The positive correlations were not as high as seen during quarters with significant supply disruptions, but still statistically significant.

- Positive correlation: price moves down, implied volatility moves down. This has not been observed in any quarter over the last 10 years in the WTI crude oil market. The case where price and uncertainty would both move lower together is when large amounts of new supply are delivered into the market.

Figure 11. WTI price and WTI implied volatility relationship matrix

In general, if the correlation between price and implied volatility is negative, then expectations for future economic growth are the main drivers of crude oil prices. If the correlation is positive, then news and events relating to supply side issues are the dominant motivations behind changes in the price in crude oil. Some of the strongest negative correlations between the price of WTI and its implied volatility occurred at the same time that the price of crude oil exhibited strong correlations with other commodities and asset classes, further evidence that a negative relationship between price and volatility implies that changes in expectations for economic growth and demand for petroleum products are driving the price of oil higher or lower (Figure 12).

Figure 12. Quarterly correlation of WTI implied volatility and WTI crude oil prices
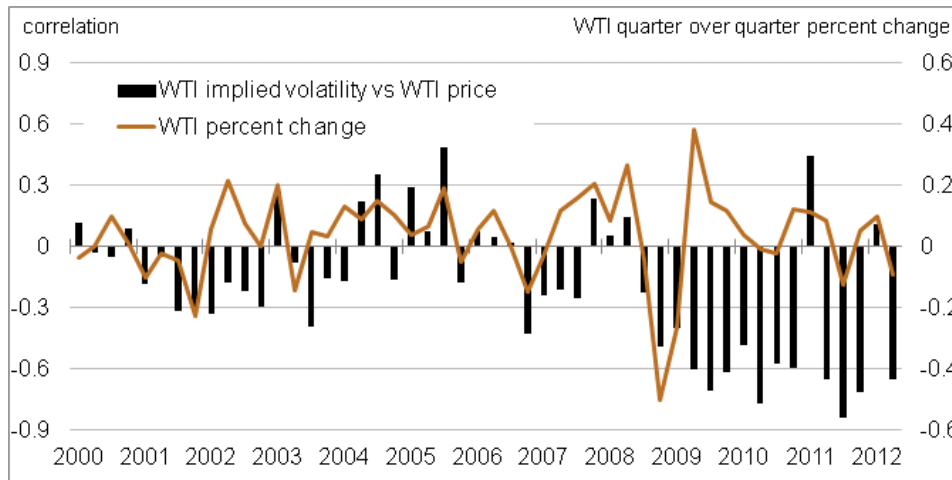
Conclusion

Whether the cause is increased investment in commodities as an asset class or through the trading behaviors of hedge funds in multiple assets, the crude oil market became more closely linked with other commodities and asset classes beginning in 2006. The elevated levels of correlation may be the result of expectations surrounding future economic growth hinging on large, macro events over the last four to six years such as the financial crisis in the U.S. banking sector, the current debt crisis in some European countries, and the possibility for a "hard landing" in the Chinese economy. As the probabilities of these types of macro-economic events wax and wane, so does the demand outlook for various commodities and the valuation of various asset classes.

A drop or sign change in these correlations shows a change from prices being dictated by fluctuations in economic growth expectations to a situation in which crude oil or the other commodity or asset class in question is being driven by factors unique to that market. For crude oil and other commodities, this usually entails a supply disruption. For other asset classes, the change in correlation could be due to supply side factors in the crude oil market or some market event or intervention that would have a large effect on that asset class and not crude oil. The relationship with WTI crude oil prices and its implied volatility can also provide evidence as to whether supply or demand factors are driving the price of oil. Increases in uncertainty over future economic growth will tend to depress crude oil prices, a negative correlation, while increases in uncertainty over future supplies of crude oil will tend to increase prices, a positive correlation.