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Crude Oil Prices

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Predicting Price Differentials Based on Quality

Many developing countries are becoming oil exporters, producing crude oils that often differ markedly in quality from those principally traded. Governments must predict the prices of such crudes to forecast revenue and evaluate the fairness of the price they receive from companies selling on their behalf. Oil companies and industry consultants have models for analyzing price differentials with well-known "marker" crudes, but these models have not been widely known or adapted to account for increasingly important quality characteristics such as acidity. This Note explains a methodology for price analysis and a new extension for incorporating acidity, which can have a big effect on the price differential.

The world produces and trades more than 160 varieties of crude oil, which range widely in price: while the United Kingdom's Brent Blend averaged US$43.04 in August 2004, Syrian Heavy averaged US$29.97. Such large differentials show why a single price cannot serve as a forecast for all crudes.[1]

In recent years many new producer countries have started to export substantial amounts of crude oil, including Azerbaijan, Chad, Equatorial Guinea, Kazakhstan, and Sudan. Several others are promoting petroleum exploration, with good prospects of finding commercially viable amounts of oil. And existing producers are opening new fields where the quality of oil can differ greatly from that of fields already under production. In all these cases governments need to understand the revenue implications of new production streams, because these can account for a large share of their budget. Long-term price forecasts are regularly published for key crudes—such as Brent Blend, West Texas Intermediate, or Dubai—but no forecasts are published for other crudes. Instead, forecasts for a "marker" crude are adjusted by a discount (or premium) specific to each crude that is based on various aspects of quality.

Under production sharing contracts the government often relies on the oil company to sell its share. Similarly, under royalty agreements the concessionaire usually sells the oil and transfers the royalties, linked to the price of crude, to

the government. Since the price governments receive may differ, sometimes substantially, from the well-publicized marker crude prices, they need to understand the factors that influence the discount. For new producer countries, where the quality of crude may differ substantially from that of the marker crudes, this understanding is critical for projecting revenue and establishing more trusting relationships with oil companies.

Defining quality

Crude oils differ from one another in a large number of chemical and physical properties, many of which play an important part in their refining and subsequent sale as petroleum products. Until now statistical analysis of price differentials has focused on two main properties: the specific gravity (lightness) measured in degrees API (a scale devised by the American Petroleum Institute) and the percentage of sulfur content by weight.

Lighter crudes (with higher API) produce a larger number of lighter products, such as gasoline, which have higher resale value. So other qualities being equal, lighter crudes are expected to sell at a premium over heavier crudes. By extension, if the prices of all petroleum products rise by the same percentage amount, the absolute price differential between a heavy crude and a light crude (the discount) can be expected to grow.

A high sulfur content has an adverse effect on the value of crudes, because it leads to higher operating costs for refineries due to special processing and maintenance requirements. In addition, in many countries new legislation mandates lower sulfur content for gasoline and diesel. So a high-sulfur (sour) crude is expected to sell at a discount relative to a low-sulfur (sweet) crude of the same API. And an increase in the share of high-sulfur crude in the world market, or a relative increase in the demand for low-sulfur products, is expected to result in larger discounts for high-sulfur crudes.

Another important property is acidity. The recent emergence of West African and other producers has led to an increase in the supply and number of crudes with high acidity as measured by the total acid number (TAN), an aggregate index that includes various types of acid. Some of these acids pose no particular problems in the refinery process. But above a certain limit acidity has a corrosive effect on refineries. Blending low-TAN with high-TAN crude can deal with this problem, but it increases logistical costs. New refineries constructed using special materials can tolerate higher acidity but are few in number. Thus crudes with a high TAN (greater than around 0.5), because they limit the options for refining, are likely to command a discount.

In recent years high-TAN crude has accounted for a growing share of the global oil supply: an industry study reports that crude with a TAN greater than 1.0 increased from 7.5 percent of the global supply in 1998 to around 9.5 percent today.[2] For West African crude the picture is even more dramatic: in 2001 only 5 percent had a TAN greater than 1.0, but by 2006 this share is expected to rise to 13 percent. If a high TAN means a substantial discount, this forecast has important implications for developing countries depending on oil for a large share of government revenue. Moreover, if the share of high-TAN crude grows more rapidly than the refineries able to accommodate it are constructed, the discount can be expected to increase.

Relating quality to discounts

Oil companies and analysts have developed models for predicting discounts, some of which are commercially available as off-the-shelf products. But these models have centered on API and sulfur content. The growing importance of high-TAN crudes, especially from developing countries, calls for extending these models. Two approaches have been used. The first is based on a simple pairwise comparison of crudes identical in all major aspects of quality except the one being investigated. The second is based on a regression model that can simultaneously incorporate all quality differences.

If crude oils differ in only one dimension of quality, pairwise comparisons can be used to relate the price differential to that difference in quality. But any single comparison would be affected by factors relating to the period or to nonquality characteristics of the crudes being compared. As a result, a series of comparisons

for several different crudes or for several different periods will not yield identical results, so that the results need to be averaged over a group of crudes. This approach can be extended to comparisons of crudes differing in more than one dimension of quality by utilizing a series of pairwise comparisons.

A regression model overcomes these difficulties by simultaneously incorporating differences in all important qualities in relation to the price differential. Assuming that the effects of a one-unit difference in quality are the same regardless of the crudes being considered, and that the effects of differences in several measures of quality are additive, the discount effect can be formulated as follows:

$$\Delta \text{ price} = a + \Sigma_i \, b_i \, (\Delta \text{ quality}_i)$$

where Δ price is the difference in price between a given crude and some marker crude, Δ quality$_i$ is the difference in quality i between that crude and the marker crude, Σ represents the sum of the qualities (three in the case considered below), and a and b_i are parameters to be established by regression analysis.

In this model the parameter b measures the effect on the price differential of a one-unit increase in the difference in each dimension of quality between the crude in question and the marker crude.

Although a regression model will not fully explain each difference in price in terms of differences in quality, evidence for a large number of crudes can identify effects common to all. Moreover, since the effects (other than those relating to the general oil price level) are not expected to change rapidly, the model should be applicable to a succession of intervals and the values of the coefficients should be stable. So data for a number of crudes and for a number of periods can be used in the same regression (utilizing a pooled cross-section time-series approach). The quality characteristics of each crude are assumed to remain stable throughout each period, since there is no published evidence on changes over time. But if the period used is too long, the physical characteristics of crude oils, especially blends, may change enough to introduce inaccuracies.

The model as presented above is static. Thus it would predict that the set of price differentials between all crudes would stay constant as long as the qualities of the crudes remained constant. In fact, a plot of the average price difference between crudes, period by period, shows substantial movement, roughly matching the movement of the Brent price, with a greater spread of differentials at higher prices. To allow for the hypothesis that a given difference in API has a greater effect at higher prices, the API differential term is modified by scaling it by the current Brent price. Another extension to the model introduces a lagged value of the price differential into the equation, recognizing that price differentials may not fully adjust within a month (the data period used) to a change in the average Brent price within that period, but that some adjustment may spill over into the next month.

Estimating the model

Estimating the model required identifying the crudes for which data on both quality specifications and spot prices were publicly available for a number of months. Data on 56 crudes were collected for the period January 2003–June 2004, with data on quality taken from several Web sites and data on monthly average prices (fob) taken from the Platts Oilgram Price Report.

Brent Blend was taken as the reference crude, since it is among the most common markers for commercial deals. Brent is a high-quality light crude (API of 38.3) with low sulfur (0.37 percent) and a very low TAN (0.07), so that most other crudes would be expected to sell at a discount relative to it. During the period analyzed the price of Brent ranged between US$25 and US$38 a barrel.

The model that was estimated includes several refinements to the simple framework described above:

- The difference in API is multiplied by the current Brent price because the absolute difference in the lightness of the crude is expected to lead to a larger absolute price differential when the general oil price is higher.
- The difference in TAN is included only for crudes whose TAN is above 0.5, allowing for the assumption that below a certain threshold refiners need to take no special action.
- Freight rates between Europe and the region

Box 1 Checking the price differential for Syrian Heavy crude in June 2004

The case of Syrian Heavy illustrates how the model can be used to estimate what a price would have been given the model's assumptions. Syrian Heavy has low API (24.1), a high sulfur content (3.9 percent) but a TAN (0.17) below the threshold at which the model takes it into account.

Price of Brent Blend in June 2004		= US$35.04
Discount in May 2004		= –US$5.93
Effect of lagged discount	= 0.67 (5.93)	= –US$3.98
Effect of lower API	= 0.00154 x 35.04 (24.1 – 38.3)	= –US$0.77
Effect of higher sulfur	= 0.27 (3.9 – 0.37)	= –US$0.95
Effect of higher TAN	= 0 (0.17 – 0.07)	= –US$0.00
Effect of transport differentials		= –US$0.28
Total predicted discount relative to Brent		= –US$5.98
Actual discount relative to Brent		= –US$6.24
Predicted Syrian Heavy price at actual Brent price		= US$29.06
Actual Syrian Heavy price		= US$28.80

The strong coherence between the prediction and the actual data confirms, within the margin of error of such a regression model and taking quality characteristics into account, that the price of Syrian Heavy conformed to those of other crudes.

from which the other crudes originate are introduced to allow for systematic differences due to transport costs and for variations over time due to changes in transport costs. This term also includes a constant effect common to all crudes.

All variables are strongly significant and of the expected sign, and the overall squared correlation coefficient is 80 percent. The coefficient of the lagged price differential is estimated at 0.67. The long-run effects of the variables, evaluated as if the Brent price settled at some constant level, are as follows:

Per unit of sulfur	–US$0.82
Per unit of TAN	–US$0.88
Per unit of API per dollar of Brent	+US$0.0047

The interpretation of the API coefficient is particularly interesting. At a price of US$20 a barrel for Brent each degree of API is worth 9.4¢, while at a price of US$40 it is worth 18.8¢, supporting the hypothesis that differentials increase as crude prices rise.

The model can be used to predict the price of future streams of crude of known quality under assumed Brent prices or to "backcast" by estimating what the price of a known crude would have been given the model's assumptions, to see whether there was anything unusual about the actual price received (box 1).

Conclusion

A regression model relating price differentials to differences in quality characteristics can be a valuable tool for analyzing the price of new crudes whose quality differs greatly from that of the marker crude. This capability enables governments whose country produces such crudes to better forecast future revenue streams and to verify that the prices received from companies selling the oil on their behalf are reasonable.

Notes

This Note is taken from a larger study now under preparation.

1. Conventionally the industry focuses on absolute (dollar) differentials rather than relative (percentage) differentials.

2. Anne Shafizadeh, Gregg McAteer, and John Sigmon, "High-Acid Crudes," paper presented at Crude Oil Quality Group meeting, New Orleans, January 30, 2003 [http://www.coqg.org/20030130special.asp].

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