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"CLOSER TO ONE GREAT POOL? EVIDENCE FROM STRUCTURAL BREAKS IN OIL PRICE DIFFERENTIALS"

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Closer to One Great Pool? Evidence from Structural Breaks in Oil Price Differentials

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https://www.dallasfed.org/-/media/documents/research/papers/2019/wp1901.pdf

Our research investigates how the size of price differentials between different grades of crude oil have changed over time. We show that these price differentials have generally become smaller. We document, in particular, that many of them experienced a major structural break in or around 2008, after which there was a marked reduction in their means and volatilities. A growing ability of the global refinery sector to process lower-quality crude oil and the U.S. shale boom, which has unexpectedly boosted the supply of high-quality crude oil, are two factors consistent with these changes.

Introduction

The physical characteristics of different crude oils can vary significantly, making them imperfect substitutes for one another in the refining process and creating price differentials between the various grades of crude oil.

These price differentials are important to many oil market participants. For refiners, they can affect profitability and influence investment decisions about specific equipment, such as cokers, that could improve the profitability of processing lower grades of crude. Oil producers and fiscal authorities are concerned about these differentials because of their effect on revenues earned from producing or taxing certain types of oil. Finally, for analysts, academics and others interested in understanding the upstream and downstream oil markets, these differentials provide important signals about how supply and demand conditions change for one type of crude relative to others.

This paper investigates how the size of these quality-driven price differentials has changed over time. More specifically, we consider if these differentials have experienced permanent shifts, or structural breaks, in their average values. The research was motivated by a simple observation: in the data, many differentials between high- and low-quality crude oils appear to have significantly narrowed and become less volatile since 2008.

Data and Econometric Results

Our price data extends from 1997 to 2018 and includes 14 crude oils. The data covers a variety of geographical areas including the U.S. Gulf Coast, northwest Europe, the Middle East and Asia. A wide range of quality is considered, as our data set contains prices for high-, medium- and low-quality crude oils.

Dr. Michael Plante, Ph.D., Senior Research Economist at the Federal Reserve Bank of Dallas, presenting at the JPMCC's 3rd Annual International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2019.

The data is used to construct percent differentials between various pairs of prices. Our main set of results considers 27 differentials where the pairs of crude are of different qualities. These differentials are based mainly on daily price data. Some further results, based on monthly price data covering additional crudes, are presented in the appendix of the comprehensive paper and cover 42 differentials.

A structural break test, Bai (1997), is used to formally document when the mean of a price differential has changed. Our most interesting finding is that a large number of quality-related oil price differentials experienced a major structural break around the time of the Great Recession: specifically, 25 out of 27 possible differentials in our daily price data, and 38 out of 42 cases when using monthly data.

We also use the test to investigate whether oil price differentials between crudes of the same quality experienced a similar set of breaks around 2008. If so, that would suggest a broader change in the oil market not necessarily connected to crude quality. Overall, we do not find any evidence for such breaks, although we do find evidence that these differentials have experienced breaks at other times. One group of breaks occurs after the start of the U.S. shale oil boom and affects many differentials involving U.S. based, light, sweet crude oils.[1]

Visual inspection of the price differentials between various types of crude point to a marked reduction in their means and volatilities after the breaks that occur around 2008. A table in the comprehensive paper compares the pre- and post-break values for those statistics, where the pre-break sample goes from 1997 until the end of 2008 and the post-break sample runs from 2009 to the end of 2018. The average size post-break is often half that of the pre-break sample, and post-break volatilities are usually half to three-quarters the size of those before 2009.

Putting a Story to the Breaks

The econometric test does not provide a story for why a structural break occurs, let alone why we find a cluster of breaks around the time of the Great Recession. Part of our research investigates changes in the oil market that would be consistent with the emergence of smaller oil price differentials between higher- and lower-quality crude oil. This included looking at longer-term market changes, as well as potentially important events around the time of the breaks.

Given the complexity of the upstream and downstream oil sector, knowing where to look for clues was initially daunting. To guide our work, we researched how the refining process works and the role of crude quality. This turned out to be very fruitful, leading us to a handful of potentially important factors meriting further investigation.

Crude Quality and the Refining Process

While crude oil has a number of characteristics important to refiners, the two receiving the most attention are density and sulfur content. Density is formally measured by a crude oil's American Petroleum Institute gravity, hereafter API gravity. It is typically a number between 10 and 70—the lower the value, the denser the oil. Sulfur content is often measured as a percent of crude weight and can range from near 0 percent to more than 3.5 percent.

The industry has found it convenient to lump crude oils into several groups based on these properties. It is common to label oils as light, medium or heavy depending upon their API gravity and sweet or sour depending upon whether they have low or high sulfur content.

There is a price hierarchy of quality in terms of density, with light at the top and heavy at the bottom, and in terms of sulfur content, with sweet crudes preferred to sour ones. In terms of prices, light, sweet crudes usually command a premium relative to other grades, while heavy, sour crude oils usually sell at a discount.

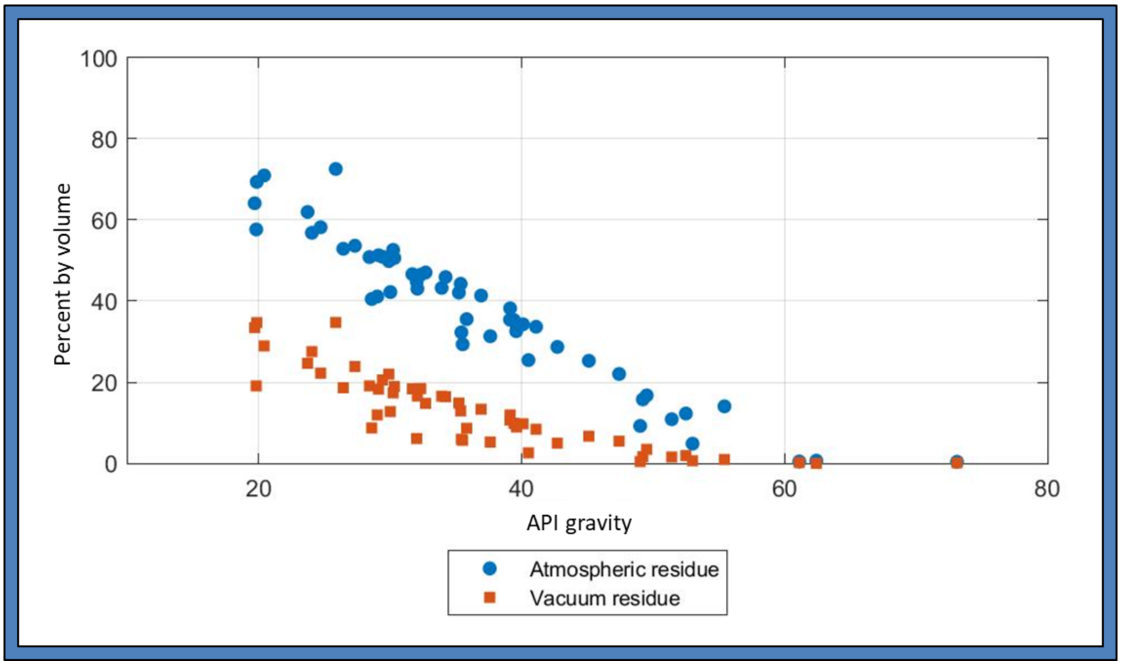
Why a Price Hierarchy?

Sulfur is a pollutant and also prevents the use of sophisticated emissions control technologies in vehicles. As a result, many countries' environmental regulations require gasoline and diesel to meet strict specifications limiting sulfur content. Removing the sulfur requires refiners to invest in costly desulfurization units, also known as hydrotreaters. This creates a premium for sweet crude oil, as it generally requires less processing than sour crude oil. While these rules only target sulfur content, they disproportionately impact lower-quality crude oil because those crudes often have higher sulfur content than do light crude streams.

Regarding density, it turns out the API gravity of a crude is related to the proportion of the different products found within a specific type of crude oil. Light crudes, i.e., those with a high API gravity, tend to have greater proportions of gasoline and diesel than residual products, while medium and heavy crude oils usually contain greater amounts of residual products. These proportions determine how much of each product is available after the first step of refining: distillation.

The residual from the first stage distillation, literally the bottom of the barrel, is often referred to as atmospheric residue. The circles in Figure 1 show the relationship between API gravity and the amount of atmospheric residue present for 54 crude oils.[2] It is possible to further distill the atmospheric residue into a product known as vacuum gas oil and vacuum residue, which is essentially residual fuel oil. The squares in the figure show the residual fuel oil content for the 54 crude oils.

Figure 1
Heavy Crude Oil Contains More Residual Content, Less Gasoline and Diesel



Note: This chart shows the amount of residual content by volume for 54 different crude oils. The x-axis is a crude oil's API gravity, a measure of its density, while the y-axis is the percent by volume of either atmospheric residue (circles) or vacuum residue (squares).

Refiners can Arbitrage across Crude Quality

Unlike gasoline or diesel, the physical properties of residual fuel oil make it impractical to use as a fuel in a wide range of settings. As a result, it sells at a much lower price than gasoline or diesel. This inherently makes medium and heavy crude less valuable than light crude.

It is here that complex refineries step into the picture. These refineries try to take advantage of the price differential between light crude and lower quality crude oil by using equipment to transform the residual content into higher-valued petroleum products. Collectively, this capital is often referred to as upgrading capacity or conversion capacity.

The most complex refineries can transform almost all of the residual fuel oil into other products. This is done using an expensive piece of equipment known as a coker. As the residual content is highest in heavy crude oil, refiners specializing in that type of crude most often use cokers. The equipment can also be used to upgrade medium crude oils.

Long Term Shifts in Refining, Crude Quality

Based on our research into the refining process and crude quality, we decided to investigate how four specific factors evolved over our sample period. The factors are: (1) environmental regulations governing sulfur content in petroleum products; (2) demand for residual fuel oil relative to lighter petroleum products; (3) the relative supplies of various types of crude oil; and (4) global refining capacity to process low-quality crude oil. Each of these could theoretically influence the long-run values of price differentials between high- and low-quality crude oil.

For each factor, we collected as much relevant data as possible and used those data to inform our understanding of oil market developments over the sample period. We find that changes in the relative supplies of different types of crude and changes in the refining sector are consistent with smaller oil price differentials, while changes in environmental regulation and in the relative demand for different fuels are not.

More specifically, the data show that the supply of light crude relative to heavy crude has increased dramatically and somewhat unexpectedly over the past 10 years due to the U.S. shale boom. At the same time, the global refining sector has become more complex due to greater upgrading capacity.

On the other hand, we find that environmental regulations on sulfur have become more stringent and cover a growing proportion of consumption of the affected fuels, which should lower the relative demand for low-quality crude oil. Likewise, consumption data show a clear negative trend in the use of residual fuel oil and significant growth in consumption of other, lighter petroleum products.

What Happened Around 2008?

Since we found a cluster of structural breaks around the start of the Great Recession, it seemed natural to take a closer look at events around that time. Consumption data show the Great Recession played a role by unexpectedly and significantly reducing global petroleum product demand in 2008 and 2009, particularly for lighter products such as gasoline and diesel. In fact, those two years are the only period when the demand of such products relative to residual fuel oil declined. At the same time, additions to global upgrading capacity begun before the downturn continued uninterrupted—the result of the long lead times for refiner expansions. Both of these outcomes would contribute to lower price differentials.

The fact that price differentials have remained smaller and less volatile since then suggests that global refining capacity additions after the Great Recession have been sufficient, in light of the other trends affecting the market, to meet growing demand for gasoline and diesel, without leading to an oversupply of residual fuel oil.

Endnotes

Dr. Plante presented on this topic at the JPMCC's 3rd Annual International Commodities Symposium during the "Economics and Policy Issues on Energy Markets" session on August 12, 2019. The symposium, in turn, was organized by Professor Jian Yang, Ph.D., CFA, the J.P. Morgan Endowed Chair and JPMCC Research Director at the University of Colorado Denver Business School.

For further coverage of the crude oil markets, one can read past *GCARD* articles on these markets.

1 The literature has previously documented and discussed the importance of some of those breaks. See, for example, Buyuksahin *et al*. (2013), Borenstein and Kellogg (2014), Scheitrum *et al*. (2018), and Agerton and Upton (2019).

2 This data comes from Exxon's crude oil assay library and can be accessed at https://corporate.exxonmobil.com/Crude-oils/Crude-trading/Assays-available-for-download.

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Monopoly Power in the Oil Market and the Macroeconomy

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This paper studies the macroeconomic consequences of oil price shocks caused by innovations in the monopoly power in the oil market. Monopoly power is interpreted as oil producers' ability to charge a markup over marginal costs. We propose a novel way to identify markup shocks based on meetings of OPEC and show the organization's unique macroeconomic consequences compared to supply and demand shocks. In particular, global real economic activity expands when oil producers' monopoly power rises. A general equilibrium model suggests that higher monopoly profits attract investments in oil producing capital, which drive down marginal costs and stimulate economic growth.

Introduction

It is well known that the oil price is driven by supply and demand shocks that have first-order implications for the world economy. In perfectly competitive markets, the forces of supply and demand result in an equilibrium price that is equal to the marginal cost of production. Recent evidence for the oil market suggests that producers charge a markup over their marginal costs (e.g., De Loecker and Eeckhout, 2017; Asker *et al*., 2019), which is in line with the notion that oil producers possess some degree of monopoly power. This markup is positive and time-varying. Shocks to the markup charged by oil producers may therefore represent another important determinant of the oil price and potentially have different macroeconomic effects than supply and demand shocks. Identifying and understanding the responses of the macroeconomy to markup shocks is the goal of our paper.

Empirical Evidence

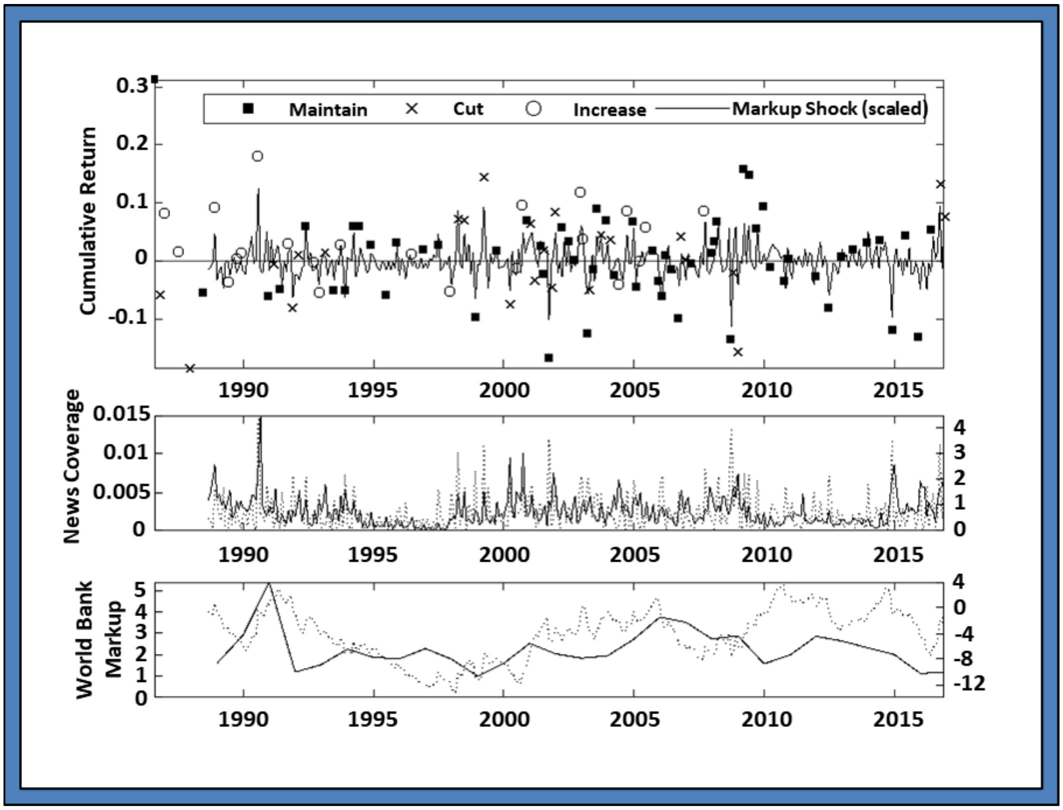
In order to identify the macroeconomic effects of unanticipated markup shocks in the global oil market, we develop a novel strategy that does not involve estimation of the markup itself, since this is hampered by data limitations. Rather, we exploit the fact that the oil market is dominated by the Organization of the Petroleum Exporting Countries (OPEC). OPEC regularly holds conferences to agree on future oil production quotas and publicly announces its decisions at the end of each meeting. Economically speaking, OPEC expresses its competitive policy at these meetings and exerts power in the global oil market by optimally choosing supply to maximize profits. The oil price reacts to such announcements. Oil price movements, i.e., cumulative returns, over event windows surrounding the announcements are often large in magnitude and reflect changes of the markup and marginal costs. We want to isolate the *unanticipated* changes of the monopoly power of *all* oil producers. For this reason, we measure cumulative returns and marginal cost changes such that they come as a surprise to agents. Changes of the markup, i.e., the residual, are then fully unexpected, too. Moreover, we measure cumulative returns and marginal cost changes at the aggregate market level, which means that we capture changes of the common markup that all oil producers can charge.

Mr. René Marian Flacke, Chair of Derivatives and Financial Engineering at the Finance Center, University of Münster, Germany, responds to a question during the "Commodities Matter Everywhere" session at the J.P. Morgan Center for Commodities' 3rd Annual International Commodities Symposium in August 2019. To Flacke's right are Dr. Xiaoqing Zhou, Ph.D., Economist, Federal Reserve Bank of Dallas and Dr. Lutz Kilian, Senior Economic Policy Advisor, Federal Reserve Bank of Dallas, and the chair of the "Commodities Matter Everywhere" session. Dr. Kilian is also a member of the JPMCC's Research Council.

Our goal is to study how markup shocks affect the macroeconomy. For this purpose, we augment the workhorse structural vector autoregressive model of Kilian (2009). Our model includes global oil production, global real economic activity, the real price of oil, and cumulative returns around OPEC announcements as endogenous variables, recursively ordered. Our identification strategy can be motivated as follows. First, it is important to note that the original model of Kilian (2009) does not include any forward-looking variable and thereby assumes that agents in the economy act on present and past information only. This assumption is likely to be violated in our case because we introduce the financial market's reactions to announcements of OPEC's quota decisions as a new variable. The new production quotas are typically effective only in the future, such that the information set of agents involves some expectations that need to be accounted for. For this reason, we use the futures price when computing cumulative returns. We consider the 3-month futures traded on NYMEX because it is liquidly traded and expires after the effective dates of new production quotas. Price movements of futures over short event windows are a nearly pure measure of unanticipated shocks (Kuttner, 2001). We construct event windows of 11 trading days symmetrically surrounding OPEC announcements. We therefore capture any information leakages prior to the announcements and any comments on the meetings' outcomes and atmosphere by OPEC members after the announcements. In other words, the event windows are long enough to allow the shocks to unfold fully. However, they span almost half a month and open up the possibility for other shocks to distort the measurement. In particular, it is possible that the cumulative returns not only reflect changes in oil producers' markup but also changes in marginal costs. We address this issue by ordering cumulative returns in our model last. We therefore correct the cumulative returns and separate out contemporaneous marginal cost changes arising from supply and demand shocks.

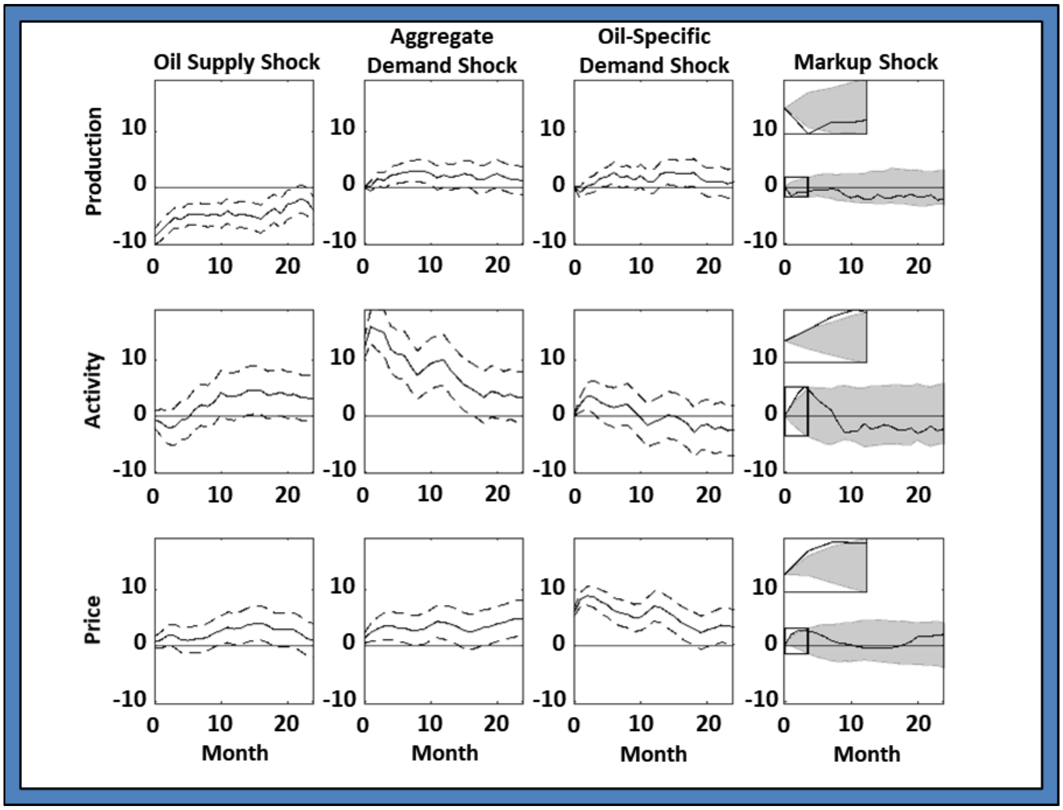
We calculate cumulative returns around 104 OPEC announcements within the sample period from August 5, 1986 to November 30, 2016. We construct a continuous monthly time series by setting cumulative returns in months in which OPEC did not meet to zero. The scope of our measure is therefore limited. It is possible that oil producers' monopoly power also changes when OPEC is not meeting. Our approach overlooks those cases. On the upside, however, focusing on OPEC announcements allows us to pin down the underlying cause of the oil price movement and lets us identify the macroeconomic effects of markup shocks in a narrow, concrete, and conservative manner. In particular, our event study approach greatly limits the role of other events that take place in the same month and also move the oil futures price, but are not properly accounted for in the model, e.g., monetary policy shocks around Federal Open Market Committee (FOMC) meetings.

Figure 1
Markup Shocks



We estimate the model with ordinary least squares (OLS) and orthogonalize shocks using the Cholesky decomposition. Figure 1 plots the obtained time series of markup shocks as a solid line in the first panel. It shows that the futures price reacts to OPEC announcements over the entire sample period, even after controlling for contemporaneous changes in marginal costs. To check the plausibility of this time series, we examine two alternative measures that look at oil producers' importance and power from different perspectives. OPEC's news coverage, which is defined as the number of newspaper articles written about OPEC relative to the total number of articles (Plante, 2019), is plotted in the second panel of Figure 1 along with the absolute of markup shocks (dotted line, right axis). In line with intuition, we observe that media attention spikes when oil producers experience significant losses or gains of power, while little attention is paid when the monopoly power remains relatively constant. In the third panel of Figure 1, we compare a yearly estimate of the level of the markup in the global oil market provided by the World Bank with a cumulated version of markup shocks (dotted line, right axis). We find a positive relation between the two time series as expected. However, while our markup shocks are based on forward-looking information and are fully unanticipated, the estimated markup level of the World Bank only incorporates backward-looking information and reacts to anticipated shocks, too. Taken together, the two plausibility checks of the time series of markup shocks corroborate the view that our measure captures unanticipated innovations in the monopoly power of oil producers. We provide further evidence based on narrative records in the full version of our paper.

Figure 2
Structural Impulse Responses



Responses of global oil production, global real economic activity, and the real price of oil to one-standard deviation structural shocks are plotted as solid lines in Figure 2. The macroeconomic consequences of supply and demand shocks (first three columns) confirm previous studies (e.g., Kilian, 2009; Baumeister and Hamilton, 2019). In comparison to supply and demand shocks, markup shocks (fourth column) affect the macroeconomy in a unique way, although all shocks raise the real price of oil. Oil production sharply drops in the first month after a positive markup shock. This reaction is statistically significant at the 5% level, since it lies outside the 95% confidence interval obtained through bootstrapping pseudo event dates (shaded area). Markup shocks do not have any considerable effect on oil production afterwards. Besides, markup shocks are associated with increases in real economic activity within the first 3 months following the initial shock. This impact is at least statistically significant at the 10% level. Consequently and perhaps surprisingly, real economic activity in the world *expands* when oil producers' monopoly power rises. Furthermore, markup shocks drive up the real price of oil within the first 2 months. This effect is statistically significant at the 5% level, but starts to fade away afterwards. Thus, oil producers are indeed able to charge a higher price for some time if the monopoly power in the oil market increases – as indicated by our measure of markup shocks.

The presented empirical results are robust to using different futures contracts (1-, 2-, 4-, 6-month futures), extending the event window (21, 31, 41 trading days), and employing different proxies for real economic activity (Hamilton, 2019), as shown in the full version of our paper. Moreover, when replacing

OPEC announcements with other major events (reflecting other oil-, inventory-, stock market-, monetary policy-, or general policy-related news), we arrive at macroeconomic responses that are very different, suggesting that OPEC announcements provide unique information to agents.

Theoretical Framework

In order to understand the mechanisms that are at work when the economy is hit by a markup shock, we propose a tractable general equilibrium model that is able to replicate the empirical findings. The key ingredient of our model is the oil sector, which is modeled as being in monopolistic competition, such that oil producers can set the price in accordance with their monopoly power and charge a markup over their marginal costs. The markup is specified to be highly persistent and matches the empirical estimate of De Loecker and Eeckhout (2017). We introduce time variation in the markup in order to study the macroeconomic implications of changes in the competitive structure of the oil market. Oil producers employ oil producing capital (e.g., oil wells and rigs) in their production and sell their output to the final good sector. The final good sector produces the consumption good and cannot perfectly substitute oil with other inputs. Two additional, auxiliary sectors, the sector for patented goods and the research and development (R&D) sector, are introduced to generate sustained endogenous growth as in Kung and Schmid (2015).

We expose the economy to supply, demand, and, most importantly, markup shocks. The model confirms our empirical finding that markup shocks have distinctly different macroeconomic implications than supply and demand shocks. A positive markup shock, first and foremost, exogenously raises the price of oil. Oil as an input becomes more expensive such that the demand for and, in equilibrium, the production of oil decline. Due to the final good sector's limited ability to substitute inputs, final good production initially declines, too. As a result, economic growth decelerates for the moment. However, as a persistently heightened markup suggests higher present and prospective monopoly profits, the oil sector increases investment in oil producing capital in order to reap these profits. In the long run, a higher stock of oil producing capital implies lower marginal costs. Despite a lastingly increased markup, lower marginal costs eventually drive down the oil price below its pre-shock level. In turn, oil as an input becomes less expensive, triggering final good and oil production. Reversing and overcompensating its immediate negative effects, a markup shock eventually fuels long-term economic growth. Comparing the model-implied responses to those implied by the data, we observe that our model can replicate the sharp downturn in oil production and the surge in the price of oil following a markup shock. The reaction of economic growth is positive – as in the data – but the timing is somewhat different. While the model's response is positive only in the long run, the data shows an immediate positive effect on real economic activity.

Conclusion

Our paper makes the point that changes in the markup charged by oil producers represent another important source of oil price shocks. In the empirical part, we propose a novel way to identify markup shocks in a structural vector autoregression based on oil futures price movements around meetings of OPEC. We show that markup shocks have unique macroeconomic consequences compared to supply and demand shocks. A positive markup shock raises the real price of oil and results in a sharp decline of global oil production in the first month after the initial shock. Most surprisingly, global real economic activity expands for a couple of months when oil producers' monopoly power rises. We explain these findings in a general equilibrium model. The model suggests that a higher markup signals higher prospective monopoly profits and triggers investment in oil producing capital. In the long run, an elevated stock of oil producing capital drives down marginal costs of oil production. Despite a lastingly heightened markup, the oil price therefore drops below its pre-shock level. This, in turn, stimulates long-term growth in the economy and explains our empirical finding of an expansion of global real economic activity.

Endnotes

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The Effect of Oil-Price Shocks on Asset Markets: Evidence from Oil Inventory News

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https://www.bankofcanada.ca/wp-content/uploads/2020/03/swp2020-8.pdf

This paper quantifies the reaction of U.S. equity, bond futures, and foreign exchange returns to oil-price shocks. Using instrumental variables methods based on U.S. oil-inventory announcements, the authors find that equity prices decrease in response to higher oil prices before the 2007/08 crisis but increase after it. The U.S. dollar tends to depreciate against a basket of currencies in response to positive oil-price shocks, and this effect is larger after the financial crisis. By contrast, oil-price shocks have a modest effect on bond futures returns. The authors argue that changes in risk premia help to explain the time-varying effect of oil-price shocks on U.S. equity returns.

Introduction

Oil-price fluctuations have important implications for the terms-of-trade, investment, output, and other macroeconomic aggregates of both oil-importing and oil-exporting economies. Even before oil-price shocks are fully transmitted to the real economy, the prices of financial assets adjust to reflect market expectations about the response of macroeconomic fundamentals to such shocks. Recent empirical research has related oil-price fluctuations to variation in equity market returns (Kilian and Park, 2009; Ready, 2018), exchange rates (Chen *et al*., 2010), and interest rates (Datta *et al*., 2018; Kilian and Zhou, 2019).

However, because oil-prices and asset prices move for a variety of reasons -- for example, oil prices and asset prices mutually influence each other and respond jointly to macroeconomic developments -- identifying the effects of oil price fluctuations on asset prices remains a significant challenge. The authors address this challenge by using the information contained in weekly U.S. oil inventory news to investigate and quantify the effect of oil-price shocks on the returns of different financial assets and the shifts in expectations that the changes in returns reflect.

Changes in oil inventories are a fundamental feature of oil markets and play a central role in the intertemporal relationship between current and future supply and demand conditions (Alquist and Kilian, 2010; Kilian and Murphy, 2014). As such, higher-than-expected (lower-than-expected) U.S. oil inventories lead to systematic decreases (increases) in oil prices in the minutes following the announcement. By combining variation in oil prices and a comprehensive, high-frequency data set of the returns of different financial assets, including stocks, bonds, and exchange rates, the authors study how information about oil-market fundamentals is transmitted to asset prices and the broader economy.

Dr. Reinhard Ellwanger, Ph.D., Senior Economist, Bank of Canada, presenting at the JPMCC's 3rd Annual International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2019.

Data

The data for commercial U.S. inventories of crude oil, gasoline, and distillate inventories are from the U.S. Energy Information Administration's (EIA's) *Weekly Petroleum Status Report*, which is typically released on Wednesday at 10:30 am Eastern Time. Ahead of each release, Bloomberg collects market participants' expectations about crude oil, gasoline, and distillate inventories. This set of expectations permits the authors to measure the news component of the change in each type of inventory by subtracting the expected change in inventories from the actual change of inventories reported in the release.

The financial asset data are the intraday price series of the S&P 500 Exchange-Traded Fund (ETF) and eight sector-level ETFs, U.S. Treasury bond futures, and selected foreign exchange rates, including those of both commodity-exporting and importing countries. The sample period for the equity and bond returns is 2003M10 to 2017M10, while the exchange rate data start from 2006 or later.

Methodology

The empirical approach is based on instrumental variables (IV) estimation methods that use the three types of inventory news as instruments for nearby WTI futures returns during a narrow window of 15 minutes around the announcement. The predicted values of the oil futures returns are then used as the principal explanatory variables for the various asset returns during the announcement window.[1] Because the inventory news is determined before the EIA release, they are uncorrelated with other macroeconomic news during the announcement. Hence, the IV estimates identify the response of asset returns to oil-market-specific news. Moreover, if their principal effect on the returns of other assets works through the price of oil, the IV strategy identifies the causal effect of oil-price shocks on asset returns. As the authors show, the inventory news explains a significant share of the variation in oil futures prices around the announcement, which is a necessary condition for the IV approach to be valid.

The regressions are estimated using the weekly data from October 2003 to October 2017. Existing evidence suggests that the relation between oil-price fluctuations and asset returns shifted around the time that the financial crisis began. This shift has been documented in reduced-form correlations at a variety of different frequencies (see, e.g., Lombardi and Ravazzolo, 2016; Ait-Sahalia and Xiu, 2016), as well as in the context of structural oil market models (Foroni, *et al*., 2017; Datta *et al*., 2018). The authors' empirical specification includes an interaction term with a time dummy that takes on the value of 1 after September 2008. This specification permits the authors to compute different effects for the pre-crisis and post-crisis period and use conventional t-statistics to test for a structural break around this date.

Results

The empirical results support existing evidence of a structural break in the relation between oil-price shocks and asset returns around September 2008. The authors document that before the 2007/08 crisis, higher oil prices are associated with lower equity market returns, while after the crisis, higher oil prices are associated with higher equity market returns. Both effects are economically significant: a 10% increase in oil prices is associated with a 0.8% decline (1.1% increase) in the aggregate stock market in the pre-crisis (post-crisis) period. Interestingly, the pattern observed in aggregate equity market returns is pervasive across different sectors, including those with limited direct exposure to energy prices, such as health care. The authors also find that the sector ETF that is the most responsive to oil-price fluctuations is the consumer discretionary fund. This result is consistent with the idea that oil-price shocks affect the U.S. economy through their effect on the discretionary income of consumers (Baumeister and Kilian, 2016).

The estimates for bond returns follow the reverse pattern. Bond futures returns tend to increase with higher oil prices pre-crisis and to decrease with higher oil prices after the crisis. While these results suggest that nominal interest rates became increasingly aligned with oil-price fluctuations, the estimates are economically small and indicate that the effects of oil price changes on nominal interest rates are limited. Finally, higher oil prices are associated with a depreciation of the U.S. dollar against a broad range of currencies. This depreciation is particularly strong against currencies of oil exporters (such as the Canadian dollar) and those of other commodity-exporting countries (the Australian dollar). Interestingly, however, the U.S. dollar also depreciates relative to the currencies of other oil-importing economies, the Euro and the British Pound.

Further, the paper provides evidence for different interpretations of its findings, particularly the time-varying response of U.S. stock market returns to oil-price shocks. For example, oil inventory news might reflect different structural oil-price shocks in the post-crisis period. The authors investigate whether the informational content of U.S. oil inventories about global oil supply or demand conditions changed over time but find little evidence for this claim.

A different interpretation has highlighted the usefulness of investigating the response of stock market returns through their three primitive drivers: expected interest rates, dividends, and risk premia (Boyd *et al*., 2005). The response of interest rates to oil prices, in combination with the time-varying effect of oil prices on equity returns, suggests that oil prices may have become increasingly related to equity risk premia in the post-crisis period. More generally, the results show that oil-price changes associated with inventory news have, on average, a more negative effect on U.S. stock returns than other types of news, highlighting the importance of this transmission mechanism for oil market-specific news.

Conclusion

The authors study the transmission of news from oil markets to financial assets. They find that equity and exchange rate returns react strongly to oil-price shocks, but that bond futures do not. Interestingly, they find equity prices, both in the aggregate and across most sectors, respond differently to oil-price shocks before and after the financial crisis. They attribute this difference to the time-varying equity risk premia across different stages of the business cycle.

Endnotes

Dr. Ellwanger presented on this topic at the JPMCC's 3rd Annual International Commodities Symposium during the "Issues on Mineral and Oil Markets" session, which took place on August 13, 2019. The symposium, in turn, was organized by Professor Jian Yang, Ph.D., CFA, the J.P. Morgan Endowed Chair and JPMCC Research Director at the University of Colorado Denver Business School.

For further coverage of the crude oil markets, one can read past *GCARD* articles on these markets.

1 In practice, the IV estimations are implemented using a 2SLS procedure, which accounts for estimation uncertainty in the 2nd stage regression.

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On Real Options in Ethanol: Producers, Blenders, Valuation and Empirics

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Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3307105

This paper explores the existence and relevance of real options in the ethanol industry. It focuses on the behavior of ethanol producers and blenders in response to government mandates and economic incentives. Through a realistic yet stylized model the authors derive closed form expressions for the ethanol price and industry physical output in terms of gasoline and corn prices. In addition, the value of an ethanol producer is expressed as that of a portfolio of real options on a gasoline-corn spread. These predictions are tested empirically on market and output data for the 2000-2017 period, and by comparison with the market value of the largest ethanol producer in the U.S. Support is found for several implications of the model. The authors conclude that real options are relevant for a quantitative understanding of the ethanol industry.

Introduction

Increased concern about energy security and the environment led to the adoption of the Renewable Fuel Standard (RFS) in 2005 and, two years later, the Energy Independence and Security Act. A very large increase in the demand for ethanol followed, which in turn caused strong growth in ethanol production capacity and physical output. Between 2005 and 2017 the number of ethanol plants in the U.S. roughly tripled and the ethanol blend rate, or proportion of gasoline fuel provided by ethanol, reached 10.0%. According to the Renewable Fuels Association (2017), roughly 30% of U.S. corn output has been recently used as an input by ethanol producers, who sell their output to ethanol blenders for its final use as fuel. The large size of the ethanol market makes it economically significant in the energy landscape. It also has implications for the price of food, for geopolitical and environmental concerns, and for the transportation industry.

In this paper the authors study, through theory and empirical analysis, optimal operation in the ethanol industry and its consequences for ethanol market dynamics. The authors make realistic assumptions for the dynamics of corn and gasoline prices that drive the price of ethanol and take into account the incentives faced by competitive ethanol producers and gasoline blenders under realistic government mandates and capacity constraints. The theoretical model implies explicit formulas for the ethanol price and aggregate physical output, and for the value of an ethanol producer. Predictions are set in terms of the exogenous dynamics of gasoline and corn by focusing on the possible substitution of gasoline by ethanol. The paper also includes empirical testing for the model using aggregate and microeconomic data. Hence, some empirical support is found for a nonlinear pricing mechanism and production rule for ethanol. Then, focusing on firm level data, the share price of a major ethanol producer is found to reflect some essential elements of the model. The paper builds on Ghoddusi (2017) who observed that ethanol may function either as a substitute or a complement for gasoline depending on their relative prices. However, this paper focuses on the substitution effect between ethanol and gasoline in a general setting, derives testable implications and brings them to the data.

Dr. Nicolás Merener, Ph.D., Dean, School of Business, Universidad Torcuato Di Tella, Argentina, presenting at the JPMCC's 3rd Annual International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2019.

Among the research agendas close to this paper, three stand out. First, there is a large literature devoted to understanding the prices of ethanol, energy sources and corn. Some examples are Mallory *et al*. (2012) on pricing ethanol in terms of futures prices of natural gas and corn, McPhail and Babcock (2012) on the RFS and ethanol prices, and Abbott (2014) on the contributions of ethanol capacity constraints versus ethanol mandates. These mechanisms are also behind our model. Trujillo-Barrera *et al*. (2012) and Serra and Zilberman (2013) studied and reviewed transmission mechanisms between corn and energy markets. Second, it is important to understand the determinants of investment and ethanol physical output. The value of the real option in ethanol production under optimal operation was studied in Kirby and Davison (2010), Schmit *et al*. (2011), Maxwell and Davison (2014) and Ghoddusi (2017) among others. Finally, the optimal operation of commodity firms has been subject of study as well.

The Model

The agents in the model, in the spirit of Ghoddusi (2017) but avoiding certain assumptions therein, are ethanol producers and ethanol blenders operating in a competitive environment. Producers have the real option to turn production on or off depending on the profitability of their operation. This is determined by the market price of ethanol and its cost of production driven by corn. Engineering parameters are as in Irwin (2016). Blenders face a floor on the amount of ethanol they must purchase, set by the government mandate. However, blenders can increase the proportion of ethanol mixed with pure gasoline if it is economically convenient to do so. Hence, the amount of ethanol demanded depends on the relative pricing of gasoline and ethanol. In equilibrium the model holds that:

1) The price of ethanol is a nonlinear function of the prices of corn and gasoline. Specifically, it is the maximum of two affine functions, one in each of these variables. Hence, when gasoline is relatively expensive, ethanol is priced as fuel. When the corn prices are high, ethanol is priced as its cost of production.

2) Industry output is set jointly with prices. When the price of gasoline is relatively high, ethanol demand is strong and the capacity utilization ratio reaches 1. On the other hand, low gasoline prices decrease the appetite for ethanol which is then produced solely to satisfy the government mandate. The capacity utilization ratio reflects this through the relative size of the mandate and installed capacity.

3) The profit of an ethanol producer is determined by the spread between gasoline and corn. Hence, the producer can be understood as holding a collection of real call options on such a spread. Closed form solutions for the value of an ethanol producer are derived under the additional assumption of a stochastic process for the spread.

The Data

The paper uses monthly data on gasoline, ethanol and corn spot prices, ethanol production, installed capacity and additional parameters such as extra costs and credits. These are taken from the USDA. Mallory *et al*. (2012) proposed a model for ethanol in terms of futures prices of natural gas and corn. We also work with CME corn futures (4th contract) and ICE NY RBOB gasoline futures (6th contract), which correspond to expiration roughly between 6 and 9 months away from spot. Each year the Renewable Fuel Association publishes a list of ethanol producers. Green Plains satisfied the joint condition of being publicly traded and focused almost exclusively on ethanol, hence a good candidate for testing the predictions of the model regarding the valuation of ethanol producers. As of 2017 Green Plains had an approximate production capacity of 1.5 billion gallons per year, close to 10% of U.S. ethanol production. Yearly data for Green Plains on outstanding number of shares, ethanol production capacity and outstanding debt were obtained from the 10K reports to the U.S. Securities and Exchange Commission.

Empirical Results

Under the model proposed in this paper, the price of ethanol is a nonlinear function of the prices of gasoline and corn. In a direct test of this statement, the formula was implemented empirically on historical prices of gasoline and corn between 2000 and 2017, and then compared with historical ethanol prices. Fitting errors, of the order of 30 cents per gallon of ethanol are shown to be not larger for the theoretical model than for the best-fit linear models with more degrees of freedom. Hence, the nonlinear mechanism proposed in the model seems relevant to explain its performance in reproducing the dynamics of historical ethanol prices to some extent.

The model predicts that the capacity utilization ratio should be an increasing function of the gasoline corn spread. It is then found empirically that between 2008 and 2017 such a relationship was present in the data. For months with a large gasoline corn spread, theoretical and historical utilization ratios were close to 1, while for instances with a small spread, theoretical and historical utilization ratios were close to 0.90.

Finally, according to the model in this paper, the value of an ethanol producer should be that of a portfolio of real call options on the gasoline corn spread. Regardless of the choice of dynamical model for the spread, the producer's value should be increasing on the spread and it should exhibit some positive convexity. These notions were tested on monthly data for Green Plains, a major ethanol producer in the U.S., between 2012 and 2017. Time series regressions were run after controlling for variations in the general level of equity markets and adjusting for installed capacity, outstanding debt and number of shares. The authors find strong statistical and economic significance for the gasoline corn spread in explaining fluctuations in the share price of Green Plains and in its first order sensitivity. Moreover, unrestricted regressions of Green Plains share price against gasoline and corn prices rediscover weightings in line with those predicted by the theoretical model from first principles.

Conclusions

This paper developed, implemented and tested a real option model for the ethanol market. Optionality arises from the interaction between producers and blenders, who respond to incentives. The cost of ethanol production, driven by corn, and the value of ethanol as fuel, driven by the price of gasoline, are the fundamental inputs to the model, which also incorporates engineering settings, industry capacity, government incentives and mandates as external parameters. The model makes precise predictions for the price of ethanol as a nonlinear function of the prices of gasoline and corn, for the magnitude of ethanol physical output in terms of the relative pricing of gasoline and corn, and for the value of an ethanol producer as that of a call option on the spread between gasoline and corn. Empirical tests for each of these predictions found support for the model. However, certain features of the ethanol industry were left outside of the model. In particular, heterogeneity among producers, exit, and entry, seem relevant questions for future research as the story of the ethanol market in the last fifteen years has had firm entry as a main feature. The possibility of ethanol storage is also likely to have an impact on the decision process faced by producers and blenders. This, too, should be explored in the future.

Endnote

Dr. Merener presented on this topic at the JPMCC's 3rd Annual International Commodities Symposium during the "Agricultural Commodity and Freight Markets" session on August 13, 2019. The symposium, in turn, was organized by Professor Jian Yang, Ph.D., CFA, the J.P. Morgan Endowed Chair and JPMCC Research Director at the University of Colorado Denver Business School.

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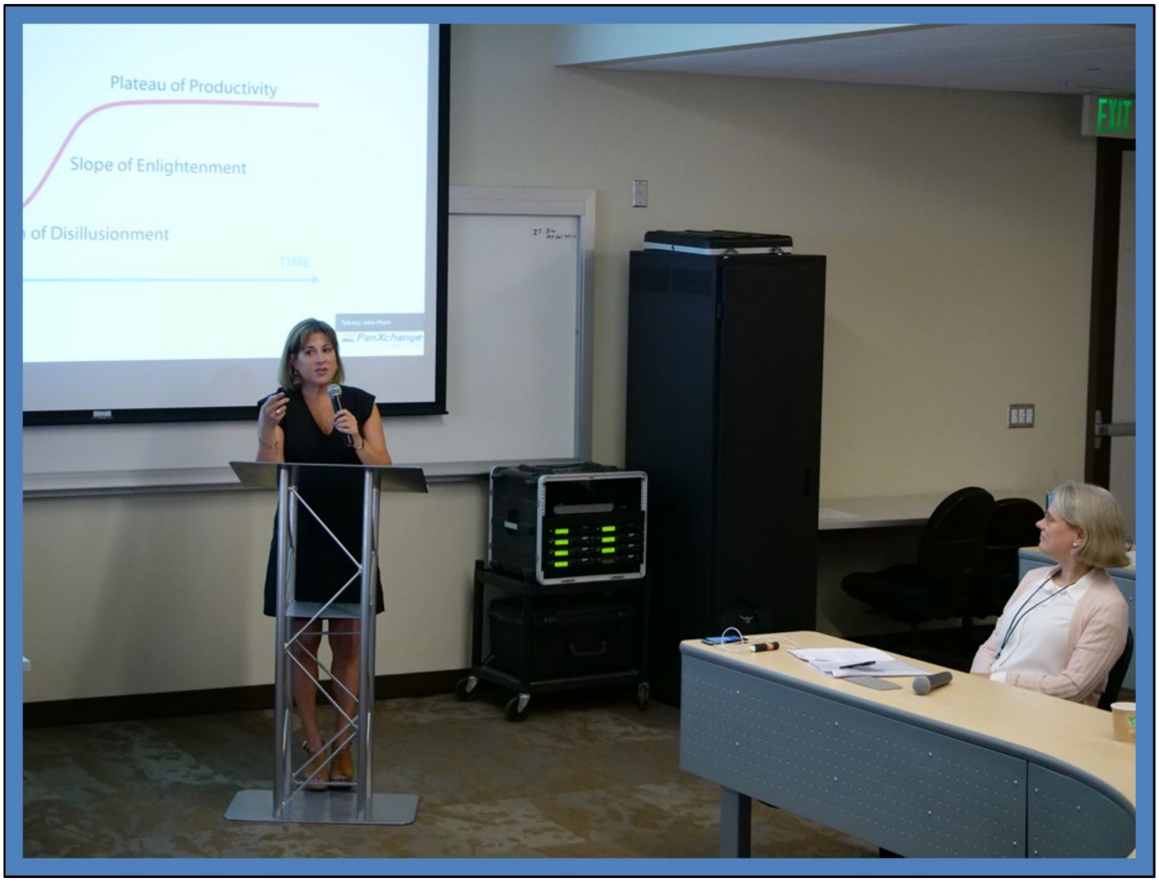
Prior to joining Western as a faculty member, he was Assistant Vice President, Equity Arbitrage, at Deutsche Bank Canada from 1997-1999, and he was a postdoctoral research fellow in the Physiology Institute of the University of Bern (Switzerland) from 1995-1997. He holds a Bachelor of Applied Science (Engineering) from the University of Toronto and an M.Sc. and Ph.D. in Applied Mathematics from Western.

The Seven Stages of Commodity Market Evolution

Julie Lerner
Chief Executive Officer, PanXchange



Ms. Julie Lerner, Chief Executive Officer, PanXchange, participated in the commodity industry panel during the JPMCC's 3rd Annual International Commodities Symposium, which was held at the University of Colorado Denver Business School in August 2019. The panel was moderated by the *GCARD*'s Contributing Editor, Hilary Till, who is in the right-hand-side of this photo.

Introduction

2019 will be remembered as a watershed year for physical commodities. The 120 million-ton U.S. proppant market felt the sting of oversupply, the nascent hemp industry opened up following its 2018 legalization and, in an unprecedented move, the "Big Six" agribusinesses formed a partnership to digitize the highly manual international grain trade. Despite these various commodity sectors cycling at different rates, there remains a common thread to the evolution of these - and all - physical markets.

Equities Take the Lead

Physical commodity markets, whether they be energy, metals, grains, hemp or others, are unified in one significant way: they lag behind their capital markets counterparts when it comes to technology. Commodity trading, especially in agricultural sectors, is still highly manual and almost totally reliant on paper processes for contracting, invoicing and payments. To give the reader an idea of the scope of the issue and the need for modernization and harmonization in the sector, a *Reuters* report revealed that 275 million emails are sent by commodity traders each year in order to process 11,000 ocean-bound shipments of grain (Plume, 2018).

On the flipside, the capital markets have embraced technology far more speedily. Nasdaq launched in February 1971, becoming the first electronic share market. From its beginnings as an electronic bulletin board, it is now the world's second-largest stock exchange by market capitalization of shares traded behind the New York Stock Exchange. In 1987 work began on the nascent Globex Trading System, which was developed by the Chicago Mercantile Exchange (CME). The first electronic future began trading on the system in 1992, making it the first international electronic trading system to allow off-hours trading in exchange contracts.

1991 saw the launch of online trading pioneer E*Trade. By 1994, its revenues had climbed to $11 million, becoming at the time the fastest-growing private company in the United States, and allowing anyone with access to a computer to trade stocks (Encyclopedia.com, 2019). Over the course of the next decade, investment firms began to spend on electronic trading technology, and traditional floor trading waned. Since the inception of Nasdaq, computer-based high frequency trading (HFT) has risen, as have the speeds with which trades can take place. At the beginning of the 2000s, HFT accounted for less than 10% of equity orders, but according to the NYSE this volume grew by around 164% between 2005 and 2009.

Physical Markets Playing Catch Up

For the commodities industry, modernization has occurred at a much more languid pace. It was not until 2015 that the CME announced plans to close the majority of its futures trading pits in New York and Chicago – the same year that open outcry futures trading fell to just one percent of the company's total futures volume (CME Group, 2015).

Even as late as the mid-2010s, oil traders were still using Yahoo Messenger as their main communication tool, something which had been an industry standard since the 1990s. The ultimate closure of the benchmark-compliant version in 2016 sent physical traders into a tailspin, and even today industry participants are still fishing in the dark for deal flow (Gloystein, 2016). Whether by phone, WhatsApp or text, they're still using suboptimal technology for price discovery.

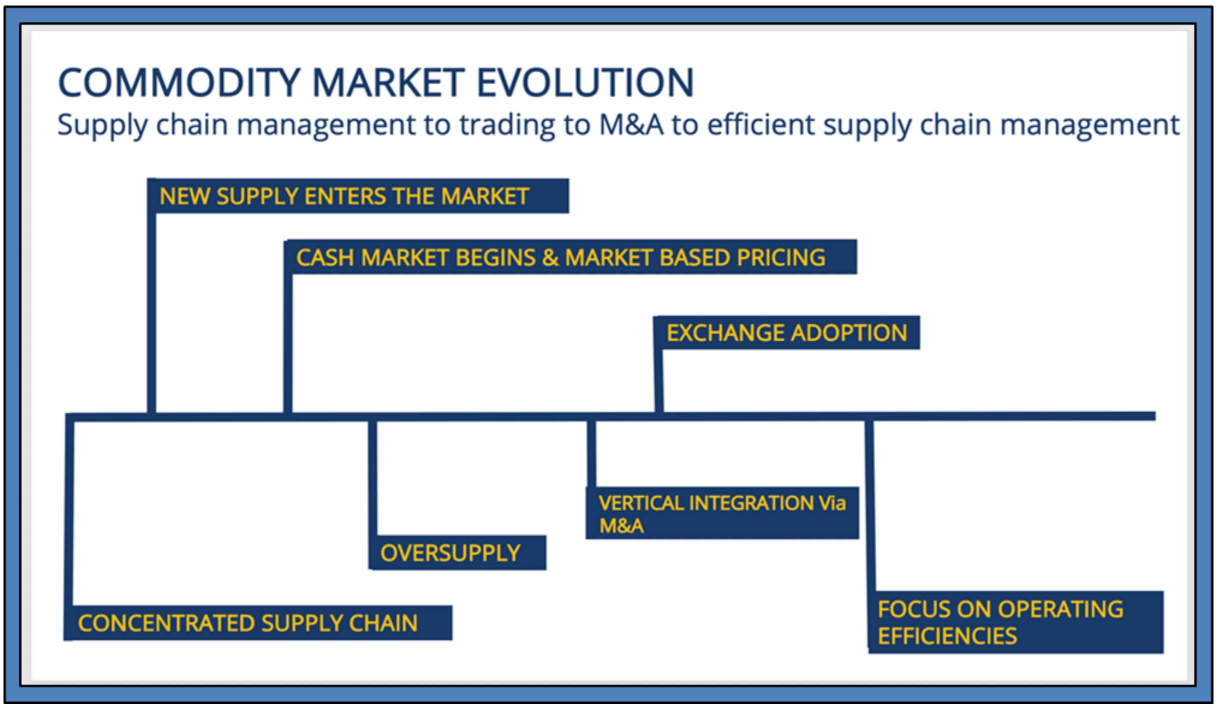
Adding to this issue is the lack of an agreed upon, satisfactory solution for end users who need to move physical supplies around the globe. Of great concern to many industry participants is the fact that the status quo process, in which a dozen different documents are stuffed into manila envelopes each time a vessel of grain is traded, is extremely challenging to move onto burgeoning technologies like blockchain.

And yet, more than a decade after its introduction to cryptocurrency markets, blockchain has yet to be fully adopted by any financial industry, which is arguably simpler for mass adoption than physical supply chains.

The Evolution of Nascent Markets

Another commonality of food, metals and energy markets is that in order for a physical item to go from being simple raw material to a full-fledged commodity, it must traverse seven key steps; see Figure 1. PanXchange's experience with nascent markets - both frac sand and hemp - illustrates the challenges of opacity and fragmentation as commodity markets mature.

Figure 1
Commodity Market Evolution



At the beginning of the cycle, when the supply chain is concentrated (step one), surety of that supply is the absolute biggest concern. Because of this, pricing initially tends to be dominated by a few players who are tied up in long-term contracts, but by the second stage of evolution, when new supply enters the market with the promise of healthy sales margins, new entrants are able to gain market share by offering competitive pricing and execution.

The current state of the industrial hemp sector is a good example of this transition.

The passage of the 2018 Farm Bill allowed for the entry of new suppliers marked by being geographically or technologically more competitive than the incumbents. This has resulted in supply pressures easing and conversations about price taking centerstage. This sector has also seen the rise of the cash market, as well as market-based pricing which has allowed newer players to undercut more established players on price (stage three).

Why Benchmarks and Exchanges

As the pricing competition heats up, the creation of benchmarks often occurs to enable more efficient price hedging and allow for transparency and price discovery -- something which is also being seen in the nascent hemp sector. It is here that oversupply of the commodity (stage four of the cycle) becomes a very real possibility. Recent changes in the frac sand sector provide one example of this.

PanXchange launched its frac sand benchmarks[1] in Q4 2017, but two years later, the sector is now in the throes of oversupply (unlike other commodities, sand does not erode over time). The threat of oversupply is also becoming evident in the burgeoning hemp[2] market, as growers rushed into this market with promises of massive profits per acre. Unfortunately, these estimates seem to have been wildly overstated, based on retail prices of consumer-packaged goods of Cannabidiol (CBD) products which contain only a few milligrams of extracted hemp product. Despite these challenges, it is important to remember that the current state of both the hemp and frac sand markets remains a natural part of market evolution. Figure 2 offers a template of how trading in other commodity markets has evolved.

Figure 2

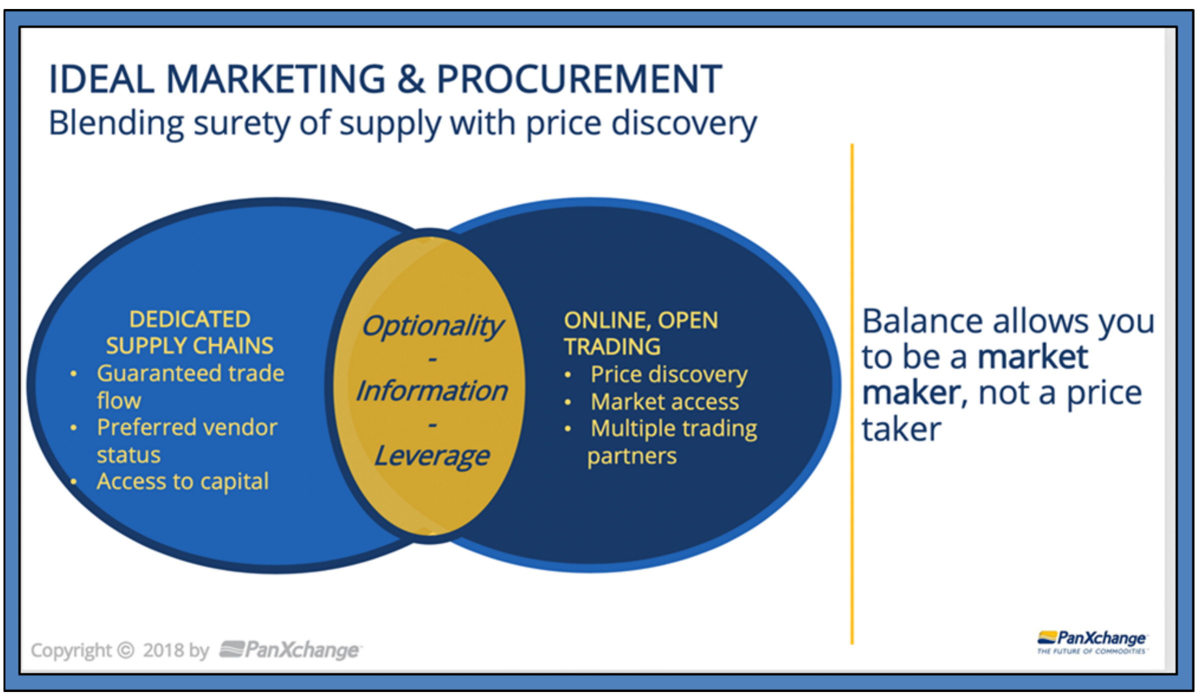
The fifth stage in commodity market evolution - and one that is being experienced in the frac sand sector - is the rise of vertical integration, often via M&A. It is here where larger players seek new profit opportunities by scooping up smaller players challenged by oversupply (as in frac sand) or long-term market fluctuations, as will be covered below on "Profit Building in Mature Markets."

As commodity markets evolve, they reach the sixth stage: exchange adoption, something often seen as a "nirvana" for industry players, where they can finally price hedge their deal flow and outside investors can enter the market. What exchanges offer is a constantly available facility for buying and selling commodities, as well as a financial inventory holding. This is a key component of the maturation of commodity markets.

PanXchange was originally designed to seek a more efficient process for locating physical sugar supply and simultaneous demand opportunities, as the old system of relying on phone calls, texts and emails became antiquated. The market needed more negotiable deals, as well as a system that was easy and efficient for traders, anonymous and without clearing. Now, PanXchange aggregates the negotiation and trade of all types of physical commodities into one web-based platform, offering instant price discovery and market access for increased operating efficiency and profit opportunities. Note that physical commodity traders use PanXchange for the actual movement of commodity from origin to destination yet use the financial derivative as listed on a regulated exchange to hedge the price of that transaction.

However, expecting all commodities players to conduct all their trading activities solely on one cash market platform is unrealistic. A good trader will always have a healthy balance between the reliability of direct relationships and the opportunities and fluidity of the cash market, as seen in Figure 3.

Figure 3
Ideal Marketing and Procurement

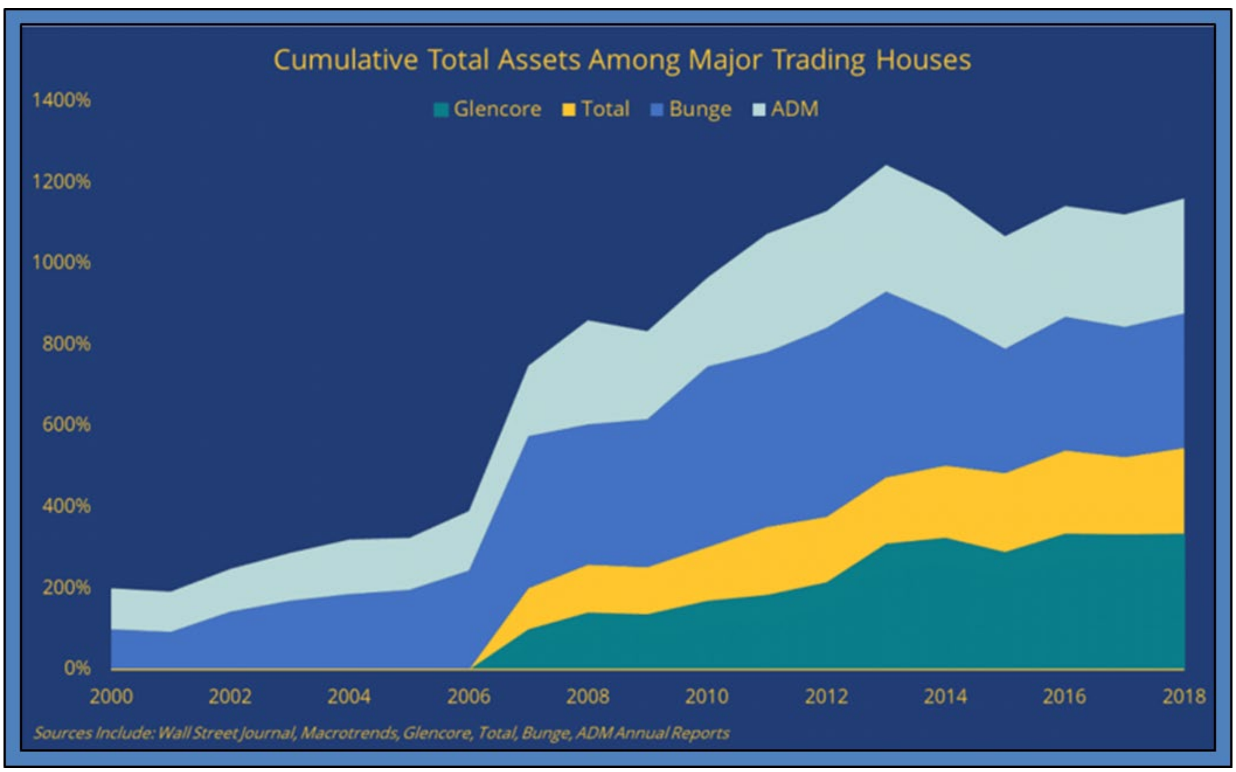


Profit Building in Mature Markets

More established physical commodity markets, like grain, have made their way through the six steps outlined above, and have also moved into the seventh and final stage: a focus on operating efficiencies. In the 2000s there was an unprecedented amount of vertical integration by the big commodity houses; however, as they made their way up and down the supply chain, they were struck by the question: where is there to go to increase profit margins?

Historical examples of vertical integration include moves made by American agribusiness company Bunge Limited. Bunge acquired Argentinian company La Plata Cereal in 2001, becoming dominant in that market. The company created Bunge Asia in 2002, acquired an Indian edible oils business in 2003 and Chinese offices in 2005.[3] Elsewhere, Archer Daniels Midland Company (ADM) bought a stake in Australian grain handler Graincorp in 2012 but sold its interest in 2016 after failing in its bid to wholly acquire the company (Plume, 2016). In 2013, Swiss commodities trader Glencore Agriculture completed its $66 billion deal for mining giant Xstrata, and that same year oil trading house Vitol announced its expansion into grain trading (Scott, 2013). Figure 3 shows the industry trend toward vertical integration and then subsequently, some divestitures.

Figure 3
Cumulative Total Assets Among Major Trading Houses



But since 2013, the global trading companies have faced new headwinds, with Dreyfus in 2016 opting to focus processing as profits fell to a 10-year low (Hume, 2016) and Bunge's chief saying in 2017 that there was “nothing off-limits” in its cost-cutting drive. By 2018, the big trading houses were looking towards digitization as a way to shore up sliding margins - in mature markets, this is really the only solution. PanXchange believes that physical trade has to move in the direction of electronic adoption for both the negotiation of the trade and the (arguably more difficult) post-trade deal execution, as this is seemingly the only solution to increased profit margins today.

The Need for Modernization

In October 2018, (Cargill, 2018a) the world’s four largest agribusinesses - ADM, Bunge, Cargill Incorporated and Dreyfus - announced that they were working together to standardize and digitize international grain trades. In December, China's largest food and agriculture company, COFCO International, joined the group (Cargill, 2018b), followed by Glencore in September 2019 (Glencore, 2019).

The group wants to replace the current system, which is so reliant on paper contracts and invoices as well as manual payments and replace this with an automated electronic system - one which it plans to launch in the second half of 2020, pending regulatory approval. It is also launching a pilot that will cover international bulk shipments of soybeans from Brazil to China.

In a statement issued in 2019, the group said it was “initially looking at new technologies - such as blockchain and artificial intelligence - to create digital solutions to automate grain and oilseed post-trade execution processes, reducing costs needed to move agricultural and food products around the globe.” (Glencore, 2019).

While these companies are to be commended for endeavoring to support the physical commodity sector’s modernization efforts, blockchain is in and of itself not a panacea for the many issues associated with the harmonization of post-trade deal flow, and while pilots are nice, they are not a proof of concept.

Conclusion

We at PanXchange strongly believe that hemp and frac sand will continue to follow the seven-step maturation process. In mature markets such as the grain markets, operating efficiencies are clearly needed to increase profit margins. It’s encouraging to see the major trade houses banding together to address the topic, but unfortunately, blockchain isn’t the only answer. Before the successful rollout of distributed ledger technology, the industry must first take measured and meaningful steps to harmonize post-trade procedures and create interoperability of all back-office systems.

Endnotes

Ms. Lerner presented on this topic at the JPMCC's 3rd Annual International Commodities Symposium during the commodity industry panel on August 13, 2019, which was moderated by the *GCARD*'s Contributing Editor, Hilary Till. The symposium, in turn, was organized by Professor Jian Yang, Ph.D., CFA, the J.P. Morgan Endowed Chair and JPMCC Research Director at the University of Colorado Denver Business School.

1 https://panxchange.com/frac-sand/

2 https://panxchange.com/hemp-benchmarks/

3 See Bunge.com for history: https://www.bunge.com/who-we-are/our-history

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Ms. Julie Lerner is the CEO and founder of PanXchange, Inc., a web-based trading and price discovery platform for physical commodities. PanXchange has the leading trading and benchmark pricing data in both the U.S. hemp market and the 120 million-ton specialty sand market for U.S. oil and gas extraction. Ms. Lerner has deep experience in regional and international agricultural and energy markets. She has worked for Cargill International, XL Financial and Sempra Energy Trading (electricity). Geographically, her area of expertise covers the U.S., Europe, Latin America and East Africa.

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