Causality in Crude Oil Prices

Bjorn Hagstromer and Szymon Wlazlowski

18. January 2007

Causality in Crude Oil Prices

Björn Hagströmer Szymon Wlazlowski *†

January 18, 2007

Abstract

The world market of crude oil has three well established benchmarks used for pricing of other crudes: West Texas Intermediate, Europe Brent and Dubai Fateh. The relevance of these are however declining, as the output of the benchmarks is decreasing, and as an increasing share of world crude produced is of worse quality than the benchmarks (pointed out by e.g. Montepeque, 2005). Particularly the segment of medium density, sour crudes is lacking a reliable benchmark.

We apply Granger causality tests to study the price dependencies of 32 crude oils empirically. The aim is to establish what crudes are setting the prices and what crudes are just following the general market trend. The investigation is performed globally as well as for different quality segments, geographical segments and the segments of OPEC and non-OPEC crudes.

The results indicate that crude oil price analysts should follow at least four different crudes that are if not benchmarks, at least good price indicators. While the well-established benchmarks WTI and Brent still lead the market, they are not the only crude prices worth paying attention to. In particular, Russian Urals drives global prices in a significant way, and Iran Seri Kerir is a significant price setter within OPEC.

Dubai Fateh does not display any significant influence as a price setter. The lack of a reliable benchmark for medium density, sour crudes is thereby confirmed.

*The authors are PhD Researchers at Aston Business School, Aston Triangle, Birmingham B4 7ET, UK. E-mail addresses: hagstrob@aston.ac.uk (B. Hagströmer), wlazloss@aston.ac.uk. (S. Wlazlowski).

†The authors would like to acknowledge the helpful comments by Dr Monica Giulietti (Aston Business School) and Dr Richard G. Anderson (Federal Reserve Bank of St. Louis). The usual disclaimer applies.

1 Introduction

With global energy demand soaring, more and more reservoirs of different varieties of crude oils enter the energy markets (see Bahree & Gold, 2006, for most recent examples). In the increasingly volatile crude oil market (Gülen, 1997;1999), the differences in crudes' qualities (light/medium/heavy, sweet/sour, etc.) prevent straightforward observations of *which* crudes swiftly reflect changes in market segments and can be regarded as benchmark crudes (for a sample discussion see Wilkinson, 2004).

Montepeque (2005) provides a list of features that a good benchmark crude ideally should fulfill, but to the best of our knowledge no empirical work that covers the global market dependencies exists. The question therefore remains which varieties of crude oil first respond to changing market conditions (and are therefore useful as guidelines for practitioners and energy economists) and which simply follow them (which must be the case in closely integrated global market). We make a distinction between *benchmarks*, that are used in price setting in practice, and *price setters*, that can be shown to be the crudes actually showing price changes first. In this paper we focus on the latter. We try to find which crude oils can be defined as *price setters* in the world and in different market segments (quality segments, geographical segments and segments for OPEC and non-OPEC products).

There are three well-established *benchmark* crudes on the market: Brent, WTI and Dubai Fateh. In practice, these serve as guidelines for price-setting of other crudes, but their relevance has declined over the years - see Wilkinson (2004) and Montepeque (2005) for discussion. This is due to several reasons.

Firstly, Brent and WTI are both high quality crudes (light and sweet), whereas global crude oil market is more and more concerned with lower quality crudes (heavy and sour). Those crudes constitute a significant share of world production (almost 50%, according to Montepeque, 2005), which is very likely to further increase, especially if heavy crude reserves are made available thanks to steam flooding and other technologies (see Bahree & Gold, 2006).

Secondly, the actual trade in benchmark crudes is small, which makes them vulnerable to market manipulation. Dubai, a medium-sour crude benchmark, has an output as small as 0.13% of world production, and is declining[1]. The same problem applies to Brent and WTI - their outputs are 0.68% and 1.77% of world production respectively[2].

The above indicates that relationships between prices should be analyzed more closely so as to establish which crudes drive prices of other crudes and thus correctly represent market behavior. Such crudes might serve if not as benchmarks then at least as indicators of the market situation. These are the *price setters* that we seek to identify in this paper.

Given the importance of finding linkages between various kinds of crude oils, causality in crude oil prices has received surprisingly little attention. Former research has stated various price setting relationships between oil qualities, but the investigation was constrained with respect to geographical markets and number of crudes.

Horsnell (2004) states that Dubai tends to be followed by Suez Blend. Montepeque (2005) states that Brent is followed by Mediterranean Russian Urals and that WTI is followed by Mars (an American sour crude benchmark, which is not in our sample). In Lin & Tamvakis (2004) it is shown that the price changes of Brent in London follows the price changes of WTI in New York. While previous research provides valuable insight into global mechanisms of crude oil pricing, it covers only parts of the market.

This article approaches the problem of modeling global crude oil market in a way that is unique in several respects:

- firstly, we model 32 different kinds of crudes, thus obtaining a complete picture of global interdependencies;
- secondly, we account for several characteristics of different crude oils, effectively analyzing both global market and its segments, such as:
  - quality segments (sweet and sour, and light, medium and heavy density crudes);
  - geographical segments;
  - segments for OPEC and non-OPEC products;
- thirdly, we apply time series techniques (Granger causality tests) that have been previously used to analyze direction of causality in energy markets, see Manning (1991), but only for the crude oil *downstream* (end product) market.

[1] Montepeque (2005) discusses the problems of Dubai as a benchmark in detail.
[2] Authors' calculations, based on Eni SpA (2006) and Montepeque (2005)

We perform Granger causality tests on each pair of 32 different crude oil qualities. The results are interpreted globally and in various sub-groups, which split the crudes according to geographical origin, crude oil characteristic (API and sulphur content) and OPEC membership of the origin country. Those tests allow us to distinguish:

- which crudes first respond to changes in market environment - and therefore are *price setters*;
- which crudes mainly follow other price changes - and therefore are *price takers*.

The results enable us to analyze which varieties of crude are leading the price changes in the global energy market and as such could be considered benchmarks.

2 Data Analysis

Weekly FOB spot prices per barrel of crude oils for the period January'97 - March'06 were obtained from Energy Information Agency website. A total number of 32 crudes were analyzed. We also gathered additional information on quality of the crudes (as described by light/medium/heavy and sweet/sour varieties) and labeled them accordingly. Light, medium and heavy refer to the density of the crude and is measured in degrees API. The higher API degree a crude has, the lighter it is and the higher the quality is. Sweet and sour refer to the sulphur content of the crude. Sulphur causes pollution and hence its content should be low. Low sulphur content crudes are sweet, high sulphur content crudes are sour. Grouping was based on definitions from OPEC (2005):

- crudes with API$> 35^\circ$ are *light*, $26^\circ <$API$< 35^\circ$ are *medium* and API$< 26^\circ$ are *heavy*;
- crudes are considered to be *sweet* when the sulphur content does not exceed 0.5% and *sour* otherwise.

The sample is split into four major groups:

- the global market, including all crudes in the sample;
- crudes of the same quality segment (the quality segments considered are *light density & sweet*, *medium density & sweet*, and *medium density & sour*;

- crudes of same geographical region (the regions considered are *Europe*, *Middle East & Northern Africa* [the MENA countries], *Americas* [including North, Central and South America], *Sub-Saharan Africa*, and *Asia & Australia* [excluding Middle East]);

- crudes from OPEC / non-OPEC countries.

Table 1 presents details of the crudes analyzed. We analyze three quality segments: light density, sweet crudes contain 9 crudes; medium density, sour crudes contain 13; and medium density, sweet crudes contain 6. Our sample size for the quality segments of light density , sweet crudes and heavy density, sour crudes are too small to perform any useful analysis. The geographical segments are Europe (4 crudes), North and South American (8), Middle East and North Africa (13), Sub-Saharan Africa (4), and Asia and Australia (4). There are 17 crudes produced in non-OPEC countries, while the remaining 15 come from OPEC countries.

Table 1: Details of Crudes analyzed.

Symbol	**Crude**	**API**	**Sulphur (%)**
	Non-OPEC		
$x_t^{(1)}$	WTI Cushing	40° - light	0.2 - sweet
$x_t^{(2)}$	Europe Brent	38° - light	0.4 - sweet
$x_t^{(3)}$	Europe Norwegian Ekofisk	43° - light	0.1 - sweet
$x_t^{(4)}$	Canadian Par	40° - light	0.3 - sweet
$x_t^{(5)}$	Canada Lloyd Blend	22° - heavy	3.1 - sour
$x_t^{(6)}$	Mexico Isthmus	35° - medium	1.5 - sour
$x_t^{(7)}$	Mexico Maya	22° - heavy	3.3 - sour
$x_t^{(8)}$	Colombia Cano Limon	30° - medium	0.5 - sweet
$x_t^{(9)}$	Ecuador Oriente	29° - medium	1.0 - sour
$x_t^{(10)}$	Angola Cabinda	32° - medium	0.2 - sweet
$x_t^{(11)}$	Cameroon Kole	35° - medium	0.3 - sweet
$x_t^{(12)}$	Egypt Suez Blend	32° - medium	1.5 - sour
$x_t^{(13)}$	Oman Blend	34° - medium	0.8 - sour
$x_t^{(14)}$	Australia Gippsland	45° - light	0.1 - sweet
$x_t^{(15)}$	Malaysia Tapis	44° - light	0.1 - sweet
$x_t^{(16)}$	Mediterranean Russian Urals	32° - medium	1.3 - sour
$x_t^{(17)}$	China Daqing	33° - medium	0.1 - sweet

Table 1: Details of Crudes analyzed.

Symbol	**Crude**	**API**	**Sulphur (%)**
	OPEC		
$x_t^{(18)}$	Saudi Arabia Saudi Light	34° - medium	1.7 - sour
$x_t^{(19)}$	Saudi Arabia Arab Medium	31° - medium	2.3 - sour
$x_t^{(20)}$	Saudi Arabia Saudi Heavy	28° - medium	2.8 - sour
$x_t^{(21)}$	Asia Murban	40° - light	0.8 - sour
$x_t^{(22)}$	Asia Dubai Fateh	32° - medium	1.9 - sour
$x_t^{(23)}$	Qatar Dukhan	40° - light	1.2 - sour
$x_t^{(24)}$	Mediterranean Seri Kerir Iran Light	34° - medium	1.4 - sour
$x_t^{(25)}$	Medit. Seri Kerir Iran Heavy	31° - medium	1.6 - sour
$x_t^{(26)}$	Kuwait Blend	31° - medium	2.5 - sour
$x_t^{(27)}$	Algeria Saharan Blend	44° - light	0.1 - sweet
$x_t^{(28)}$	Europe Nigerian Bonny Light	37° - light	0.1 - sweet
$x_t^{(29)}$	Europe Forcados	30° - medium	0.3 - sweet
$x_t^{(30)}$	Europe Libyan Es Sider	37° - light	0.4 - sweet
$x_t^{(31)}$	Indonesia Minas	34° - medium	0.1 - sweet
$x_t^{(32)}$	Venezuela Tia Juana	31° - medium	1.1 - sour

3 Causality

For each pair of the series, a Granger causality test was performed. Bivariate Granger causality tests for two variables ($x_t^{(i)}$ and $x_t^{(j)}$) evaluate whether the past values of $x_t^{(i)}$ are useful for predicting $x_t^{(j)}$ once $x_t^{(j)}$'s history has been modelled. The null hypothesis, evaluated at a confidence level of 5%, is that the past p values of $x_t^{(i)}$ do not help in predicting the value of $x_t^{(j)}$. The test is implemented by regressing $x_t^{(j)}$ on p past values of $x_t^{(i)}$ and p past values of $x_t^{(j)}$. An F-test is then used to determine whether the coefficients of the p past values of $x_t^{(i)}$ are jointly zero - Granger (1969). The pair of these two prices is evaluated as follows:

$$
\begin{aligned}
x_t^{(i)} &= \sum_{l=1}^{p} a_l x_{t-l}^{(i)} + \sum_{m=1}^{p} b_m x_{t-m}^{(j)} \\
x_t^{(j)} &= \sum_{l=1}^{p} c_l x_{t-l}^{(i)} + \sum_{m=1}^{p} d_m x_{t-m}^{(j)}
\end{aligned} \tag{1}
$$

In that setting the coefficients of interests (b_m and c_l) indicate causality. If $x_t^{(j)}$ Granger causes $x_t^{(i)}$ then at least one element of b must be different from zero. In the same way, if $x_t^{(i)}$ Granger causes $x_t^{(j)}$ then at least one element of c must be different from zero. The F test of the null hypothesis that all elements of b (or c) vectors helps to distinguish which crudes are price setters (i.e. Granger causes other prices) and which are takers (i.e. are Granger caused by other prices).

The p parameter was set 16 (4 months), which is reasonable given the rapid developments on the markets.[3] A total of 992 tests were conducted. Each test shows (a) whether $x_t^{(i)}$ is a price setter of $x_t^{(j)}$ and accordingly (b) whether $x_t^{(j)}$ is a price taker. This yields 31 tests for each crude oil's price setter characteristics and 31 tests of whether it is a price taker.

Furthermore, crudes were separated in accordance with the segments presented above, and appropriate tests were repeated, but this time to see if prices of crude from a particular group Granger cause prices of other crudes from that segment only. For example, prices of 17 non-OPEC crudes were analyzed to see which ones are takers and which ones are setters within that particular segment.

Table 7 (in the appendix) presents the results of all Granger tests. For each crude's respective group, the percentage of Granger tests statistics where the null was rejected is given, i.e. the fraction of cases where price setter and price taker characteristics respectively were implied. In such a setting, a ratio of 1 in the price setter (price taker) section of Table 7 implies that the crude is causing (is being Granger caused by) all the other crudes in the group, whereas a number closer to 0 implies the opposite. The same logic applies for all the tables below.

[3]The calculations were repeated for different values of p, the results were not changed.

4 Results

The results are interpreted by the following logic. Crudes that consistently have price setter factors that equal one are regarded as price setters, and may be benchmarks.

On the assumption that all crude prices eventually will follow the market movements, high price setter factors combined with low price taking factors are interpreted as strong ability to quickly respond to market changes. Low price setter factors combined with high price taker factors, on the other hand, are taken as indications of slow market adaptation behavior. For example, in Table 2 that displays overall results, West Texas Intermediate ($x_t^{(1)}$) is a price taker in 13% of the tests and a price setter in 100% of the tests, and is hence a clear world-wide price setter. Canadian Lloyd Blend ($x_t^{(5)}$) have high percentages of significance in both tests (100% price taker and 94% price setter), and can hence be concluded to respond quickly to market changes. An example of a crude that responds slowly to world market price changes is Malaysia Tapis ($x_t^{(15)}$) with 100% price taker and 13% price setter properties.

The general results that can be observed from Table 2 are that:

- the acclaimed benchmarks, WTI ($x_t^{(1)}$) and Brent ($x_t^{(2)}$), are global price setters, and within their quality segment (light and sweet) in particular;
- Mediterranean Russian Urals ($x_t^{(16)}$) is, in spite of little public attention, a third global price setter;
- Asia Dubai Fateh ($x_t^{(22)}$) and Oman Blend ($x_t^{(13)}$), that together serve as a benchmark crude for its segment, does not display price setter properties on the world market.

To further analyze our results, we study each grouping defined above separately, beginning with the different quality segments, followed by the OPEC/non-OPEC division, and last the geographical regions.

Table 2: Results: World

Symbol	Crude	Taker	Setter
$x_t^{(1)}$	West Texas Intermediate	0.13	1
$x_t^{(2)}$	Europe Brent	0.26	0.97
$x_t^{(3)}$	Europe Norwegian Ekofisk	0.68	0.71
$x_t^{(4)}$	Canadian Par	1	0.65
$x_t^{(5)}$	Canada Lloyd Blend	1	0.94
$x_t^{(6)}$	Mexico Isthmus	0.45	0.87
$x_t^{(7)}$	Mexico Maya	0.16	0.71
$x_t^{(8)}$	Colombia Cano Limon	0.26	0.84
$x_t^{(9)}$	Ecuador Oriente	0.87	0.68
$x_t^{(10)}$	Angola Cabinda	0.74	0.65
$x_t^{(11)}$	Cameroon Kole	0.87	0.74
$x_t^{(12)}$	Egypt Suez Blend	0.84	0.55
$x_t^{(13)}$	Oman Blend	0.84	0.77
$x_t^{(14)}$	Australia Gippsland	0.77	0.61
$x_t^{(15)}$	Malaysia Tapis	1	0.13
$x_t^{(16)}$	Mediterranean Rusian Urals	0.42	1
$x_t^{(17)}$	China Daqing	1	0.35
$x_t^{(18)}$	Saudi Arabia Saudi Light	0.48	0.58
$x_t^{(19)}$	Saudi Arabia Arab Medium	0.52	0.65
$x_t^{(20)}$	Saudi Arabia Saudi Heavy	0.52	0.61
$x_t^{(21)}$	Asia Murban	0.81	0.84
$x_t^{(22)}$	Asia Dubai Fateh	0.81	0.68
$x_t^{(23)}$	Qatar Dukhan	0.84	0.77
$x_t^{(24)}$	Medit. Seri K Iran Light	0.61	0.84
$x_t^{(25)}$	Medit. Seri K Iran Heavy	0.77	0.84
$x_t^{(26)}$	Kuwait Blend	0.9	0.87
$x_t^{(27)}$	Algeria Saharan Blend	0.58	0.61
$x_t^{(28)}$	Europe Nigerian Bonny Light	0.81	0.58
$x_t^{(29)}$	Europe Forcados	0.71	0.68
$x_t^{(30)}$	Europe Libyan Es Sider	0.9	0.77
$x_t^{(31)}$	Indonesia Minas	1	0.48
$x_t^{(32)}$	Venezuela Tia Juana	0.94	0.52

Table 3: Light density & sweet

Symbol	Crude	Taker	Setter
$x_t^{(1)}$	West Texas Intermediate	0.25	1
$x_t^{(2)}$	Europe Brent	0.25	1
$x_t^{(3)}$	Europe Norwegian Ekofisk	0.62	0.62
$x_t^{(4)}$	Canadian Par	1	0.5
$x_t^{(14)}$	Australia Gippsland	0.75	0.62
$x_t^{(15)}$	Malaysia Tapis	1	0.12
$x_t^{(27)}$	Algeria Saharan Blend	0.5	0.62
$x_t^{(28)}$	Europe Nigerian Bonny Light	0.62	0.5
$x_t^{(30)}$	Europe Libyan Es Sider	0.88	0.88

Table 4: Medium density & sweet

Symbol	Crude	Taker	Setter
$x_t^{(6)}$	Mexico Isthmus	0.31	0.85
$x_t^{(9)}$	Ecuador Oriente	1	0.46
$x_t^{(12)}$	Egypt Suez Blend	1	0.46
$x_t^{(13)}$	Oman Blend	0.92	0.85
$x_t^{(16)}$	Mediterranean Russian Urals	0.54	1
$x_t^{(18)}$	Saudi Arabia Saudi Light	0.62	0.62
$x_t^{(19)}$	Saudi Arabia Arab Medium	0.62	0.62
$x_t^{(20)}$	Saudi Arabia Saudi Heavy	0.62	0.62
$x_t^{(22)}$	Asia Dubai Fateh	0.92	0.62
$x_t^{(24)}$	Medit. Seri K Iran Light	0.46	0.85
$x_t^{(25)}$	Medit. Seri K Iran Heavy	0.69	0.77
$x_t^{(26)}$	Kuwait Blend	1	0.85
$x_t^{(32)}$	Venezuela Tia Juana	1	0.46

Table 5: Medium density & sweet

Symbol	Crude	Taker	Setter
$x_t^{(8)}$	Colombia Cano Limon	0.15	0.85
$x_t^{(10)}$	Angola Cabinda	1	1
$x_t^{(11)}$	Cameroon Kole	1	1
$x_t^{(17)}$	China Daqing	1	0.75
$x_t^{(29)}$	Europe Forcados	0.5	1
$x_t^{(31)}$	Indonesia Minas	1	0.75

Table 6: OPEC

Symbol	Crude	Taker	Setter
$x_t^{(18)}$	Saudi Arabia Saudi Light	0.5	0.71
$x_t^{(19)}$	Saudi Arabia Arab Medium	0.57	0.79
$x_t^{(20)}$	Saudi Arabia Saudi Heavy	0.5	0.71
$x_t^{(21)}$	Asia Murban	0.86	0.93
$x_t^{(22)}$	Asia Dubai Fateh	0.86	0.79
$x_t^{(23)}$	Qatar Dukhan	0.86	0.86
$x_t^{(24)}$	Medit. Seri K Iran Light	0.64	1
$x_t^{(25)}$	Medit. Seri K Iran Heavy	0.86	0.93
$x_t^{(26)}$	Kuwait Blend	0.93	0.86
$x_t^{(27)}$	Algeria Saharan Blend	0.5	0.71
$x_t^{(28)}$	Europe Nigerian Bonny Light	0.86	0.64
$x_t^{(29)}$	Europe Forcados	0.57	0.71
$x_t^{(30)}$	Europe Libyan Es Sider	0.93	0.79
$x_t^{(31)}$	Indonesia Minas	1	0.5
$x_t^{(32)}$	Venezuela Tia Juana	1	0.5

With respect to quality segments:

- the nine light density and sweet crudes (presented in Table 3) are, as expected, dominated by WTI and Brent. Norway Ekofisk ($x_t^{(3)}$), Australia Gippsland ($x_t^{(14)}$), Algerian Saharan Blend ($x_t^{(27)}$), Nigeria Bonny Light ($x_t^{(28)}$), and Libya El Sider ($x_t^{(30)}$) adjust quickly to benchmark price changes, whereas Canada Par ($x_t^{(4)}$) and Malaysia Tapis ($x_t^{(15)}$) respond slower. (The results do not show the direction of causality between WTI and Brent, which has been studied by Lin & Tamvakis, 2004);

- for medium density and sour crudes (presented in Table 4), Asia Dubai Fateh ($x_t^{(22)}$) is the benchmark in practice, but, according to Montepeque (2005), it is badly working, mainly due to low output. In our investigation, Dubai Fateh does not display a strong price setting position. Instead, Mediterranean Russian Urals is a very clear price setter in the segment. However, Seri Kerir Iran Light and Mexico Isthmus also display price setting properties. This plethora of price setters confirms the lack of leading benchmark in the medium sour segment, discussed by Montepeque

(2005). Oman Blend ($x_t^{(13)}$) and Kuwait Blend ($x_t^{(26)}$) respond quickly to price changes, whereas Ecuador Oriente ($x_t^{(9)}$), Egypt Suez Blend ($x_t^{(12)}$), and Venezuela Tia Juana ($x_t^{(32)}$) are apparent price takers in the segment, responding slowly to market changes;

- the segment of medium density and sweet crudes (presented in Table 5), Colombia Cano Limon ($x_t^{(8)}$) and Europe Forcados from Nigeria ($x_t^{(29)}$) indicate a price setting influence, but all the other crudes in the segment follow very quickly. None of the crudes in the segment is a price setter in the world-wide comparison, indicating that the whole segment follows price setters in some other quality segment, probably WTI and Brent;
- Our sample sizes for the quality segments of light density & sour and heavy & sour crude oils are too small to perform any useful analysis.

With respect to the OPEC/non-OPEC division (presented in Table 6):

- prices of crudes from OPEC countries follow each other more closely than prices of non-OPEC crudes do, which is in line with the organization's pricing policy. Mediterranean Seri Kerir Iran Light ($x_t^{(25)}$) stands out as a price setter within the group. Two crude oils of non-Arabic origin respond clearly slower to price changes – Indonesia Minas ($x_t^{(31)}$) and Venezuela Tia Juana ($x_t^{(32)}$).

With respect to the geographical regions:

- the Middle Eastern and North African region (the *MENA* countries) generally consists of OPEC members, and the crudes in the group follow in general the pattern seen in the OPEC category, with Iranian Light ($x_t^{(25)}$) as a leader. Furthermore, the crudes from the region are all of similar quality – light/medium density and sour. The non-OPEC Egyptian Suez Blend ($x_t^{(12)}$) is a price taker in the region. The Oman Blend ($x_t^{(13)}$), also non-OPEC, and Dubai Fateh ($x_t^{(22)}$), which together form a benchmark, follow the market closely, but do not display price setting influence here either;
- the Sub-Saharan African crudes are all of light or medium density and sweet. The tests indicate no dependencies within the region (0% in all cases), and none of them

are price setters in the world-wide comparison either. As for sweet crudes in general, WTI and Brent has influence in the price setting. The region is interesting though, as the African countries' share of world production is growing;

- On the North and South American markets, no general patterns can be seen. The region is represented here by many different crude qualities and market systems. A bigger sample that would allow division in sub-regions would probably give a clearer picture.

While the results reported above are consistent and present a global coherent picture of relations between crudes, we do acknowledge that there is a significant room for further research, especially:

- with higher frequency data, perhaps even tick data;
- with data on futures, which might also provide some valuable insight into causality in crude oil markets, as they convey significant information on linkages between prices of crudes;
- with time series data on trade volumes, so as to determine whether the price-setters tend to be trading in larger volumes and vice versa.

5 Conclusions

Crude oil price analysts should follow at least four different crudes that are if not benchmarks, at least good price indicators. The traditional benchmarks Brent and WTI are confirmed to be global price setters. More surprisingly, Russian Urals exhibits significant global price setting behavior maintain as well, and Seri Kerir Iran Light is an important price setter within OPEC. The lack of dominant benchmark in the segment of medium density, sour crude, pointed out by Montepeque (2005), is confirmed. The benchmark in practice for that segment, Dubai Fateh, is not indicated as a price setter.

References

B. Bahree & R. Gold (2006). 'Saudi Heavy Oil May Help in Global Energy Crunch'. *The Wall Street Journal Europe* **24**(111):1–2.

Eni SpA (2006). 'World Oil & Gas Review 2006'. Tech. rep., Eni SpA.

C. Granger (1969). 'Investigating Causal Relations by Econometric Models and Cross-spectral Methods'. *Econometrica* **37**(3):424–438.

S. Gülen (1997). 'Regionalization in the World Crude Oil Market'. *The Energy Journal* **18**(2):109–126.

S. Gülen (1999). 'Regionalization in the World Crude Oil Market: Further Evidence'. *The Energy Journal* **20**(1):125–139.

P. Horsnell (2004). 'Oil Price Differentials: Markets in Disarray'. *The OIES Series of Papers on Gulf and World Oil Issues* (3).

S. X. Lin & M. N. Tamvakis (2004). 'Effects of NYMEX trading on IPE Brent Crude Futures Markets: A Duration Analysis'. *Energy Policy* **32**:77–82.

D. Manning (1991). 'Petrol prices oil price rises and oil price falls some evidence for the UK since 1972'. *Applied Economics* **23**:1535–1541.

J. Montepeque (2005). 'Sour Crude Pricing: A Pressing Global Issue'. *Middle East Economic Survey* **XLVIII**(14).

OPEC (2005). 'Monthly Oil Market Report August 2005' .

R. Wilkinson (2004). 'WEC: Brent Crude Challenged as Oil Price Benchmark'. *Oil & Gas Journal* **102**(34):24.

Appendix

Table 7: Results of Granger tests. Percentages of pairs when null of no Granger Causality was rejected.

Symbol	Price Taker				Price Setter			
	Overall	**OPEC**	**Region**	**Quality**	**Overall**	**OPEC**	**Region**	**Quality**
				Non-OPEC				
$x_t^{(01)}$	0.13	0.25	0.29	0.25	1.00	1.00	1.00	1.00
$x_t^{(02)}$	0.26	0.19	0.50	0.25	0.97	0.94	0.50	1.00
$x_t^{(03)}$	0.68	0.75	1.00	0.62	0.71	0.69	0.00	0.62
$x_t^{(04)}$	1.00	1.00	1.00	1.00	0.65	0.69	0.57	0.50
$x_t^{(05)}$	1.00	1.00	1.00	1.00	0.94	0.88	1.00	1.00
$x_t^{(06)}$	0.45	0.62	0.43	0.31	0.87	0.75	0.71	0.85
$x_t^{(07)}$	0.16	0.31	0.43	1.00	0.71	0.75	0.71	1.00
$x_t^{(08)}$	0.26	0.38	0.29	0.15	0.84	0.75	0.57	0.85
$x_t^{(09)}$	0.87	0.81	1.00	1.00	0.68	0.69	0.43	0.46
$x_t^{(10)}$	0.74	0.81	0.00	1.00	0.65	0.56	0.00	1.00
$x_t^{(11)}$	0.87	0.94	0.00	1.00	0.74	0.75	0.00	1.00
$x_t^{(12)}$	0.84	0.81	1.00	1.00	0.55	0.56	0.50	0.46
$x_t^{(13)}$	0.84	0.88	0.83	0.92	0.77	0.69	0.83	0.85
$x_t^{(14)}$	0.77	0.75	0.67	0.75	0.61	0.56	1.00	0.62
$x_t^{(15)}$	1.00	1.00	1.00	1.00	0.13	0.19	0.67	0.12
$x_t^{(16)}$	0.42	0.38	0.00	0.54	1.00	1.00	1.00	1.00
$x_t^{(17)}$	1.00	1.00	1.00	1.00	0.35	0.44	1.00	0.75

Continued on next page

Table 7 – continued from previous page

Symbol	**Price Taker**				**Price Setter**			
	Overall	**OPEC**	**Region**	**Quality**	**Overall**	**OPEC**	**Region**	**Quality**
				OPEC				
$x_t^{(18)}$	0.48	0.50	0.58	0.62	0.58	0.71	0.75	0.62
$x_t^{(19)}$	0.52	0.57	0.67	0.62	0.65	0.79	0.75	0.62
$x_t^{(20)}$	0.52	0.50	0.58	0.62	0.61	0.71	0.75	0.62
$x_t^{(21)}$	0.81	0.86	0.83	0.00	0.84	0.93	0.83	0.00
$x_t^{(22)}$	0.81	0.86	0.83	0.92	0.68	0.79	0.75	0.62
$x_t^{(23)}$	0.84	0.86	0.92	0.00	0.77	0.86	0.83	0.00
$x_t^{(24)}$	0.61	0.64	0.58	0.46	0.84	1.00	1.00	0.85
$x_t^{(25)}$	0.77	0.86	0.75	0.69	0.84	0.93	0.92	0.77
$x_t^{(26)}$	0.90	0.93	1.00	1.00	0.87	0.86	0.83	0.85
$x_t^{(27)}$	0.58	0.50	0.67	0.50	0.61	0.71	0.75	0.62
$x_t^{(28)}$	0.81	0.86	0.00	0.62	0.58	0.64	0.00	0.50
$x_t^{(29)}$	0.71	0.57	0.00	0.50	0.68	0.71	0.00	1.00
$x_t^{(30)}$	0.90	0.93	1.00	0.88	0.77	0.79	0.75	0.88
$x_t^{(31)}$	1.00	1.00	1.00	1.00	0.48	0.50	1.00	0.75
$x_t^{(32)}$	0.94	1.00	1.00	1.00	0.52	0.50	0.43	0.46