Product Quality and Business Contracts: Intermediary Crude Oil Pricing in a Southwest-US Regional Market

Subhasish M. Chowdhury
School of Economics, Centre for Behavioural and Experimental Social Science, and ESRC Centre for Competition Policy, University of East Anglia

Oindrila De
Economics Area, Indian Institute of Management Indore

Stephan Martin
Department of Economics, Purdue University, West Lafayette

CCP Working Paper 13-6

Abstract
We study upstream and downstream prices and the profit margin of crude oil in a Southwest-US regional crude oil intermediary market, where oil is transported by motor vehicle. We analyze a proprietary data set that permits a unique account of intermediation in a regional market. This contrasts with existing empirical studies, which rely on national/international level crude oil data that is heavily influenced by macroeconomic and political factors. We estimate panel hedonic models to analyze the effects of geographic variables, the characteristics of bilateral business deals between an intermediary and the upstream and downstream trading partners, and the quality components of the crude oil on prices and margins. Selection bias involving crude oil posted price is accounted for using a standard instrumental variable approach and a Hausman-Taylor instrumental variable approach. Results show that in this market, the characteristics of bilateral business deals and logistic issues

ISSN 1745-9648

have significant effects on oil prices and the profit margin, independent of oil quality. In line with existing results, we find significant effects of quality components such as basic sediment and water, sulfur content, and specific gravity on buying and selling prices and on the profit margin, but only effects of gravity is non-linear.

Acknowledgements: We thank Robert Kluin, Catherine Waddams, participants at the 9th IIOC Conference, EU Rotterdam Energy and Finance Conference, and the seminar participants at the Centre for Studies in Social Sciences Calcutta, University of East Anglia, and the University of Stirling for useful comments. Any remaining errors are our own.

Product Quality and Business Contracts: Intermediary Crude Oil Pricing in a Southwest-US Regional Market*

Subhasish M. Chowdhury [a], Oindrila De [b], and Stephen Martin [c]

[a]School of Economics, Centre for Behavioural and Experimental Social Science, and ESRC Centre for Competition Policy, University of East Anglia, Norwich NR4 7TJ, UK

[b]Economics Area, Indian Institute of Management Indore, Indore 453 331, India

[c]Department of Economics, Purdue University, West Lafayette, IN 47906-2056, U.S.A.

This Draft: April 25, 2013

Abstract

We study upstream and downstream prices and the profit margin of crude oil in a Southwest-US regional crude oil intermediary market, where oil is transported by motor vehicle. We analyze a proprietary data set that permits a unique account of intermediation in a regional market. This contrasts with existing empirical studies, which rely on national/international level crude oil data that is heavily influenced by macroeconomic and political factors. We estimate panel hedonic models to analyze the effects of geographic variables, the characteristics of bilateral business deals between an intermediary and the upstream and downstream trading partners, and the quality components of the crude oil on prices and margins. Selection bias involving crude oil posted price is accounted for using a standard instrumental variable approach and a Hausman-Taylor instrumental variable approach. Results show that in this market, the characteristics of bilateral business deals and logistic issues have significant effects on oil prices and the profit margin, independent of oil quality. In line with existing results, we find significant effects of quality components such as basic sediment and water, sulfur content, and specific gravity on buying and selling prices and on the profit margin, but only effects of gravity is non-linear.

JEL Classifications: D22, L11, L72, R11

Keywords: Crude oil pricing, product quality, hedonic price, business contracts

Corresponding author: Subhasish M. Chowdhury (s.modak-chowdhury@uea.ac.uk)

** We thank Robert Kluin, Catherine Waddams, participants at the 9th IIOC Conference, EU Rotterdam Energy and Finance Conference, and the seminar participants at the Centre for Studies in Social Sciences Calcutta, University of East Anglia, and the University of Stirling for useful comments. Any remaining errors are our own.*

1. Introduction

Crude oil plays an important role in the world economy. In the United States, domestic oil production has increased and increased in importance, and this holds the prospect of fundamentally changing the balance of power in the world crude oil market. This in turn lends importance to the determinants of performance in the U.S. submarket of the world oil market.

We examine one such set of determinants. There are four modes of transportation in the US domestic crude oil: water tanker, pipelines, railways and motor transport. Pipeline is the predominant form of crude oil transportation, but for nearly two decades, motor transportation has continuously gained importance (Figure 1). Although total domestic crude oil transport decreased by 1.5% between 1990 and 2007, crude oil transported via motor vehicles showed a positive growth rate of 1% in the same period.[1] In this paper we analyze the pricing of motor-transported crude oil in the Southwest-US region, over the time period of 2007-2008.

[Figure 1 about here]

This regional market has a vertical structure. We analyze a proprietary dataset from an intermediary firm in this region that buys crude oil from well owners and transports it by motor vehicle to downstream buyers, mostly oil refineries.

In the rural areas of Oklahoma and Texas, small well owners (often individual households) extract crude oil using small pumpjacks, commonly known as the *nodding donkeys*. Their daily output is limited by technical and regulatory restrictions. It is not profitable for them to transport such small amounts of crude oil to distant oil refineries. Hence, the well owners and the refineries deal with intermediaries that specialize in collecting and transporting crude from small crude oil producers. Once crude oil is extracted, intermediary firms contact the owners and buy the oil for transport and resale to refineries.

[1] Association of Oil Pipelines, (2007) “Report on Shifts in Petroleum Transportation", Statistics, Table 1.

[Figure 2 about here]

The intermediaries are middlemen, who "*stand ready to trade at bid and ask prices they quote on a private basis to consumers or producers*", rather than market makers, who "*facilitate trade by posting publicly observable bid and ask prices*" (Ju et al., 2010, p. 2). As a result, transaction prices are the result of bilateral business deals. The parties involved bargain over several aspects of the price of the crude oil. Crude oil quality, frequency of payment, type of pricing, and distance from the oil well to the refinery are all included in the bargaining process. As the oil wells are small and many and are owned by individuals, the owners have limited market power. During the time frame covered by our database, six intermediaries operated in the regional market we examine. The intermediary that generated the database we analyze was the fourth largest. Hence the upstream of the market was essentially oligopsonistic in nature. Although we have data from only one intermediary, we have preliminary daily prices for various qualities of crude oil. We use this as a proxy for competition in the market. In the downstream market, however, refineries are much larger than intermediaries, and intermediaries had limited bargaining power. We observe the locations of refineries, but not their technological characteristics.

We estimate hedonic price models of the purchase (from the well owners) and sales (to the refineries and other buyers) prices of crude oil in terms of distance between the buying and the selling locations, characteristics of bilateral business deals between the intermediary and well owners, and the quality components of the crude oil. We also analyze the profit margin of the intermediary (sales price minus purchase price minus unit transportation cost). To our knowledge, the current study is the first micro-level analysis of a domestic regional crude oil market. It is also the first analysis to control for aspects of business contracts and geographic variables while explaining the price of crude oil. Adding to the literature, we find that these variables have significant effects on oil prices and the profit margin. Received results, that quality components have significant effects on both prices and profit margin, are also supported. We further show that both sulfur content and specific gravity play major roles in determining the prices, but only the effect of specific gravity is non-linear.

2. Literature review

A number of studies related to crude oil pricing analyzes fluctuations in international crude oil prices.[2] Bernard and Weiner (1996) model crude oil as a differentiated product, with prices depending on characteristics of importing countries. Yang et al. (2002) analyze the impact of changes in OPEC output on the level and volatility of crude oil prices. Zhang et al. (2008, 2009) decompose international crude oil prices into short-term movements due to shifts in demand and supply, shocks, and a long-term trend. These analyses focus on oil prices at different levels in the vertical supply chain than the one we examine. With the exception of Bernard and Weiner (1996) they do not employ hedonic pricing models for crude oil.

A hedonic pricing equation is an empirical representation of the relationship between prices and product characteristics in the market for a differentiated product (Brown and Rosen, 1982). Rosen (1974) provides the first theoretical model of hedonic pricing. Empirical analysis using hedonic pricing concepts, however, started before its theoretical foundation was worked out. Waugh (1928) and Court (1939) used the concept for the pricing of vegetables and automobile characteristics. This was more formally introduced by Griliches (1958) for the fertilizer market and automobile market (Griliches, 1961, 1971). Following this work, a large number of empirical studies use hedonic regressions in different functional forms for a variety of products and services. See Turvey (1989) and Triplett (2004) for surveys.

The literature applying hedonic pricing to crude oil, however, is sparse. Liao and Yu (2000), Wang (2003), and Bacon and Tordo (2005) estimate hedonic price models for crude oil in the international market, and separate the price into quality components. It is then argued that the hedonic components are a direct effect of market valuation of the quality components. Liao and Yu (2000) find that crude prices are generally higher in other regions of the world (especially in Asia) than in Europe. They find a positive effect of specific gravity and a negative effect of sulfur content on implicit prices. Wang (2003) includes specific gravity, sulfur content and viscosity as oil quality characteristics and finds a non-linear relationship between implicit prices and specific gravity, and sulfur. According to Wang, the non-linear relationship

[2] See, for example, Duffy-Deno (1996), Borenstein et al. (1997) Asche et al. (2003), Chen et al. (2005) among others for analysis on the relationship between crude oil price and gasoline price. Hamilton (1983, 1996) and Hooker (1996) analyze the relationship between the oil price, the macroeconomy, and the implied policy issues.

between price and these two oil characteristics confirms that refiners' valuation of oil characteristics depends on their technology. Bacon and Tordo (2005) estimate the effect of differences in quality characteristics on the differences in prices of various crude oils with the price of Brent crude. Their results show that price differences increase with quality differences and this explains why inter-crude price differentials increase with increases in the general price level of crude oil. They also find that regional variations and transportation play important roles on the crude price differentials.

These studies examine the international crude oil market where, apart from the characteristics of crude oil, pricing depends on external factors and on speculation. From this point of view, our analysis is distinctive since we employ data on the transaction prices for regional US crude oil market, which is in a different level on the vertical supply chain and is less affected by the dynamics of the international crude oil market. Furthermore, due to data availability issues, these studies focus primarily on the quality components of crude oil whereas we are able to introduce geographic and bilateral bargaining components as possible elements in determining crude price. Moreover, unlike the existing studies we incorporate proxies for bargaining power in the empirical model to partially control for the imperfect nature of competition in the market.[3] We also estimate a hedonic model of the price-cost margin – as suggested by Feenstra (1995) – along with a hedonic pricing equation, as a robustness measure.

3. Data description

We obtained daily data from the intermediary, organized by location and time, with descriptions of the upstream selling and downstream buying parties, as well as buying and selling prices of the intermediary. The data also includes specifications of three basic characteristics of the crude: specific gravity of the oil at a particular temperature, sulfur content, and basic sediment and water content. Variables related to the geographic locations of different parties and the type of vehicles used for transport are also included. Finally, the characteristics of bilateral business deals between the

[3] Rosen's original model assumes a perfectly competitive market, but market power on either side of the market invalidates this assumption (Taylor and Smith, 2000). Feenstra (1995) suggests using the price-cost margin or mark-up in the hedonic price equation in the presence of market power to overcome this problem.

intermediary and the well owners, such as payment frequencies, payment methods, and pricing types, are part of the data set.

Table 1 contains definitions of the variables used for the analyses provided in the next section. These variables are grouped into 4 categories – those related to price, cost and profitability; those related to oil quality; those related to distance, transport and destination; and those related to the nature of the business contract.

[Table 1 about here]

We define a 'transaction' as the purchase oil bought from a particular well (origin), and the transport and sale of that oil to a particular refinery (destination) on a given day. We have an unbalanced panel data of oil transactions from 2,253 individual oil wells observed over 547 days (Jan 2007 – Jun 2008), resulting in a total of 20,285 observations. There is discrepancy between the number of origin-destination pairs times the number of days versus the actual number of observations, since it is possible to observe either multiple or zero transactions from a particular oil well to any refinery on a given day. Therefore, the cross-section unit used in this research is an oil transaction, and not individual oil wells. There are total 2,760 unique origin (oil well) destination (refinery) pairs in the data. However, observations from only 1,688 origin- destination pairs across 538 days could be used for final analysis because of missing observations of some variables (hence i = 1, 2, …, 1688 and t = 1, 2, …, 538). This reduces the total number of observations to 17,318. To keep consistency with the final econometric analysis, we present descriptive statistics also for only those 17,318 observations even though more observations are available for some particular variables.[4]

The pricing in the present context starts with a "Posted price" - posted on the internet - that is based on broad characteristics ('class') of the oil. These posted prices are initial benchmark prices determined by the oil companies. They were once published in newspapers (Davidson, 1963) and now appear on the internet. Table 2 lists the nine different 'oil classes' that are used for posted prices. For our analysis, we consolidate these oil classes into the 5 categories as shown in Table 2. 'Oklahoma sweet' (SW), which is the predominant type of oil found in this region, appears in

[4] Since trucking cost is available only for 16,977 observations (1,576 origin-destination pairs over 465 days), Net margin regressions are run on this reduced sample size. No selection bias, however, was found for the missing observations.

more than 47% of the observations. All the other *Sweet* (with lower levels of hydrogen sulfide and carbon dioxide) oil categories are combined in the 'Other sweet' group. SWTI (Sunoco (Sun Oil Company) West Texas Intermediate**)** and SUN (Sunoco Oklahoma sweet) form the SUNOCO group and NYMX (New York Mercantile Exchange) forms a single price group. All other categories of oil are grouped under 'All other'.

[Table 2 about here]

Other price, cost and profitability related variables are summarized in *Table 3*. "Purchase price" is the price the intermediary pays to the upstream individual oil well owners for a particular transaction. "Sales price" is the price received by the intermediary from its downstream customers. On average, the intermediary purchased oil at $80.72 per barrel (1 barrel = 0.158987 cubic meters), while average posted price was $82.10 per barrel. The purchase price, the result of bilateral bargaining between the individual owner of the oil well and the intermediary in question, varies with the quality of oil, other terms of the business deals, and distance, and ranges from $18.20 per barrel to $ 135.50 per barrel. This range, however, is smaller in the case of sales price. The average trucking cost is $ 1.40 per barrel.[5] Net margin (sales price – purchase price – trucking cost per barrel) ranges between -$12.53 and $36.32.

The presence of negative net margins is due to the timing of successive transactions in the vertical chain. The purchase point margin (purchase price – trucking cost) ranges between $22 and $135.05 with an average of $80.14. The intermediary presumably expects a positive return at the moment of purchase. However, at the point of sale, it may be willing to accept a price below the purchase price plus trucking cost since otherwise it would have to take the oil back to its storage facility, incurring additional transportation cost. On average, this intermediary has a net margin of $2.54 per barrel.

[Table 3 about here]

Table 4 describes our three oil quality indicators (measured in per cent). They are basic sediment and water (BSW), sulfur content, and specific gravity. High specific gravity indicates lighter and better-quality oil whereas basic sediment and water and sulfur contents are impurities. Sulfur content directly influences refinery

[5] Trucking cost data is missing for 3,308 observations. We have used the same origin-destination pair to impute missing distance and the corresponding trucking costs for most of these observations.

profitability. Lower sulfur content is associated with higher profitability. Crude oil with sulfur content up to 0.5 per cent is classified as low-sulfur crude (Davydov, 1978). The sample range is quite wide for all the three quality indicators. However, average sulfur content (0.37), average BSW (0.87) and average gravity (41.76) indicate overall good quality of oils transacted.

[Table 4 about here]

The next set of variables refers to the characteristics of the bilateral business deals. *Table 4* provides the frequency and percentage of occurrences of all these variables. A price contract specifies the type of posted price used in the transaction. In more than 50% of the contracts, the transaction price is based on end-of-the-month average prices (that is, the average price of the previous month), which has the effect of hedging the risk of price fluctuations. But contracts based on standard daily prices are also used in a large number of cases (29.41%). The remaining contracts (20.46%) are based on the current-month-to-date average price (average price from the start of the month to the transaction date). Another variable related to business contracts describes the way payments to the oil owners are made. This is mostly on a monthly basis, whereas *Quick* (immediate) pay accounts for almost 40% of the transactions.

The variables related to geography, distance, and related costs are included in the next set of variables. The intermediary transports the crude oil extracted from individual wells to different customers at different destinations. The customers are independent refineries, refineries operated by oil companies, and other larger intermediaries. There are 28 different customer-destinations reported in our database. The largest customer is a refinery (denoted as the X-org to maintain confidentiality) and its subsidiaries. There are different destinations within the X-org, but the majority of the oil is sent to Drumright, Oklahoma. We have aggregated the destinations into three broad groups – X-Dru (the share of oil sold to the X-org that is sent to Drumright), other X-org refineries, and all other refineries. *Table 5* shows that over 41% of the oil was transported to X-Dru and almost 37% was transported to other X-org refineries. The remaining amount was transported to 21 other refineries.

Table 5 also shows different modes of motor transport used for transportation. 83.36% of the oil was transported by big transport truck and almost 13% by bobtail truck (a semi-truck without a trailer attached). A small portion was transported by contract hauler. Every day on average 136.63 barrels of oil were transported an average distance of 55.63 miles.

We have further constructed a set of proxy variables to capture the state of competition in the market. We identified the oil class(es) with the highest and the lowest price on each day. The ratio of the highest and actual posted price of the seller (Maxproportion) shows the gap between the best possible price in the market and the actual price, and the ratio of lowest and actual posted price (Minproportion) shows the gap between the worst possible price in the market and the actual posted price. These ratios are used to examine whether purchase and sales prices vary according to the availability of better or worse alternatives.[6] Finally, we use a 'weekend' dummy that takes value one if it is a Saturday or a Sunday. Since not all the intermediaries operate on a weekend, this variable should reflect a higher concentration of bargaining power in the upstream market at such times.

[Table 5 about here]

4. Analytical methodology

Since oils were not collected from all the suppliers each day, the sample is an unbalanced panel. We cannot use a pooled cross-sectional OLS model since a Breusch-Pagan LM test reveals variance across cross-sections or time, confirming the existence of random effects. Hence, a pooled OLS estimator will be inefficient. A basic panel data model can be written as:

$$y_{it} = x_{it}\beta + c_i + u_{it} \quad (1)$$

where y_{it} is the dependent variable; $t = 1, 2, \ldots, T$; x_{it} is a vector of explanatory variables; c_i captures unobserved heterogeneity; and u_{it} is an idiosyncratic error term. It is obvious from the existing studies that the differences across individual oilfields and time invariant variables strongly influence our dependant variables and random effects exist. Furthermore, a fixed effect model cannot be used since the effects of the time invariant explanatory variables will then be eliminated. Therefore, in the first specification, we estimate a random effect model of the following form:

[6] We further tried two dummy variables, which take the value one when the actual price is the highest price, and when the actual price is the lowest price of the day, respectively. The qualitative results remain the same.

$$P_{it} = \beta_1 Q_{it} + \beta_2 G_{it} + \beta_3 B_{it} + \beta_4 R_{it} + \epsilon_{it} \quad i = 1,2 \ldots 1688 \text{ and } t = 1,2, \ldots 538$$ ####

(2)#

where P_{it} is the dependent variable (purchase price, or sales price, or net margin). The $Q_{it}s$ are oil-quality related variables, the G_{it}s are geographic variables, and the $B_{it}s$ are business contract related variables,[7] or proxies for bargaining power. R_{it} is the posted price of the crude oil with which the intermediary starts its pricing decision. The error term (ϵ_{it}) includes the unobserved effect c_i along with idiosyncratic error ε_{it}, i.e., $\epsilon_{it} = c_i + \varepsilon_{it}$.

Final purchase price, sales price and profit margin are determined by the oil quality, business contracts and negotiation between both parties. However, the business model of the intermediary requires us to address a self-selection issue. The intermediary starts with a benchmark (posted) price based on identified oil class and calculates final purchase price by adding or subtracting terms. So the outcomes of interest, final purchase and sales prices, are correlated with the initial selection of posted price. Therefore, using posted price as an explanatory variable will cause a self-selection bias in the model and may influence the quality variables in the sense that posted price itself depends on them.

This implies that in the empirical model in equation (2) the posted price itself may be determined by some of the explanatory variables. Therefore, the idiosyncratic error term in the model may be correlated with the posted price: $Cov(R_{it}, \varepsilon_{it}) \neq 0$. To get around this issue, we estimate the model using a two-stage least square random effect instrumental variable approach. An important and reasonable instrument for posted prices is the oil class chosen by the well owner and the intermediary for different oil fields. Selection of oil class determines the particular posted price that will be chosen, but does not directly determine the final purchase price, sales price and net margin other than through posted price. In this scenario, in the second specification, we first estimate the reduced form equation:

$$R_{it} = \gamma_1 Q_{it} + \gamma_2 G_{it} + \gamma_3 B_{it} + \gamma_4 OC_{it} + \vartheta_{it}$$

(3)

[7] Some of the business contract variables (such as payment method and type of contract) and proxy variables for bargaining power of the intermediary (Maxproportion and Minproportion) are dropped, for obvious reasons, when we consider the sales price for a refinery and the intermediary's net margin as dependent variables.

where OC represents oil class, the instrumental variable chosen for posted price, and it is assumed that $Cov(OC_{it}, s_{it}) = 0$. We thus obtain the estimated value of $\hat{R}_{it}$ which we use as a regressor in the second stage equation:

$$P_{it} = \beta_1 Q_{it} + \beta_2 G_{it} + \beta_3 B_{it} + \beta_4 \hat{R}_{it} + \epsilon_{it} \quad (4)$$

This procedure is also adopted for sales price and net margin equations.

It is possible that the estimated posted price in the reduced form equation have less explanatory power in the structural equation with sales price and net margin. Moreover, some unobservable characteristics may influence both posted price and final prices, i.e., $Cov(R_{it}, c_i) \neq 0$. An obvious solution to these issues would be to use a fixed effect estimate which will be consistent. But, again, a fixed effect model cannot be used, since the effects of crucial time-invariant explanatory variables such as sulfur, distance, and payment methods cannot be estimated. To incorporate this we rewrite the model in (1) with a Hausman-Taylor (H-T) method in the third specification:

$$y_{it} = x'_{1it}\beta_1 + x'_{2it}\beta_2 + w'_{1i}\gamma_1 + w'_{2i}\gamma_2 + c_i + u_{it} \quad (5)$$

where $x's$ are time variant and $w's$ are time invariant variables. Furthermore, x'_{1it} and w'_{1i} are uncorrelated to c_i whereas x'_{2it} and w'_{2i} are correlated with c_i. However, all regressors are assumed to be uncorrelated with u_{it}. Following Hausman and Taylor (1981), this model uses random effect transformation to estimate time-invariant regressors and also uses instrumental variable method to estimate regressors which are correlated with unobserved effect. The endogenous time variant regressor is posted price, whereas sulfur, sulfur-squared and payment method dummies are time invariant exogenous regressors. All other regressors in the model are time varying and they are assumed to be uncorrelated with random effect.

5. Results

Table 6 presents the results from the hedonic regressions on purchase price, sales price and net margin, using the first specification of a standard random effect model (Equation 2). *Table 7* presents the second specification, the IV random effect approach (Equations 3 and 4). Table 8 reports the third specification, the Hausman-Taylor (H-T) instrumental variable approach (Equation 5). The coefficients are implicit prices of oil quality characteristics, distance related variables, and business contract related variables.[8]

[Table 6 about here]

[Table 7 about here]

[Table 8 about here]

A very first observation confirms that although there are significant differences in terms of methodology used in the three specifications, variation in final results is not significant. Coefficients of posted price are positive and significant across the three specifications for both buying and selling crude prices and for the profit margin. Since the posted price reflects international price fluctuations for a broad oil class and the transaction process starts with the posted price, these effects on the prices are expected. However, the positive effect of posted price on profit margin portrays the relative bargaining power of the intermediary over the well owners. An increase in the posted price increases both purchase and sales price, but the relative increase in the purchase price is less than the increase in sales price. As a result the intermediary gains, in terms of the profit margin, when the posted price increases.

The oil quality and nature of the business deal are the primary factors in the purchasing process; the distance between oil wells and the refineries does not have a significant effect on the purchase price. On the other hand, as the distance between oil wells and refineries increases, it also increases the intermediary operating cost and the intermediary mark up the cost on the sales. Hence distance has a robust, positive, and significant effect on sales price across specifications. But, as discussed, refineries have greater bargaining power over the intermediaries, and as a result the overall profitability of oil transactions decreases with the distance travelled. Transport by big semi-truck as opposed to smaller bobtail truck and contract hauler has a positive effect on purchase price. However this effect is not consistent for sales price where the IV regression (*Table 7*) shows a no effect. The effect of the identity of the destination refinery, after controlling for distance, is ambiguous. Still, compared to the biggest purchaser X-Dru (the reference group), all other non X-org oil refineries (grouped together) have higher prices and profit margins. This result confirms that X-Dru has considerable monopsony power compared to non X-org refiners, which forces the intermediary to sell at lower prices and receive a lower margin. However, compared

[8] In each of the Table 6, 7 and 8, a 'group' is an origin-destination pair, standard errors are reported in parentheses, and ***, **, and * indicate significance at the 10%, 5% and 1% level.

to X-Dru, the intermediaries have received lower prices and lower margin from other X-org refiners.

Moving on to the quality components of the oil, we test whether sulfur content has a non-linear effect on purchase price, as shown by some existing research. Our data does not unambiguously support this hypothesis. Only the standard Panel model (Table 6) shows a concave effect of sulfur content on purchase price, whereas the other two specifications do not show a non-linear effect. As expected, sales price agreed by the refineries also decreases with an increase in sulfur content across specifications. However, net margin increases with sulfur level.[9] Similarly, Basic Sediment and Water content has a predictable negative effect on prices but has an opposite effect on net margin across specifications. These results, similar to posted price, portray the relative bargaining power – probably in terms of market information – of the intermediary over the individual well owners. The effect of specific gravity, however, is different and non-linear. Purchase price initially increases with specific gravity and then falls, but specific gravity has an exactly opposite non-linear effect (except the H-T specification) on sales price received by the intermediary. This apparently surprising result, though, can be explained in terms of the molecular content of crude oil. A similar issue was discussed by the Louisiana State Mineral Board in 1989. Since higher gravity means lighter crude oil, it was concluded that *"…although light crude is good, lighter crude is not necessarily better … as the crude gets lighter .., it contains shorter molecules, or less of the desired compounds useful as high octane gasoline and diesel fuel, the production of which most refiners try to maximize."*[10] This is why the well owners expect higher (but concave) price for higher gravity. But since the crude is already light enough (average gravity: 41.76), the refineries earn less when specific gravity increases further. This causes its overall non-linear effect on net margin. In summary, unlike existing studies we find no concave relationship for sulfur but find a non-linear relation of specific gravity on the price of crude oil.

---

[9] If we regress only sulfur and $(\text{sulfur})^2$ on net margin, excluding other explanatory variables, we obtain a non-linear, concave-shaped effect. But this effect disappears while we control for other variables.

[10] "Comments on Crude Oil Gravity Adjustments", Report Presented to The Louisiana State Mineral Board for the Royalty Oil Task Force, September 13, 1989. Baton Rouge, Louisiana.

As expected, the variables directly related to bargaining and business contracts are more relevant determinants for purchase price but do not have a strong influence on sales price. Therefore, we do not include most of these variables for sales price and net margin equations. Daily contracts (the reference group), which carry more risk, significantly lower purchase prices compared to the end-of-the-month-average price schedule. However this effect is opposite compared to the current-month-to-date-average. Contrary to expectations, the transactions that use the immediate payment method earn higher prices compared to those settled by monthly payments. Recall that Maxproportion (Minproportion) identifies the best (worst) possible posted price in the market compared to actual price. Maxproportion has a negative and significant impact on purchase price, whereas Minproportion has exactly the opposite effect. A negative effect of Maxproportion on purchase price implies that the seller's ability to negotiate a higher price varies inversely with the difference between best alternative price and actual price. Similar logic holds for Minproportion. Weekends, in which many of the other intermediaries as well as refineries do not operate, also indicate change in relative bargaining power. It has a significant negative effect on both purchase/sales prices – confirming an increase in bargaining power of the buying side in both up and downstream. As a net result, however, the effect on profit margin is not significant.

6. Conclusion

We study the buying and selling prices of crude oil in a vertically-structured Southwest-US region intermediary market, where oil is transported by motor vehicle. We analyze the effects of geographic variables, the characteristics of imperfect competition through bilateral business deals, and the quality components of the crude oil on prices. We also decompose the intermediary net margin with respect to the characteristics variables. Moreover, we employ a novel IV approach where crude oil class is used as an instrument to determine posted price in the first stage and then estimated posted price is used as an explanatory variable in the second stage. A Hausman-Taylor instrumental variable approach is also estimated to control for unobserved heterogeneity that may affect posted and final prices.

The current study is the first analysis on a regional domestic crude oil industry. It is also the first analysis of the specific part of the vertical supply chain in which crude oil is transported by motor vehicle. It is asserted in the existing literature that a hedonic analysis of crude oil reflects only the market valuations of the oil components, as the production cost per barrel is negligible. Our analyses show that the crude oil prices may depend not only on the market valuation of the oil quality, but also on other transaction characteristics. We identify microeconomic factors such as distance and business contracts that influence crude oil price in this regional market. We find a non-linear relationship between specific gravity with prices. However, we find no such relationship between sediment and water component or sulfur content and prices.

It may be possible to adapt a theoretical structure a.la. Ju et al. (2010) to the kind of market we analyze empirically. It could also be possible to analyze price dispersion and price differentials in this set up. We leave these questions for future research.

References

Asche, F., Gjolberg, O., and Volker, T. (2003). Price relationships in the petroleum Market: An analysis of crude oil and refined product prices. Energy Economics, 25, 289– 301.

Bacon, R., and Tordo, S. (2005). Crude Oil Price Differentials and Differences in Oil Qualities: A Statistical Analysis, Energy Sector Management Assistance Programme (ESMAP) Technical Paper 081. Washington: World Bank.

Bernard, J., and Weiner, R.J. (1996). Export pricing in state-owned and private MNEs: Evidence from the international petroleum market, International Journal of Industrial Organization, 14, 647-668.

Borenstein, S., Cameron, A.C., and Gilbert, R. (1997). Do Gasoline Prices respond asymmetrically to Crude Oil Price Changes?, Quarterly Journal of Econ, 112, 305-339.

Brown, J. N., and Rosen, H.S. (1982). On the Estimation of Structural Hedonic Price Models, Econometrica, 50, 765-68.

Chen, L.H., Finney, M., and Lai, K. (2005). A threshold cointegration analysis of asymmetric price transmission from crude oil to gasoline prices. Economics Letters. 89 (2), 233–239.

Court, A. T. (1939) Hedonic price indexes with automotive examples, in The Dynamics of Automobile Demand, General Motors, New York, 98-119.

Davidson, P. (1963). Public Policy Problems of the Domestic Crude Oil Industry, American Economic Review, 53, 85-108

Davydov, B.N. (1978). Differentiation of crude prices depending on sulfur content, and profitability of petroleum refineries, Chemistry and Technology of Fuels and Oils, 14(1), 36-40.

Duffy-Deno, K.T. (1996). Retail price asymmetries in local gasoline markets. Energy Economics, 18, 81–92.

Feenstra, R. C. (1995). Exact Hedonic Price Indexes, Review of Economics and Statistics, 77(4), 634-53.

Griliches, Z. (1958). The demand for fertilizer: An econometric reinterpretation of a technical change, Journal of Farm Economics, 40, 591-606.

Griliches, Z. (1961). Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change, in: Price Statistics Review Committee, National Bureau of Economic Research, The Price Statistics of the Federal Government: Review, Appraisal, and Recommendations, General Series No. 73. New York, NY: NBER, 173-196.

Griliches, Z. (1971). Price Indexes and Quality Change: Studies in New Methods of Measurement, Harvard Univ. Press, Cambridge, MA.

Hamilton, J.D. (1983). Oil and the macroeconomy since World War II, Journal of Political Economy, 91, 228-48.

Hamilton, J.D. (1996). This is what happened to the oil price-macroeconomy relationship. Journal of Monetary Economics, 38(2), 215-220.

Hausman, J. A., and Taylor, W. E. (1981), Panel Data and Unobservable Individual Effects.
Econometrica, 49 (6), 1377-1398.

Hooker, M.A. (1996). What Happened to the Oil Price Macroeconomy Relationship?, Journal of Monetary Economics, 38, 195-213.

Ju, J.D., Linn, S.C., and Zhu, Z. (2010). Middlemen and oligopolistic market makers, Journal of Economics and Management Strategy, 19(1), 1-23.

Liao, H.C., and Yu, T.H. (2000). An Examination of Current Crude-Oil Price Formulas, Journal of energy and development, 26 (1), 109-126.

Rosen, S. (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition, Journal of Political Economy, 82, 34–55.

Taylor, L.O., and Smith, V.K. (2000). Environmental Amenities as a Source of Market Power, Land Economics, 76(4), 550-568.

Triplett, J. (2004). Handbook on Hedonic Indexes and Quality Adjustment in Price Indexes: Special Application to Information Technology Products, OECD Science, Technology and Industry Working Papers 2004/9.

Turvey, R. (1989). Consumer Price Indices: An ILO Manual, ILO, Geneva.

Wang, Z. (2003). Hedonic prices for crude Oil, Applied Economics Letters, 10, 857–861.

Waugh, F.V. (1928). Quality factors influencing vegetable prices, Journal of Farm Economics, 10, 185–96.

Yang C.W., Hwang, M.J., and Huang, B.N. (2002). An analysis of factors affecting price volatility of the US oil market, Energy Economics, 24, 107-119.

Zhang, X., Wang, S.Y., and Lai, K.K. (2008). A new approach for crude oil price analysis based on empirical mode decomposition, Energy Economics, 30(3), 905-918.

Zhang, X., Yu, L., Wang, S.Y., and Lai, K.K. (2009). Estimating the impact of extreme events on crude oil price: an EMD-based event analysis method, Energy Economics, 31(5), 768–778.

Figures

Figure 1. Percentage USA domestic crude oil transported via motor vehicles (1990-2007)

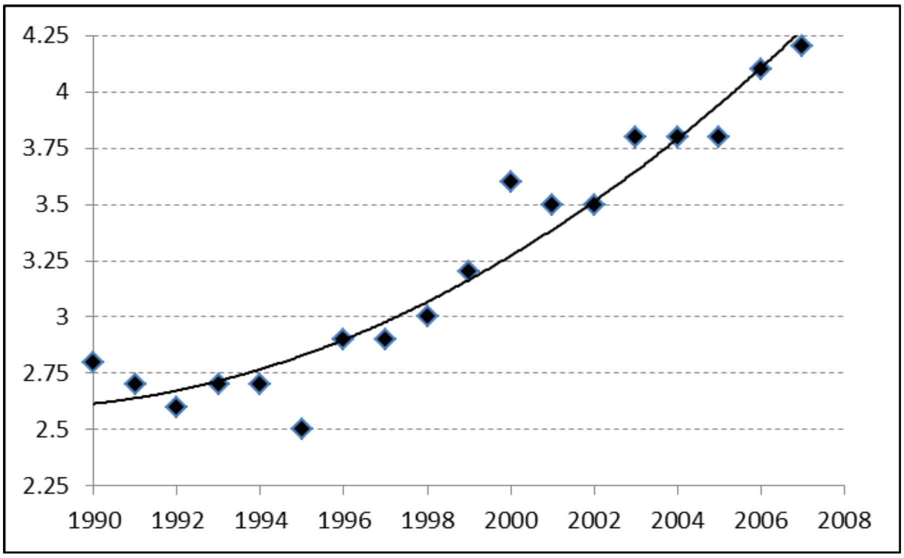
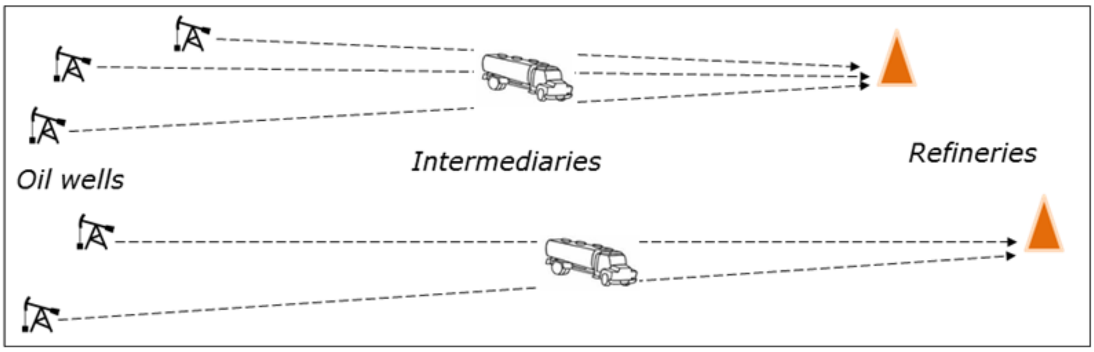


Figure 2. Structure of the regional crude oil industry



Tables

Table 1. Variable definitions

VARIABLE NAME	DESCRIPTION
Prices, cost and profitability variables	
Posted price	Official price for a particular oil class in a particular day
Purchase price	Actual purchase price per barrel
Sales price	Actual sales price per barrel
Trucking cost	Transportation cost
Net margin	Sales price – purchase price – unit trucking cost
Oil quality	
BSW	Basic sediment and water level of the crude oil
Sulfur	Sulfur level of the crude oil
Sulfur2	$Sulfur^2$
Gravity	Gravity of the crude oil
Gravity2	$Gravity^2$
Broad Oil Class based on the quality of oil (more information in Table 2)	
CLAS_IND_SW	Dummy for Oklahoma sweet
CLAS_IND_NYMX	Dummy for NYMX
CLAS_IND_OTHSW	Dummy for other sweet (CCSW, POSW, CTSW)
CLAS_IND_SUNOCO	Dummy for Sunoco (OK sweet and WTI)
CLAS_IND_ALLOTH	Reference group: Dummy for all others Includes: SC, FSTS (Flint Hills South Texas Sour), PWTI, WTI
Distance, destination and transport	
Distance (miles)	Distance between buying and selling points in miles
Destination-refineries	
DEST_IND_X-DRU	Destination dummy for X-org, Drumright, OK (ref. group)
DEST_IND_XOTH	Destination dummy for other X-org purchaser
DEST_IND_ALLOTH	Destination dummy for All other purchaser
Transport type	
TRANS_IND_BOB	Transport type dummy = Bobtail truck
TRANS_IND_TRUCK	Transport type dummy = Semi truck (ref. group)
TRANS_IND_CONTR	Transport type dummy = Contract hauler
Business contract	
Pay type	
PAY_IND_MONTH	Dummy for long time payment (monthly, weekly, special pay, and 10th of the month pay)
PAY_IND_QCK	Quick pay (reference group)
PAY_IND_MISS	Missing pay indicator

Contract type	
CONT_IND_DAILY	Dummy for price calculated on daily price (ref. group)
CONT_IND_EMAVG	Dummy for price calculated on end of month average price
CONT_IND_CMDAV	Dummy for price calculated on current month to date average price
Miscellaneous	
Weekend	Dummy for Saturday and Sunday
Maxproportion(%)	(Maximum posted price of the day/Actual posted price of the day)*100
Minproportion (%)	(Minimum posted price of the day/Actual posted price of the day)*100
Maxdummy	=1, if Actual posted price = Maximum posted price
Mindummy	=1, if Actual posted price = Minimum posted price

Table 2. Summary statistics of posted oil classes before and after consolidation

Posted oil class	*Frequency*	*Percentage*
CTSW (Company OK Sweet)	931	5.38
NYMX (New York mercantile Exchange)	1,863	10.76
POSW (Plains OK Sweet)	1,155	6.67
PWTI (Plains West TX Intermediate)	1,138	6.57
SC (Conoco West TX Intermediate)	713	4.12
SUN (Sunoco OK Sweet)	2,687	15.52
SW (OK Sweet)	8,269	47.75
SWTI (Sunoco West TX Intermediate)	352	2.03
WTI (West TX Intermediate)	210	1.21
Posted oil class	Frequency	Percentage
Sweet	8,269	47.75
NYMX	1,863	10.76
Other sweet	2,086	12
SUNOCO	3,039	18
All other	2,061	12

Table 3. Summary statistics of the prices, cost and profitability

Variable	*Posted price*	*Purchase price*	*Sales price*	*Trucking cost*	*Net margin*
Obs	17318	17318	17318	14892	14892
Mean	82.10	80.72	84.77	1.40	2.54
Std. Dev.	22.70	22.65	23.33	1.14	4.02
Min	46.65	18.20	51.40	0.45	-12.53
Max	140.21	135.50	134.99	11.11	36.32

Table 4. Summary statistics of the oil quality indicators

Variable	*BSW**	*Sulfur*	*Gravity*
Obs	17318	17318	17318
Mean	0.87	0.37	41.76
Std. Dev.	1.46	0.35	16.48
Min	0	0.003	0
Max	40	2.04	98.4

*BSW = Basic sediment and water; variables measured in per cent.

Table 5. Frequency table of contract, pay, destination and transport variables

Contract type	*Frequency*	*Percentage*
Current month to date average	3,543	20.46
Daily	5,094	29.41
End of the month average	8,681	50.13
Pay type	*Frequency*	*Percentage*
Long term pay	10,399	60
Quick pay	6,919	39.95
Destination type	*Frequency*	*Percentage*
X-DRU	7,130	41.17
Other X-org	6410	37.02

All other	3778	21.83
Transport type	*Frequency*	*Percentage*
Bobtail truck	2,243	12.95
Contract hauler	639	3.69
Transport truck	14,436	83.36

(Percent sum might not add up to 100 due to missing values)

Table 6. Hedonic purchase price, sales price and net margin (Random effect regression)

	Purchase Price	*Sales Price*	*Net Margin*
Posted price	0.973***	1.014***	0.056***
	(0.001)	(0.001)	(0.001)
Distance	0.001	0.005***	-0.017***
	(0.001)	(0.001)	(0.001)
BSW	-0.608***	-0.042*	0.491***
	(0.017)	(0.019)	(0.016)
Sulfur	-3.520***	-0.621***	3.595***
	(0.612)	(0.161)	(0.237)
Sulfur square	-0.879*		
	(0.367)		
Gravity	0.118***	-0.056***	-0.197***
	(0.017)	(0.016)	(0.016)
Gravity square	-0.001***	0.000**	0.002***
	(0.000)	(0.000)	(0.000)
Weekend	-0.189**	-0.254**	-0.062
	(0.072)	(0.084)	(0.066)
Maxproportion (%)	-0.002		
	(0.20)		
Minproportion (%)	0.050***		
	(0.006)		
TRANS_IND_BOB	-0.218*	0.137	-0.370***
	(0.087)	(0.091)	(0.084)
TRANS_IND_CONTR	-0.635***	-0.572***	
	(0.142)	(0.159)	
PAY_IND_MONTH	-1.219***		
	(0.156)		
DEST_IND_ALLOTH	0.067	0.128	0.240***
	(0.069)	(0.079)	(0.065)
DEST_IND_XOTH	-0.115	-0.328***	-0.289***
	(0.064)	(0.069)	(0.062)
CONT_IND_CMDAV	-1.772***		

	(0.096)		
CONT_IND_EMVAG	2.225***		
	(0.125)		
Constant	-4.716*	3.104***	2.247***
	(2.262)	(0.457)	(0.459)
sigma_u	1.700	0.661	1.923
sigma_e	2.853	3.457	2.450
rho	0.262	0.035	0.381
R sq (within)	0.981	0.975	0.245
R sq (Between)	0.974	0.980	0.447
R sq (overall)	0.978	0.976	0.386
Chi square (17, 11, 10)	873224.070	691995.178	5634.714
Prob (Chi sq)	0.000	0.000	0.000
N	17318	17318	14892
Number of groups	1688	1688	1576
Obs per group: Min	1	1	1
Obs per group: Average	10.3	10.3	9.4
Obs per group: Max	538	538	465

Table 7. Hedonic purchase price, sales price and net margin (IV regression)

	(1)	(2)	(3)
	Purchase Price	Sales Price	Net Margin
Posted price	0.880***	1.028***	0.082***
	(0.016)	(0.006)	(0.002)
Distance	-0.000	0.004***	-0.017***
	(0.001)	(0.001)	(0.001)
BSW	-0.627***	-0.037	0.490***
	(0.019)	(0.020)	(0.017)
Sulfur	-5.379*	-0.597**	4.096
	(2.090)	(0.194)	(2.338)
Sulfur square	0.163		
	(1.312)		
Gravity	0.090***	-0.058**	-0.154***
	(0.021)	(0.019)	(0.018)
Gravity square	-0.001***	0.001**	0.002***
	(0.000)	(0.000)	(0.000)
Weekend	-0.842***	-0.215*	-0.007
	(0.127)	(0.084)	(0.065)
Maxproportion (%)	-0.803***		
	(0.128)		
Minproportion (%)	0.057***		
	(0.007)		

TRANS_IND_BOB	-0.316**	0.112	-0.508***
	(0.107)	(0.099)	(0.091)
TRANS_IND_CONTR	-1.292***	-0.364	
	(0.201)	(0.193)	
PAY_IND_MONTH	-2.655***		
	(0.481)		
DEST_IND_ALLOTH	0.272**	0.179*	0.252***
	(0.083)	(0.082)	(0.065)
DEST_IND_XOTH	-0.196**	-0.281***	-0.128*
	(0.073)	(0.074)	(0.065)
CONT_IND_CMDAV	-0.035		
	(0.369)		
CONT_IND_EMVAG	4.229***		
	(0.333)		
Constant	87.004***	2.003**	-1.896
	(14.405)	(0.666)	(1.197)
sigma_u	8.777	1.132	28.175
sigma_e	3.248	3.482	2.514
rho	0.880	0.096	0.992
R square (within)	0.979	0.975	0.240
R square (between)	0.964	0.980	0.399
R square (overall)	0.968	0.976	0.284
Chi square (17, 11, 10)	396264.258	54886.116	2693.268
Prob (Chi square)	0.000	0.000	0.000
N	17318	17318	14892
Number of groups	1688	1688	1576
Obs per group: Min	1	1	1
Obs per group: Avge	10.3	10.3	9.4
Obs per group: Max	538	538	465

Table 8. Hedonic purchase price, sales price and net margin (Hausman-Taylor IV regression)

	Purchase Price	*Sales Price*	*Net Margin*
Posted price	0.970***	1.014***	0.055***
	(0.002)	(0.001)	(0.001)
Distance	0.000	0.003**	-0.017***
	(0.001)	(0.001)	(0.001)
BSW	-0.604***	-0.042*	0.485***

	(0.017)	(0.020)	(0.016)
Sulfur	-5.182***	-0.515	4.563***
	(1.213)	(0.315)	(0.458)
Sulfur square	-0.282		
	(0.764)		
Gravity	0.078***	-0.019	-0.132***
	(0.019)	(0.023)	(0.018)
Gravity square	-0.001***	0.000	0.001***
	(0.000)	(0.000)	(0.000)
Weekend	-0.253***	-0.210*	-0.041
	(0.071)	(0.083)	(0.064)
Maxproportion (%)	-0.074***		
	(0.021)		
Minproportion (%)	0.043***		
	(0.006)		
TRANS_IND_BOB	-0.143	-0.049	-0.544***
	(0.091)	(0.104)	(0.087)
TRANS_IND_CONTR	-0.577***	-0.571***	
	(0.145)	(0.170)	
PAY_IND_MONTH	-1.473***		
	(0.262)		
DEST_IND_ALLOTH	0.076	0.296***	0.285***
	(0.069)	(0.083)	(0.065)
DEST_IND_XOTH	-0.189**	-0.352***	-0.208***
	(0.066)	(0.077)	(0.063)
CONT_IND_CMDAV	-2.025***		
	(0.102)		
CONT_IND_EMVAG	2.444***		
	(0.136)		
Constant	5.385*	2.404***	0.039
	(2.473)	(0.666)	(0.546)
Sigma_u	3.796	2.299	4.032
Sigma_e	2.851	3.456	2.449
Rho	0.639	0.307	0.731
Chi square (17, 11, 10)	877220.898	636737.048	4940.828
Prob (Chi sq)	0.000	0.000	0.000
N	17318	17318	14892
Number of groups	1688	1688	1576
Obs per group: Min	1	1	1
Obs per group: Average	10.3	10.3	9.4
Obs per group: Max	538	538	465