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

BY MICHAEL PLANTE AND GRANT STRICKLER

Morris Adelman famously wrote in 1984, "The world oil market, like the world ocean, is one great pool." If this were literally true, all crude streams would be perfectly substitutable for one another and we would expect price differentials between different crude streams to generally be small, reflecting mainly transportation costs.

Instead, one often observes large price differentials between crude streams, particularly those of different qualities. These quality differentials are important for many oil market participants, including refiners, oil producers, fiscal authorities, as well as academics and analysts interested in understanding the workings of the oil market.

The main question of interest in our paper is whether the average values of such quality-related differentials have declined over time. That is, has the oil market become closer to one great pool in the sense that prices have become closer to each other?

To answer this, we construct price differentials between numerous crude oils of different types and then test whether these differentials have experienced shifts in their means using a structural breakpoint test.

Motivation for this exercise is provided in Figure 1, where we plot one example of a differential between a higher and lower grade crude. Visually, there is strong evidence of at least one break in the mean, occurring sometime around 2007 or 2008. Many other quality-related differentials, not shown here, share this feature.

Crude oil properties and price differentials

The two main physical characteristics of a crude oil are its American Petroleum Institute gravity (API gravity), which measures density, and its sulfur content. Both features vary between crude oils, and both are the main drivers behind the differentials. The industry labels a crude oil as light, medium or heavy based on its API gravity; sweet or sour based on its sulfur content.

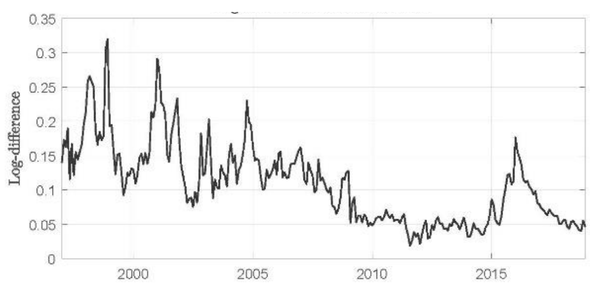

Figure 1. LLS-Mars Differential

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See footnote at end of text.

There is a hierarchy of quality in terms of density, with light at the top and heavy at the bottom; in terms of sulfur content, from sweet crudes to sour ones. Prices follow the same order—with light-sweet crudes usually selling at a premium and heavy-sour crudes at a discount. The premiums attached to light-sweet crude oil versus a heavy-sour crude, for example, can be substantial, at times exceeding 30 percent.

Light-sweet crude commands this price edge for two reasons. When distilled—the first step of processing any crude oil—it yields a large percentage of high-value petroleum products, such as gasoline and diesel. Denser oils (medium and heavy crudes), on the other hand, yield less of those products when distilled and more of what is, essentially, residual fuel oil, a low-value product mostly used to fuel ships. Gasoline and diesel typically command a hefty premium to residual fuel oil.

The second reason for light-sweet crude's premium is due to sulfur content and government regulation. Sulfur is a pollutant, and many countries impose strict requirements on how much sulfur is allowed in petroleum products. Light-sweet crude has low sulfur content and requires less processing to remove sulfur than sour crude.

The discount placed on low-quality crude creates a potential arbitrage opportunity for anyone with a way to transform residual content into higher-value products. This is where complex refineries come into play. They possess specialized equipment, generically known as upgrading or secondary processing units, which enable production of more gasoline and diesel from a given barrel of low-quality feedstock. The most complex refiners processing a heavy crude can often produce as much gasoline and diesel as many simpler refineries can with more expensive, high-quality crude oil.

Data and Method

We construct pairwise log-differentials using 14 daily price series from 1997 to 2018. The use of log-differentials has the advantage of converting units to percent differences. We consider differentials between crudes of different qualities as well as those of similar quality. In order to determine the number and timing of breaks, we use the sequential breakpoint test of Bai (1997)[1].

Results

We first focus on differentials of crude oils of different types. A large number of these quality-related differentials—26 out of 27 cases, to be exact—experienced a break around 2007 and 2008. In most of those cases, there has been a large reduction in the mean, often accompanied by a major drop in volatility. The means and volatilities are often half their pre-break levels.

We next investigated whether oil price differentials between crudes of the same type, for example, two light-sweet crude oils, have experienced a similar set of breaks, particularly around 2008. If that were true, it would suggest a broader change in the oil market not necessarily connected to quality. Overall, we do not find any evidence for this.

Finally, we also document that differentials between high-valued petroleum products, i.e. gasoline and diesel, and low-valued residual fuel oil have experienced breaks of a similar nature to the quality differentials around 2008. The breaks result in a significant decline in the mean value of the residual fuel oil differentials.

Explanations

We consider four factors that could potentially explain our findings: a shift toward greater demand for residual fuel oil; a weakening of government regulations on sulfur emissions; a greater amount of upgrading capacity; and the shale boom.

It is quite easy to rule out shifts in consumer demand for residual fuel oil and government regulations on sulfur emissions as potential explanations. In fact, these two forces should be contributing to larger quality differentials. Data from the International Energy Agency show that since 1997, demand for lighter products, such as gasoline and diesel, has boomed by 19 million barrels per day (mb/d), a 28 percent increase, while residual fuel oil use has declined by 4 mb/d, a 37 percent decline. Government regulations on sulfur emissions have tightened as well.

One factor that can explain our findings is the continued global buildup of more complex refineries. By one measure, upgrading capacity has increased by 69 percent over 17 years.

Another important factor is the U.S. shale oil boom, which has unexpectedly boosted the supply of high-grade, light crude oil. By the end of 2018, U.S. light tight oil production had increased to 7.4 mb/d, 6.7 mb/d higher than it was at the start of 2010. This unexpected boom has reduced, on the margin, the need for more complex refineries to process low-grade crude oils.

Footnote

[1] Bai, J. (1997). Estimating and Testing Linear Models with Multiple Structural Changes. Econometric Theory, (13), 315-352. https://doi.org/10.1017/s0266466600005831.

Closing Plenary Session: How to Align Energy Transition with Climate Objectives?

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The closing plenary was chaired by Mr. Christopher Bonnery, the 2019 IAEE President. Mr. Bonnery introduced the Keynote speaker Professor Weyant from Stanford University, who started his speech by pondering on the question "How to align energy transitions with climate objectives?" The answer to this question, according to professor Weyant, is "Carefully and with great humility".

Professor Weyant further broke the question down to three main questions that require careful consideration:

1. What should our climate objectives be?
2. What role should energy sector transition play in achieving these goals?
3.How should we allow/cause these transitions to occur?

Furthermore, Professor Weyant emphasised that economics plays a significant role while attributing the impacts and calculating the risks of climate change. He referred to his previous work with the IPCC focusing on the economics of climate change policy, seeking to answer the question "what policy instruments are required for containing climate change?" He discussed nuances related to the choice of frameworks, data availability, assumptions and the scope of economic research which can provide answers to questions such as: Are we aiming for a 2-degree rise or 1.5-degree rise in temperature? What are the different impacts? What is the economic impact? What policy instruments and architecture should we use?

After Professor Weyant's speech, the focus was put on the past IAEE presidents on the panel. The panel was made up of Professor Peter Hartley (IAEE President 2015), Professor Andre Plourde (IAEE President 2007) and Professor Ricardo Raineri (IAEE President 2017). They were all asked to reflect on the conference in their year and identify how the conference topics and main concerns have evolved. The past presidents from various years remarked that the discussion on the topic of energy sector transition is new and was not as much of a focus in the previous years. While in the 2000s the discussion focused mainly on electricity sector de-regulation, over the past decade the conversation has moved on to low carbon fuels, and natural gas has seen heavy focus at IAEE conferences over the past few years. It was interesting to hear how the pressing energy sector issues have evolved over the past decades, and we look forward to seeing how it evolves in the future, influencing local energy and global markets.