A STUDY OF STRATEGIES FOR OIL AND GAS AUCTIONS

A Dissertation

by

DAVID PAUL NORDT

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2009

Major Subject: Petroleum Engineering

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ABSTRACT

A Study of Strategies for Oil and Gas Auctions.

(August 2009)

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Chair of Advisory Committee: Dr. Richard A. Startzman

Oil and gas auctions help transact billions of dollars in property sales in the US each year. Value is lost by participants with ineffective strategies. Federal lease auctions have been investigated from public data, but research in this narrow area peaked in the 1980s. Private property auctions did not emerge as a transaction force until nearly a decade later; however, today they dwarf federal lease sales in volume and value. This is the first study to publish research on private auctions and the first to consolidate historical lease research findings with private auction strategies.

This dissertation reviews past research, interviews industry professionals, analyzes case histories, conducts game experiments, and synthesizes these views for strategic application. Findings from these efforts include the following: Reducing uncertainty increases bid values; Federal lease bid values tend to be log normal; Aggressive bidding results in a poor portfolio performance; Increasing competition increases bid values; Inexperience increases aggressive bidding; A significant group of companies do not follow consistent auction strategies; Top winning bid drivers are

aggressive 3P reserves and commodity prices; Top value risks are commodity prices, capital, and operating expenses; Properties with upside value receive higher bids using sealed-bid auctions; Auction players can bid significantly less and sustain a high win probability; More money is left on the table in federal lease sales than private auctions; Poor data is primary reason auctions fail to complete the transaction; Profit taking is primary reason for selling properties though an auction; Market metrics are useful in valuation analysis; Producing properties receiver higher bids than undeveloped properties with same common knowledge including total proved reserves; Oral auctions receive higher bids than sealed-bid auctions with same common knowledge; Competition increases bid values in sealed-bid auctions; Reserve size does not increase relative value in sealed-bids with same common knowledge other than a magnitude of volume.

DEDICATION

Semper Fidelis . . . Margie

ACKNOWLEDGEMENTS

I am foremost thankful for the lifetime of professional and personal opportunities that God has brought my way. I am fortunate to live in this great country. It has an unparallel record of protecting individual freedoms under its constitution and providing opportunities for all its citizens to succeed.

Dr. Startzman, thank you for your support, mentoring, and patience as my advisor and committee chair. My warmest appreciation extends to committee members Dr. Hallermann, Dr. Van Huyck, and Dr. Wattenbarger for their time and participation in my graduate journey.

I am grateful to Texas A&M University for a great educational system, and I am tremendously indebted to industry participants for their open contributions to the research and their trust in me to preserve their confidentiality.

I acknowledge Marathon Oil Company and coworkers for providing a sounding board to discuss ideas and a kindly attitude that allowed me to take vacation and flex days when needed to complete this study.

Last, but not least, I recognize my family Margie, Marcie, and Marlo for their personal sacrifices and support over six years of academic courses and research. Without you ladies I am sure I would have shipwrecked on the island of self pity several storms ago. Along the voyage we lost part of our crew, Mom, Dad, Margie’s Mom and Dad. I do miss them, but in a not so distant future I have confidence that we will find them waiting for us on a bright and sunny shore.

NOMENCLATURE

1P = proved reserves

2P = proved + probable reserves

3P = proved + probable + possible reserves

Av = actual value of property

Bch = highest competitor bid value

Bcs = second highest competitor bid value

Bn = Bid values of "n" competitors

bo = barrels oil

boe = barrels oil equivalent

bopd = barrels oil per day

Bp = player bid value

Bs = second highest bid value

Būg = geometric mean of bid values for game = $(Bp \times B1 \times B2 \times \ldots \times Bn)^{1/(n+1)}$

Bw = winning bid value

Cp = competitor profit = Av - Bw (competitor)

df = degrees freedom

Ho = null hypothesis

k = game count

LOT = money left on table = Bw – Bs (or alternative ratio of Bs/Bw)

m = player count

Mw = player wins

n = competitor count

Ncw = competitor wins

PDNP = proved not producing reserves

PDP = proved producing reserves

POS = possible reserves

Pp = player profit = Av – Bw (player)

PRB = probable reserves

PRV = proved reserves

$P\bar{u}$ = mean of all player bid values each game = (Bp1 + Bp2 + . . . + Bpm) ÷ m

PUD = proved undeveloped reserves

p-value= probability level of significance

$P\sigma$ = standard deviation of all player bid values each game

$P\sigma^2$ = variance of all player bid values each game

R1,2 = round 1 or round 2

R^2 = coefficient of determination = the square of coefficient of correlation (r)

R/P = reserves to production

Sp = common standard deviation of two populations

t-test = test statistic

Vc = competitor value of property

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1. INTRODUCTION

1.1 Importance

Sellers of oil and gas properties desire competitive methods that exceed fair market value[1], and buyers seek positions between unsuccessful and overly aggressive bids. Auctions provide a popular mechanism for oil and gas property sales in the United States (US). Fig. 1.1 shows industry transactions[2] averaged over $32 billion[3] per year from 2003 through 2007. Most of these companies used private auction processes to ensure competitive offers [Nordt 2004]. The Oil & Gas Investor [2009] listed 75 firms providing advisement services and auction processes which reemphasizes the volume and value of these transactions.

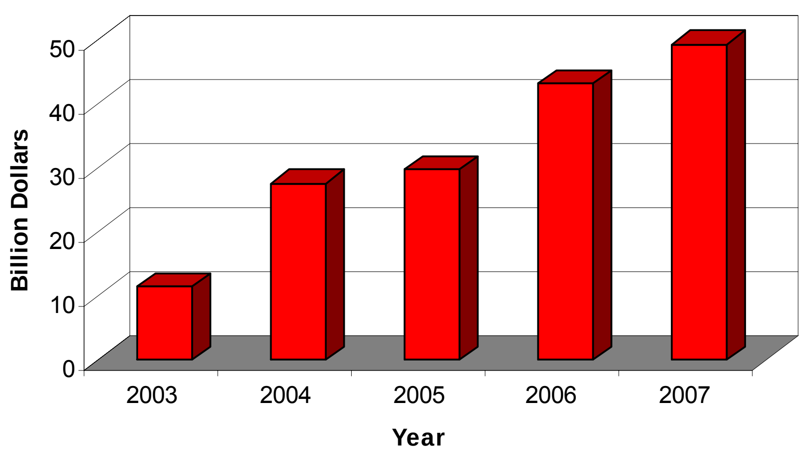


Fig. 1.1—Billions of dollars in private oil and gas property occur in the US each year with most through private auction processes (data adapted from John S. Herold, Inc. 2008 M&A Review).

This disseration follows the style of *SPE Reservoir Evaluation & Engineering.*

Fig. 1.2, a graph of total winning bids from US federal lease sales years 2003-2008, illustrates public auctions also attracted large bid values. The Department of Interior Mineral Management Service (MMS) reported [2008] record winning bids of $3.7 billion from central Gulf of Mexico Lease Sale 206 in March 2008. This sale received bids on 615 offshore blocks from 85 companies. Winning bids from all federal lease sales from 1954 through 2008 totaled $75.1 billion. Deep water Gulf of Mexico and offshore Alaska lead in high-value lease sales. These areas contain large hydrocarbon resources in a politically stable country not controlled by national oil companies[4] and open to companies qualified to explore and operate in this environment.

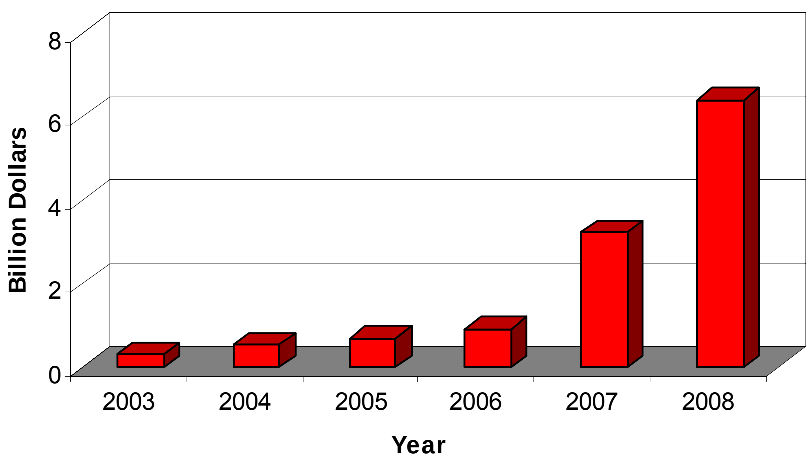


Fig. 1.2—Federal lease sale winning bid totals by year 2003–2008 (data adapted from DOI, MMS historical lease sales reports).

The amount of money left on the table in these competitive public and private auctions is staggering. Buyers maximize value by strategic analysis to justify lower winning bids (i.e., savings), and in strategic opposition, sellers maximize value by using better auction processes to increase competitive bids (i.e., profit).

1.2 Evolution

Auction research has centered on hydrocarbon drilling rights [Klemperer 1999] with most studies occurring from the 1960s through the 1980s. These studies examine federal offshore lease sales because results are open to public inspection. Private property auctions followed federal lease auctions decades later. Strevig [1989] observes private property status in late 1980s, *"Matching buyers and sellers is a slow arduous task. There is no organized marketplace, or exchange, with perspective buyers clearly identified"*. Since the early 1990s organized private auctions dramatically increased, but there are no comprehensive studies on the topic.

Nordt [2005] chronicles the genesis of these private auctions. Fig. 1.3 documents the evolution, from challenges in low commodity prices and the need of liquidity to the present sophisticated transaction services. The 1980s to early 1990s witnessed a proliferation of oil and gas equipment auctions. Companies struggled to control expenses to offset low commodity prices. Liquidating surplus equipment inventories through auctions became a tactic to reduce costs. Federal-regulated banks also used auctions to dispose of assets in bankruptcy litigation. As a natural progression of these events, several auction firms pioneered selling producing properties through private auctions. The use of auctions to sell oil and gas properties evolved into big business with rising commodity prices. A wide variety of advisors and services from internet e-bay style companies to global investment bankers with large professional staffs participate in these processes. Some industry observers[5] believe the next wave of auction evolution involves more internet use in evaluations.

PERIOD	GENERAL CHARACTERIZATION	COMMODITY PRICES
Genesis	**1980s to Early 1990s** - Proliferation of Oil & Gas Equipment Auction - Increase in Property Bankruptcy & Foreclosures - Application to the Oil & Gas Property	**Low**
Growth	**Middle to Late 1990s** - Improvement in Land, Commercial, Technical Data Quality - Sophistication of Market Portfolio Analysis - Improvement in Buyer/Seller Assistance - Industry Acceptance as Viable Marketing Mechanism - Enhancement of Dataroom Utility	**Volatile**
Maturing	**Early 2000s to Present** - Expansion of Technical Services - Hybrid Auction - Live/Internet - Exclusive Internet (Primary Listing Service) - Use of Internet For Data Dissemination (Paperless)	**Upward Trend Volatile**
Future	**Next Decade** - Internet Systems for Evaluation (Integrated Information & Service) - Paperless Transaction - Expansion of Technical & Financial Services - International Expansion	**Upward Trend Volatile**

Fig. 1.3–Private property auctions evolved from challenges in low commodity price and the need of liquidity to sophisticated transaction services.

Oil and gas property auctions generally fall into two types:

- Ascending bid (also called *open, oral or English auct*ion)—price is successively raised until only one bidder remains. Final called price is the winning bid. This process is most used for producing properties[6] with lower value and limited development potential.
- First-price sealed-bid (*sealed-bid auction*)—each bidder independently submits a single bid, without the benefit of seeing competitive bids. The highest bidder

wins at the highest first bid price. This process is most often used for properties that have significant value and development potential.

Today the sealed-bid auction dominates property divestments in value and volume. The sealed-bid auction is also called *negotiated sales* because a negotiated purchase sales agreement [Nordt 2004] is commonly used to formalize the transaction terms. Oral auctions command a smaller market as they tend to be high volume, but low value properties. Nordt [2005] estimated a half of billion dollars in ascending-bid auctions occur in the US each year (or approximately 2% of all bid property transaction values).

1.3 Problem

The objective of this dissertation is to study strategies for oil and gas auctions. No comprehensive work on this topic has been published. I conducted a literature review, industry interviews, game experiments, and case histories to accomplish this objective. Four questions with associated hypotheses offered below frame the problem:

1. What auction strategies are currently used to acquire or divest of properties?

- Hypothesis 1a–auction players often participate without clearly defined strategies.
- Hypothesis 1b–primary drivers in winning bids are aggressive forward price deck, inclusion of probable/possible reserves, and acceptance of lower project rate of returns.
- Hypothesis 1c– Well concentration risk, lack of development potential, and data quality are the most common reasons that properties fail to sell in auctions.

Nordt [2004] observed extreme outliers (i.e., approximately 25% greater than the second bid) in bid results from private sealed-bid auction transactions in approximately 20% of the projects managed from 2001-2004. Energy advisors I have asked agree this within their experience range of auctions. These extreme outliers may not have clear and concise acquisition strategies in pursuit of properties. Conversely, they may understand bidding risks, but competitive pressures such as reserve and rate additions can force aggressive decisions to push valuation limits.

I used interviews with active auction participants to examine the first question. As a concept precedent Grayson [1960] effectively used industry interviews to provide insight to exploration drilling decisions under uncertainty in the late 1950s and early 1960s. Analogous to his approach, I anticipated the interviews to provide a better understanding of how the industry assesses property risk in an auction environment.

2. Do bidding strategies from earlier research on federal offshore lease sales apply to contemporary private auctions?

- Hypothesis 2a–some auction research strategies developed for offshore federal leases apply to private property auctions.
- Hypothesis 2b–bid models from auction theory and lease sales research require modification to accommodate uncertainty in value and risk.

A review of earlier research on federal leases dissects strategies to find synergies with contemporary views of private auctions.

3. Which auction process, sealed-bid or oral, brings more value to the seller?

- Hypothesis 3a–The sealed-bid auction process brings more value to seller when development potential exceeds 30% of the total property value.

An answer to question 3 significantly impacts the profit of seller and buyer. Pursuit of this question uses interviews and interactive website game experiments with industry professionals.

4. Can market metrics correlate to commodity price and risk?

- Hypothesis 4a–market metrics based on $/BOE, $/BOEPD, and annual cash-flow multiples can correlate to historical commodity price and risk.
- Hypothesis 4b–Risked market metric correlations can yield valuations similar to more rigorous risked cash-flow modeling.

Financial groups, such as investment bankers and transaction advisors use market metrics to guide value decisions on auctions with proved and probable/possible reserves. In addition, energy company senior management routinely compare metrics from past property sales against proposed bids to see if they are “out of line”. A positive answer to question four has significant time-saving implication in screening property acquisitions, and it can serve to quality check more rigorous cash-flow modeling. Nordt[7] [2006] demonstrates linear regression correlations of valuation metrics to historical commodity pricing for producing properties in the time frame from 2000 to 2006 where commodity prices generally increased.

1.4 Summary and Comment

Billions of dollars in oil and gas auction sales occur in the US each year with a continuing growth in volume and sophistication. Public lease sales were studied in some detail through the 1980s, but that work was not updated. In addition, a comprehensive published study on private auctions sales does not exist. Addressing these two needs this study includes:

- Review of historical auction research.
- Interviews with industry professionals on contemporary auction strategies.
- Presentation of case histories.
- Website auction experiments with industry professionals.
- Synthesis of historical and contemporary strategies to guide bid valuations.
- Conclusions, future studies, and reflections from this work.

1.5 Notes

1. Garb [1990] discusses fair market value. His paper includes comparative sales, rule-of-thumbs, and cash flow forecast methods. Comparative sales (market metrics) and rule-of-thumb strategies are discussed in Section 5.

2. Data used with permission from IHS Herold (formerly John S. Herold, Inc.) Database includes information from press releases, public websites, and direct communications with companies. Review of the database supports that most transactions use auction processes to increase competition and maximize value for the seller.

3. Currency values in this study are in US dollars.

4. Rasheed [2009] reports that today national oil companies own 93% of the world's proved oil reserves. The competition of oil and gas reserves from integrated and independent energy companies intensifies buying and selling properties in the US. Competitive auction processes provide an efficient way to bring buyers and sellers together.

5. Formal interviews with industry professionals are presented in Section 3; however, other insights into auction strategies gained from these interviews are also documented in this study.

6. Values for oil and gas properties are based on reserves that will be ultimately produced and sold. The Society of Petroleum Engineers [Cronquist 2001] and Society of Petroleum Evaluation Engineers [Perspectives 2002] discuss reserve classifications and valuations. Proved (PRV), probable (PRB), and possible (POS) reserves comprise classification of reserves. Proved reserves are developed producing (PDP), nonproducing (PDNP), and undeveloped (PUD). Proved undeveloped, probable, possible reserves require significant investment to develop into proved producing. They have progressively higher degrees of uncertainty associated with them; therefore, they would normally have a lower value on a risked unit basis. Financial markets often use the terminology 1P, 2P, and 3P to report proved, (proved + probable), and (proved + probable + possible) reserves.

7. Nordt, D.P. 2006. Market Value Metric Correlations. Unpublished *Texas A&M Directed Study Presentation*, 1-15 (May). This study develops market metric correlations for producing properties from a private database presented by Nordt [2005].

2. HISTORICAL VIEW

2.1 Game Theory

2.1.1 General Game Concepts

I use Stevens [2008] and Binmore [1992] for general game theory definitions. A game consists of *players*, *strategies*, and *payoffs*. The player makes rational decisions using strategies which lead to profit or loss. *Rational* behavior necessitates the player's strategic choices result in the best outcome to himself[1] given his knowledge at the time. The best decision for a player is his *dominant* strategy, and he always prefers higher *payoffs* (profit). U*tility* is the satisfaction a player receives from the outcome. Utility can differ for each player as a function of *risk love* and *risk aversion*. A player is risk-adverse that is always ready to sell an opportunity at an amount equal to its expected value, and conversely, a player is risk-loving that is willing to always buy an opportunity at an amount equal to its expected value. A player is risk-neutral if he is indifferent to buying or selling. *Nash equilibrium* occurs when no player can get a better expected payoff by unilaterally changing his strategy. *Common knowledge* is information that all players have and they know each other has it.

2.1.2 General Auction Concepts

I use Klemperer [1999] and Binmore [1999] for auction theory concepts. The set of rules that govern how an object is to be sold are called an *auction*. An auction is a game form often used when there is uncertainty about the *true value* of an object. A seller is not likely to know all the buyers' true valuations, and buyers usually do not know at what *reserve price* the seller is willing to sell. *Revenue Equivalence Theorem*[2] implies when bidders are risk-neutral, have common values, but independent estimates of values, then all auction processes will generate the same revenue; however, when the conditions are not met, then different auction types can have different outcomes.

Most oil and gas auctions use the *first-price* oral or sealed-bid mechanisms. Price is successively raised until only one bidder remains in oral auctions, and the final called price is the winning bid. The winning price guarantees an outcome as good as the second-best bid price, but no better. In sealed-bid auctions each bidder independently submits a single bid, without the benefit of seeing competitor bids. Under the conditions that satisfy the equivalence revenue theorem outcome potentially is no better than the second-best bid price. However, without those constraints the winning bid could be better.

Oil and gas auctions are considered *common value* (i.e., the property ultimately has the same value[3] to all bidders, but each bidder has his own estimate of what it is worth). Auction bidders routinely have the same information to evaluate the property, but the uncertainty in the interpretation of that information provides a range of estimates of its value.

Bidders are said to be *symmetric* if they draw from this same distribution of common knowledge. This pool of common information is called *complete information*. *Imperfect* information is where bidders are not aware of previous internal decisions by other bidders or information unknown to all bidders. It is possible for oil and gas auction buyers to have both complete and imperfect information.

A potential outcome of common value auctions is the *winner's curse*. This is the tendency for the winner of an auction to overpay for the common-value purchase. It occurs because the actual value to the different bidders is unknown but *correlated* (i.e., related to the same common knowledge) and the bidders make bidding decisions based on estimated values. The logical winner tends to be the bidder with the higher property value estimate, and therefore, he tends to overpay for the asset.

2.2 Auction Studies

Key early and developmental studies to gain historical perspective of oil and gas auction strategies are reviewed below.

2.2.1 Early Research, 1956-1974

Friedman [1956] pioneered competitive auction strategy with his approach to optimize expected profit in contract bidding. He supposes a government agency inviting companies to bid on a contract through a sealed-bid auction. He assumes each bidder desires to maximize total expected profit. Friedman's model includes a probability distribution of true cost as a fraction of estimated cost and a probability distribution of submitting a winning bid. The distributions require studying past data of cost estimates, actual costs, previous bid patterns, and knowledge of the number of competitors. Maximum expected profit is found by plotting expected profit for a given bid and locating the maximum value. Friedman acknowledges the number of competitors submitting bids is not likely known. He alternatively proposes combining all historical ratios of opposition bids to his bidder's cost estimate into a probability distribution function and determining the probability of being lower than some average bidder. The probability of being lower than all independent average bidders is then a multiple of the number of bidders.

Arps [1965] presents a sealed-bid strategy for acquiring undeveloped acreage independent of the number of competitors. His optimization approach appraises property values under a profit constraint, uses past behavior patterns of competitors, and maximizes the number of tracts purchased under this capital constraint. He determines property value from volumetric calculations (hydrocarbon reserves), net operating income per unit of reserves, and risked dry-hole costs. He assumes that most bidders use the same standard geological and geophysical information; however, he also comments that the interpretation of such data may vary over a wide range. He informs us that bid results often follow log-normal distributions using a 1954 Federal OCS Sale (Tract 0419) as an example. He reasons that the total impact of multiple variables in value calculations cause this outcome. Arps assumes the historical geometric mean values as good indicators of the future value. This is a common assumption by statisticians as the average of all parameter estimates often approaches the actual value [Rose and Associates, 2007]. He uses a Monte Carlo simulator to derive a probability distribution relating historical mean bids to the winning bids. He uses this correlation to develop an optimum bid strategy to maximize the number of leases under the constraints of capital and profitability.

Brown [1966] examines decision-making under uncertainty in competitive bidding for federal offshore Louisiana leases. His work discusses risk, portfolio selection, variability of results, abstract bid theory, leasing process, lease bid statistics, and a bid simulation model. He proposes maximizing expected profit on a lease tract that requires estimating the probability that a bid will be the winning bid for the tract and the probability distribution of opponent bids. His model simulates the expected profit from a bid for each tract. Brown's three variables of focus in his model are: estimated present value of the tract, the likely number of competing bidders, and the probability distributions of possible competitor bids. His model predicts less competition yields larger dispersion of the bids, and stronger competition reduces expected profit.

Crawford [1970] surmises that appraisal of an offshore lease prior to bidding is a product of many factors so that the bids may plot as a straight line on probability paper (i.e., a log-normal distribution).[4] Examples of Texas offshore lease sale bids for single tracts are plotted on probability paper to demonstrate this log-normal distribution behavior. He also provides an example of a tract that did not exhibit the typical behavior. He speculates that nonconforming bids occur with extreme outliers at lower ends as a result of minimum bidding to win the lease.

Capen, Clapp, and Campbell [1971] cite industry reports [OGJ 1969, 1970] that historical rate of returns for offshore Gulf of Mexico development are low. They believe bidders on the average value properties correctly; however, a bidder consistently wins in a competitive bid situation only when he significantly overvalues the property. They use a stochastic simulation model to analyze how much can be paid over the value of the lease tracts given the level of competition. The simulation model requires the probability of competitor bidding and *bid fractions*[5]. Assumptions include competitor tract values follow a log normal distribution and the actual value is the geometric mean of that distribution. Simulation runs compare winning to losing bids based on random variables, and compute present values, probabilities, and expected present value at each competition level. They conclude that a bidder should lower his bid level when: 1) he has less information than competitors, 2) the uncertainty of the property value estimate increases, and 3) there are more than three competitors.

2.2.2 Developing Research, 1975-1994

Dougherty and Nozaki [1975] propose that bid strategy requires an estimate of the value of the tract and application of a bid fraction to optimize expected gain. Application of a bid fraction allows for losses on tracts when actual value is less than the bid. Uncertainty of property value estimates and competition level influence the optimum bid fraction. They study the impact of variance in parameters. These parameters include standard deviation of estimates, competitor value estimates, number of competitors, and bid fraction of competitors. They find optimum bid fraction is determined by aggressive competition, accuracy of estimate, and the number of competitors. They conclude competitors' aggressiveness (i.e., higher bid fractions) influences a bidder's optimum fraction the most, and optimum bid fraction should decrease as uncertainty of estimated value increases.

Dougherty and Lohrenz [1976] conduct a statistical analysis of bids for federal offshore leases from1954 through 1974. They find that the average of standard deviation of the natural logarithm of bid values do not change over time (i.e., different lease sales) and equals approximately 1.0 standard deviation with a standard error of 0.15. The ratio of the high bid to geometric mean of all bids increases with competition while the average percent money left on the table decreases. Joint bidders tend to bid on leases receiving more bids and higher bonuses per acre than do solo bidders. Joint bidders tend bid higher than the geometric bid value than solo bidders. Winning bids of joint bidders tend to have higher relative standard deviation than solo bidders.

Dougherty and Lohrenz [1977] analyze *money left on table* (i.e., the winning bid compared to the second bid). They review 2,580 leases receiving 9,142 sealed bids of federal offshore lease sales from years 1954 to 1975. Their analysis supports that lease bids tend to follow log-normal distributions; however, higher bids tend to depart from the log-normal distribution. Individual lease sales can not be considered as having been drawn from a population of bids with a single standard deviation; however, a broad middle range of leases can be considered drawn from a population of bid values with a single standard deviation (derived from the average of the natural logarithm bid value variances) equals 1.09. The expected value of money left on table decreases as competition increases and increases as standard deviation increases.

Dougherty and Lohrenz [1977] find no consistent correlation supporting solo or joint bids decrease the number of competitive bids. The statistical study was unable to develop quantitative evidence indicating that increases in bids of any class cause a decrease in the total number of bids. The findings indicate that the effect of preventing two or more majors from bidding jointly may have increased the majors' proportionate sphere of influence. After a ban was lifted that prevented joint bidding the number of bids per lease in which a major participated was higher than before.

Lohrenz and Dougherty [1977] state that bidding results are determined by how aggressive a player is relative to his competition. They find that aggressive or conservative bid patterns are not consistent over multiple lease sales. When bidders bid jointly their bid fractions and winning bids tend be higher. They define relative aggressiveness as *bidder's bias*. An unbiased bid splits population of other bids into two equal parts with bid fraction as 0.5. Variation reflects differences in thinking and attitudes of those preparing the bids.

Lohrenz and Dougherty [1983] present evidence that more information about a lease does not mean bidders agree more on bid value, and that overall disagreement between bids consistently vary over time. On an average an aggressive bidder who wins is less profitable than a conservative bidder who wins. Profits cannot be observed from bid statistics; however it is likely that bidders' results are not satisfactory as observed from industry studies[6] where the pretax rate of returns on Federal offshore oil and gas leases in the Gulf of Mexico ranged from five to eleven percent.

Kagel and Levin [1986] conclude common value auctions constitute a market setting in which participants may be susceptible to judgment failures that affect market outcomes. They present clinical auction experiments with high and low bid values and different private and public information signals. They find providing public information about the value of the item increases seller revenue in the absence of a winner's curse, but produces contrary results in its presence of a winner's curse. Inexperience produces a strong winner's curse. Limited competition produces profits closer to the Nash

Equilibrium versus winner’s curse. With continued experience a bidder's strategy improves.

Lohrenz [1987] notes bottom line profits in the Gulf of Mexico are disappointing. More aggressive bidders tend to be less profitable than the more conservative bidders. Maximizing profit or reserves are two ways to optimize bidding. Maximizing reserves does not make sense as it could lead to negative profit. Models are built to optimize profit based on number of bidders, unknown bidders, and comparing joint versus solo bidders. A bidder achieves better results by exposing limited budget across leases of interests rather than bidding jointly. A bidder that does not apply an optimal bidding strategy will drive prices up and make less profit.

Lohrenz [1988] documents past performance and projection of future profits from federal oil and gas lease sales are poor. He advises to be wary of reasons that justify high bonuses. Meade studies showed rate of returns after tax of 9.02%. The market for leases was intensely competitive, rate of returns were low, and contested leases were lower than uncontested leases.

Lohrenz [1991] states competitive bidders seek to divide shares of "pies" of unknown value that each asset represents. Strategies can imply negative share and the seller can obtain greater value than the asset value. Lohrenz uses bid simulation to examine the results of different bid fractions of the estimated value on the net value to bidder, competitors, and seller. He finds better estimates of underlying value of offered assets can increase net expected value, but may require more aggressive bidding. Better information leading to more accurate estimates of asset value can diminish the seller share.

Phillips and Summers [1983] summarize several lease sale auction papers with a focus on lease bid models. They compare the Capen, Clapp, and Campbell [1971] and Brown [1966] models with emphasis on the former as a base model. The Capen et. al. model uses the concept of the actual value with an index of 1.0 (i.e., they assign a value of 1.0 to the actual value for every property) and then application of a bid fraction to calculate the bid level.

More recently, Furtado, Suslick, and Rodriguez [2008] discuss a lease model they developed using data from seven Brazilian offshore lease sales. They contend their model can be in formulating bidding strategies for different world regions and geological settings possessing similar competitive bidding profiles. In seemingly the reverse of the Capen et. al. model they determine bid fractions through stochastic simulation and then use the bid fractions to determine a range of expected monetary value (profit).

2.3 Summary and Comment

2.3.1 Key Concepts

Table 2.1 summarizes key concepts outlined in this section emphasizing chronology, researcher, and observations.

TABLE 2.1—SUMMARY OF KEY CONCEPTS PRESENTED IN AUCTION LITERATURE

Year	Research	Observations [Evidence]	Type
1956	Friedman	A winning bid with maximum profit requires knowing competitors and historical bid results. [Theory]	Sealed-bid General
1965	Arps	Competitors use same data, but interpretation widely varies. Geometric mean of bid values indicates the actual property value. [Theory, Empirical]	Sealed-bid Lease
1966	Brown	Maximizing expected profit on a lease tract requires knowing probabilities of winning and opponents' bids. [Theory, Empirical]	Sealed-bid Lease
1970	Crawford	Appraisal of lease sale value is a product of many factors and bids routinely assume log-normal distribution. [Theory, Empirical]	Sealed-bid Lease
1971	Capen Clapp Campbell	Bidders value properties correctly on average, but consistently win only when they overvalue. Decrease bid with decreasing data, increasing uncertainty of value, and increasing number of competitors. Set bid fraction at less than 30% for strong competition. [Theory, Empirical]	Sealed-bid Lease
1975	Dougherty Nazaki	Bid requires estimate of the actual value and application of a bid fraction to optimize expected gain. Competitors' aggressiveness influences a bidder's optimum fraction the most. [Theory]	Sealed-bid Lease
1976	Dougherty Lohrenz	The ratio of winning bid to geometric mean of all bids increases with competition and money left on table decreases. Joint bidders tend to bid higher than the geometric bid and show bid variances greater than solo bidders. [Empirical]	Sealed-bid Lease
1977	Dougherty Lohrenz	The bid money left on table decreases as competition increases and increases as bid variances increase. [Empirical]	Sealed-bid Lease
1977	Dougherty Lohrenz	There is not a consistent correlation supporting that solo or joint bids decrease the number of sealed bids. [Empirical]	Sealed-bid Lease
1977	Dougherty Lohrenz	Aggressive or conservative bid patterns are not consistent over historical lease sales. When bidders bid jointly their bid fractions and their winning bids tend to be higher. [Empirical]	Sealed-bid Lease
1983	Dougherty Lohrenz	More information about a lease does not indicate bidders have less variance in bids. There is nothing in bonus bidding which define a method to improve profits. [Empirical]	Sealed-bid Lease
1986	Kagel, Levin	Public information of value increases seller revenue in the absence of a winner's curse, but produces contrary results in its presence. Limited competition produces profits closer to the Nash Equilibrium. Experience improves bidders' profit. [Clinical Experiments]	Auction General
1987	Lohrenz	The more aggressive bidder tends to be less profitable than the more conservative bidders. A bidder does better by exposing limited budget across leases rather than bidding jointly. [Empirical]	Sealed-bid Lease
1988	Lohrenz	Past performance and projected future profits from oil and gas leasing are poor. Studies indicate historical competition increases rate of returns decreases. [Empirical]	Sealed-bid Lease
1991	Lohrenz	More accurate estimates of underlying value of a bid can increase net expected value, but may require more aggressive bidding. Better information leading to more accurate estimates can diminish the seller share. [Theory]	Sealed-bid Asset

The following discusses application of some of these concepts:

- The oral auction is the industry process of choice for predominately developed producing properties.
  - *The use of different auction processes opposes the hypothesis of the Revenue Equivalence Theorem which states all auction types yield the same result. Some of the reasons for this difference include: 1) risk nature of players, 2) uncertainty of evaluation parameters, 3) competition level, 4) asymmetrical buyers; and, 5) budget constraints.*
- Reducing uncertainty can increase bid values of sophisticated buyers.
  - *Most buyers have access to the same public knowledge, but sellers' that provide additional commercial, technical, and operational data can decrease uncertainty for participants and improve overall bid values.*
- Lease auctions[7] tend to follow log normal distributions.
  - *On the average a bidder can reduce his initial bid and still maintain a high probability of winning[8].*
- From a buyer's perspective reducing the bid fraction as the number of competitors increase will increase profit.
  - *However it also decreases the probability of not winning, but the evidence shows continued aggressive bidding over time contributes to poor portfolio results.*
- Inexperience increases aggressive bidding.

- *The seller should not count on the outlier buyer who is either inexperienced or ignorant. Although both are possible in any give auction, the best process maximizes information dissemination to buyers.*

- Competition increases the probability of higher bids if the evaluations occur from the same pool of common knowledge.
    - *More players increase the chance of higher valuations leading to higher bids. The winner's curse is rooted in increased competition.*

2.3.2 Other Comments

Most auction buyers bid from their independent valuations of an asset. They often have similar common knowledge of properties; however, uncertainty surrounds value parameters. Properties can also have different utility to participants based on factors such as infrastructure, cost of capital, technical and operational capabilities. For a large integrated energy company participation in a single auction game has minimum impact; however, cumulative strategies for auction processes over time can impact even large portfolios. For small companies a single auction event[9] can have large consequences. Oil and gas auctions can present factors beyond control or prediction (e.g., long-term future of commodity prices).

Managing risk [Bernstein 1996] is intrinsic to good business decisions. Therefore good understanding of probability, uncertainty, and utility (i.e., the elements of risk[10]) in the valuation process is essential. Probability is the chance that an event is successful. If the event is successful, uncertainty is the range of possible outcomes. Utility measures satisfaction of a successful outcome to the game player. Evaluation parameters contain these elements of risk. The foundation of property value is based on reserves which have probability of occurrence and uncertainty of size. The utility of the production depends on processing and market leading to revenue available to each auction player. Uncertainty in evaluation parameters drives greater range in value of properties.

Disparity of knowledge between competing bidders can cause a broad distribution of bids. Most auction processes provide a level of common knowledge to increase the selling price and attract buyer interests [Nordt 2004]; however, there is always the possibility that a bidder did not have time to fully evaluate the property, does not understand the level of risk, or has additional information that other bidders and possibly the seller does not have. In addition, buyers can have limited funds in which to buy auction properties. This can cause offers to be less than expected, or for buyers to concentrate value on a single auction property.

Evidence supporting the winner's curse potential exists in competitive auctions, and at times, need or ignorance may cause a buyer to sell a property below market. Nash equilibrium is a difficult achievement (i.e., no player can obtain better results by changing his position).

Increased competition increases potential for bidder to over pay for a property. A successful bidder is one that on average makes a profit from acquiring properties. With increased competition actual bids should be decreased to avoid the winner's curse. Sealed-bid auctions potentially yield significantly higher profit to sellers as uncertainty of value increases, whereas oral auction can encourage bidders to pay up to their maximum reserve value as uncertainty decreases.

Some of the above observations appear intuitive; yet, the winner's curse in public and private auctions still occur[11]. This appears as good news for the individual seller, but erodes confidence of buyers. I interviewed a growing number of buyers who believe competitive auction processes significantly cause over valuation of properties and their plans were to reduce participation.

2.4 Notes

1. I will use the masculine gender for personal pronouns in general context for simplicity, but please consider to read as he or she, herself or himself, etc.

2. Klemperer [1999] defines the Revenue Equivalence Theorem as follows:

   > *Assume each given number of risk-neutral potential buyers of an object has a privately-known signal independently drawn from a common, strictly-increasing, atom-less distribution. Then any auction mechanism in which i) the object always goes to the buyer with the highest signal, and ii) any bidder with the lowest-feasible signal expects zero surplus, yield the same expected revenue (and results in each bidder making the same expected payment as a function of her signal).*

3. The value of a property is assumed to be the same for each auction participant; however, the ultimate value is a function of technical, operational, commercial, and financial ability. Common value is a reasonable assumption given the maturity and knowledge base of the industry, and a necessary inference to advance certain discussions (e.g, bid models) presented in this paper. One notable exception can occur when regulated utility companies with guaranteed profit compete against non-regulated companies.

4. The Central Limit Theorem states that random variables that are additive will assume a normal distribution, and variables that are multiplicative will assume a long-normal distribution because the product of the variables is the sum of their logs.

5. Bid fraction is the ratio of a bid to the actual value of the property. The bidder of the property knows what he bids, but no one knows the real value of the property until the end of its life.

6. Barrow [1972], Lohrenz [1978], Mead, Sorensen [1980]. These studies are included in the references.

7. Results in Section 3 show at private sealed-bid auctions can fit a Beta distribution, while federal lease sales tend to fit log-normal distributions. Private property auctions usually have a larger component of producing and undeveloped proved reserves versus unproved resources.

8. I was curious as to how a more recent federal lease sale mirrors past lease sale research. A review of the largest federal lease sale, LS 206 [2008], on record showed the ratio of second bids to high bids averaged 43% from 223 tracts with two or more bids. Additional data from this lease sale will be presented in Section 3.

9. Anecdote—I managed a sealed-bid auction transaction where the seller of modest means originally bought a property at an oral auction, held the property for one year, and resold it for profit fifteen times his original purchase. The transaction was a life style change for the seller as he had risked a substantial amount of personal wealth in the initial transaction.

10. Drilling an oil and gas well illustrates these elements of risk in the evaluation of undeveloped reserve potential. A geoscientist estimates the *probability* of successfully finding hydrocarbons based on factors such as source rock, reservoir rock quality, and trapping mechanism. If successful, the reserve volume will be uncertain as it represents a *range* of possible recoverable volumes based on such factors as original oil in place, reservoir drive mechanism, and drainage area. *Utility* varies from player to player. For a small energy company it could be a company maker or breaker in reserve volume or costs. For a large energy company a single well has minimal impact on the company portfolio.

11. Section 3 presents evidence from private sealed-bid auction results that winning bids average greater than 10% above the second bid and current public federal lease sales have much greater ratios (see note 8 above).

3. CURRENT VIEW

3.1 Introduction

Oil and gas auction research peaked in the 1970s and early 1980s. These studies focused on federal lease sales over the concern of poor project economics and the availability of public data. Organized private property auctions first appear in the late 1980s to become a $30 billion a year business (see Section 1.1, Importance). Published research on private auctions is limited, and data, if available, comes from public press releases or personal communication.

This section presents material from industry interviews that explore private auction strategies and results. Texas A&M University Office of Research Compliance Institutional Review Board (IRB) approved the use of interview material reported in Sections 3.2 and 3.3. All interviews were confidential with full knowledge by participants that information they provided might be presented in research findings. Section 3.4 summarizes a narrower study [Nordt 2004] that gives additional insight into the subject.

3.2 Industry Interviews

3.2.1 Overview

An industry group of 22 individuals independently participated in strategy survey interviews to identify the top strategies most impact oil and gas property auction results. Only interviewees familiar with contemporary processes participated in the surveys.

They provided answers to the following questions:

- *Does your company participate in auction processes with committed strategies?*
- *What strategies most impact the value of offers?*
- *What risk factors most impact the value given to offers?*
- *When does the sealed-bid auction receive a better value than oral-bid auction?*

These questions investigate the central problem framed in Section 1. The interview questions were peer reviewed by several volunteer industry professionals that were not involved the interviews. The results of these interviews establish an industry perception of auction processes and provide data for designing simulated auction game experiments discussed in Section 4.

Table 3.1 provides participant companies and positions. The participants included employees of integrated energy companies, independents, and energy advisement firms with various positions of executive managers, managers, and technical professionals. The participants represent a 76% response from 29 interview requests. Most of the participants are from top 100 US producing energy companies and several top advisement firms.

TABLE 3.1—PARTICIPANT COMPANIES AND POSITIONS

Company Types	Count	Participant Positions	Count
Integrated Oil	2	Executive Manager	14
Independent	11	Manager	6
Energy Advisor	9	Technical Professionals	2

The participants were informed the study concerned strategies of oral bid and sealed-bid auctions. Strategies were defined for the interviews as adaptations that serve as an important function in achieving success within the constraints of the participants' companies. Some participants chose not to answer all the questions; therefore, the total response count does not always coincide with the number of participants for each question.

3.2.2 Question 1 Responses—Committed Strategies

The majority of responses in Table 3.2 specify that their companies develop strategies for auction participation; however, 14% believe that their companies do not have a systematic approach to auctions. Nine of the total participants came from energy advisement firms which by their business missions have a strategic approach to competitive marketing of assets. Considering only the energy company responses, the interview sample suggests that up to 20% of energy companies may not have formal strategies for auction participation.

TABLE 3.2—RESPONSES TO COMMITTED AUCTION STRATEGIES

Yes	No
19 (86%)	3 (14%)

3.2.3 Question 2 Responses—Top Strategies

Interviewees received a list of strategies that might impact competitive auction bids and were asked to rank them in order of importance. Strategies not listed, but deemed important, could be written in. Table 3.3 catalogs the top five strategies ranked from highest to lowest.

TABLE 3.3—TOP FIVE STRATEGIES BY RANK THAT IMPACT COMPETITIVE OFFERS
1. Aggressive Valuation of Non-proved Reserves
2. Forward Price Deck
3. Acceptance of Lower Rate of Returns
4. Core Technical Competencies
5. Hedging Master Limited Partnerships (tie for 5th)

Strategy one—the inclusion of non-proved reserves (probable and possible) in valuing auction properties coincides with recent reversal in the industry strategy from international projects towards North American energy investments. Stark [2007] states that the worldwide competition for reserves has caused many large public or privately-owned companies to return to US and Canadian open market for acquisition opportunities in unconventional resource plays, deepwater and arctic environments.

Strategy two—forward price decks are a large source of uncertainty for sellers and buyers. Rapidly rising commodity prices can cover a poor evaluation preceding a winning bid, and an acquisition followed by falling and sustained lower commodity prices can destroy returns of a thoroughly analyzed auction property. Hedging (strategy five) can protect returns for a period of contracted production, but it can also limit the upside in revenue.

Strategy three—lower rate of returns may also relate to the paradigm shift of increase interest in US properties. This pressure can force property valuations to higher levels. The Wood McKenzie Group [Deep Pockets 2007] reported on the first of two record breaking deep water lease sales in a decade coinciding with rising crude prices, *"The U.S. Gulf of Mexico (GOM) Central Lease Sale 205 attracted record amounts of interest. Spending for Deep Water blocks alone topped US$2.66 billion . . . ."* These assets provide one of the large hydrocarbon resource potential in politically stable waters and open to private companies.

Strategy four—core technical competencies are often touted as strategic competitive strengths of energy companies. A possible foreshadow implication is that as the playing field of acquiring properties narrows companies will continue to merge (or devour) weaker companies further weakening claims to technical and operational leadership.

Strategy five—hedging reduces exposure to price risk and eliminate the effects of negative fluctuations in income [Roberge 2005]. A major challenge in auction sales is the risk of volatile commodity prices. Buying properties during sustain period of rising commodity prices often means higher acquisition, operating, and development costs. If prices significantly fall post acquisition companies may face large asset write downs on acquisition projects. Write downs equate to value lost for equity holders. However, hedging also reduces the opportunity to capture upside profit in times of rising commodity prices.

Strategy five (tie)—the master limited partnership (MLP)[1] was the darling of the investment universe at the time of these interviews. Deutsche Bank [2007] captured MLP essence as follows:

> *Apparent arbitrage gap between market values of long-lived, capital intensity assets and their implied valuation within MLP structure. Look at recent returns. Under a 1986 Act of Congress designed to promote energy supply (legislation that arrived just as the oil market crashed), certain energy assets can be run in a partnership structure, known as Master Limit Partnership or MLP. The key benefit at the company level is effectively no tax is paid – liability is passed to shareholders as partners. The partnership benefits from no tax and a lower cost of capital. The shareholders benefit from attendant high dividend yield, on which of the tax liability is deferred.*

MLPs allow up to a 30% plowback of capital to maintain production. Few US fields fit a profile of low decline and maintenance.

3.2.4 Question 3 Responses—Modifying Risks

Interviewees ranked risk factors that most impact competitive auction bids. They could write-in additional risks they believed important. Table 3.4 documents the top five risks.

TABLE 3.4– TOP FIVE RISK FACTORS BY RANK THAT IMPACT COMPETITIVE OFFERS
1. Commodity Prices
2. High Capital Expenditures
3. High Operating Expenditures
4. Low Reserves to Production Ratio
5. Well Concentration

Risk one—commodity prices rank significantly above other risk factors in impacting competitive offers. A commercial study[2] illustrated that a ten percent change in price can have a magnitude greater impact on net present value than capital and operational expenses. Fig. 3.1 shows the volatility in commodity prices as West Texas

Intermediate crude oil increased nearly three-fold in three years from 2005 to 2008 followed by a precipitous decline in the last quarter of 2008. Commodity prices are a complicated variable dependent on many variables such as supply and demand, finding and development costs, conservation, access to resource, politics, and alternative energy developments. Tertzakian [2007] offers a compelling scenario that price volatility will continue at greater extremes as world crude oil demand permanently exceeds supply.

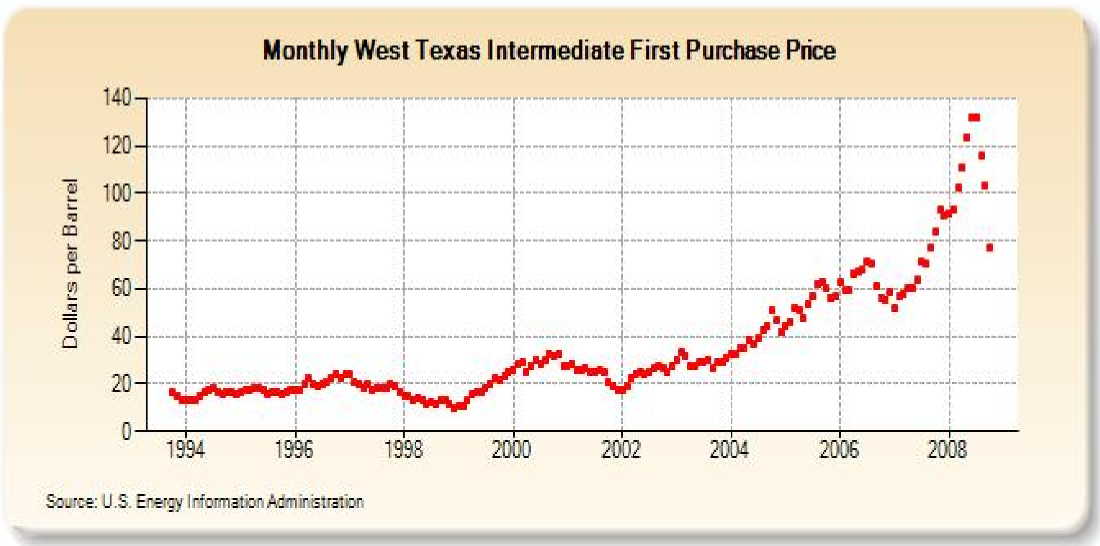


Fig. 3.1—WTI crude oil drastically increased and declined from 2007–2008 illustrating commodity price volatility.

Risk two—high capital expenses refer to excessive future costs associated with exploring and developing hydrocarbon reserves on a unit production basis. Average finding and development costs of the top 50 US companies rose from \$9.55/boe to \$15.83/boe [John S. Herold, Inc. 2008] during the years 2003 to 2007. The move toward more unconventional and deep water GOM reserves in the US creates a value disparity between legacy reserves and newly discovered fields. The uncertainty in capital requirements due to technical and commercial challenges creates more risk.

Risk three—high operating expenses refer to excessive future costs for producing and processing production for sales on a unit production basis. Average production costs of the top 50 US companies rose from $5.66/boe to $11.92/boe [John S. Herold, Inc. 2008] during the years 2003 to 2007.

Risk four—low reserves to production ratio (R/P) refers to excessive production rates relative to proved producing and undeveloped reserves which indicates a producing field are closer to its end of life cycle. Rasheed [2009] reports that US has an oil R/P of 11.7 years in contrast to the top five global oil reserve countries which have oil R/Ps 70 or greater.

Risk five—well concentration refers to excessive production relative to a few wells, and if damaged, would require significant investment to replace.

3.2.5 Question 4 Responses—Best Auction Type

83% of the interviewees expect sealed-bid auctions to receive higher bids than oral auctions when the undeveloped property value exceeds 30% of the total property value. The increase in uncertainty of valuation from proved producing to non-producing reserves categories explains this response. This also agrees with how the industry uses auction processes in marketing properties.

3.3 Auction Results

Public news releases sometimes report winners of private sealed-bid auctions; however, the complete bid results are not attainable. Confidentiality of losing bids keeps the private sealed-bid auction winner engage in completing the transaction by reducing winner's remorse and the potential of renegotiating the offer price downward following the auction. The SPEE Perspectives on Fair Market Value [2002] confirms that data regarding private property sales are treated as highly confidential.

The interviews of energy advisors presented a unique opportunity to sample private bid data results from auction asset sales over a five year period from 2002-2006. Sample data were requested from five energy advisement firms. The requests included one auction per year for five years from each firm. Four of the five firms responded with representative data. Requested data included index values of all offers, the ratio of producing to total proved reserves (PDP/PRV), and the R/P ratio from five transactions with five or more offers for each transaction. One firm provided results for more than five transactions and with less than five offers for some of those transactions. Another firm did not provide proved producing/total proved reserves or production/total proved ratios. This explains the differences in the number of data points for some categories.

Table 3.5 summarizes 28 private sealed-bid auctions. Bid results were given in index form without names of the auction players to protect confidentiality. Auction transactions managed by these companies typically range from $25 million to $1.5 billion. The second highest bids in the auctions average 0.88 with a standard deviation 0.13. The average winning bidder could offer 10% less and retained a high probability of maintaining the winning position. In two auctions (7% of the sample data) the second bids matched (i.e, the same as) the winning bids. On an average the same approximate gap of value exists between second and third highest bids.

Fig. 3.2 shows the second highest bids (green dots) contrasted to the winning bids. All winning bids (red squares) are indexed as 1.0. Significant value gaps of approximately 50% occurred between the winning bids and the second bids on auctions #12 and #15 (7% of the sample data). Several advisor firms related that extreme winning outliers occur in approximately 10%-25% of their sealed-bid auctions. This suggests that extreme outliers recognize inherent risks to a much lesser degree than their competition; or, conversely, they may understand bidding risks, but internal pressures (e.g., targeted reserve additions) force aggressive decisions to push valuation limits. It also partially[3] explains why sellers prefer sealed-bid auctions when there is uncertainty in the value (i.e., properties that are not fully developed).

TABLE 3.5—DATA SUMMARY FROM 28 PRIVATE SEALED-BID AUCTIONS

Category	Average of Auctions
Bids per transaction	8.5
2nd Highest Bid	0.88 w/SD of 0.13
3rd Highest Bid	0.80 w/SD of 0.13 (27 data points)
Mean of All Bids	0.74 w/SD of 0.12 0.71 (geometric)
Proved Producing/Total Proved	52% (22 data points)
Production/Total Proved, yrs	11.0 (22 data points)

Private sealed-bid auctions typically experience smaller bid differences between the top bidder and competitors compared to public federal sealed-bid lease sales. Arps [1965] expresses evaluations of federal offshore leases consider many product dependent variables that can have larges variations (e.g., formation area, thickness, porosity, and hydrocarbon saturations) which sometimes leads to winning bids that are a magnitude or larger than competitor bids. In contrast, the properties of private property auctions frequently have better reservoir control on valuation variables.

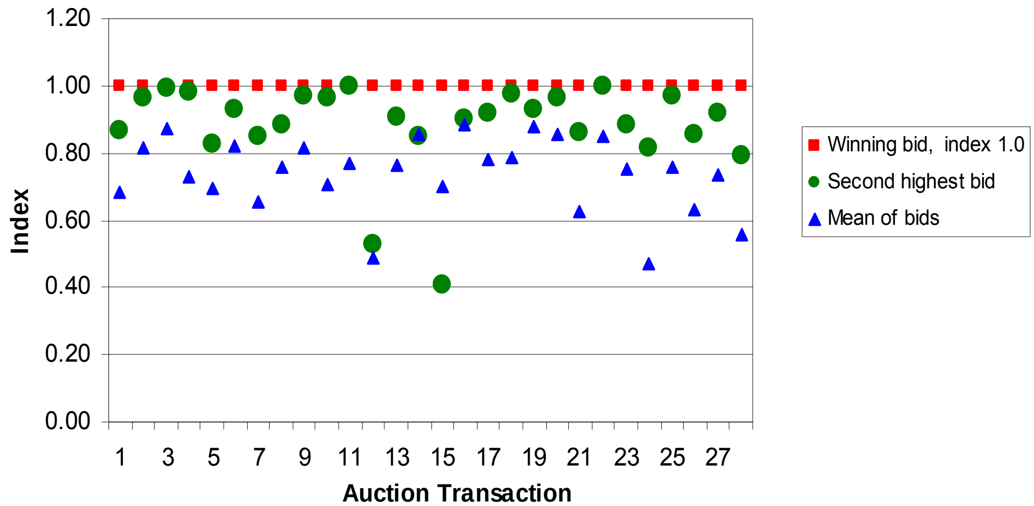


Fig. 3.2—Second highest bids and mean of all bids compared to winning bids from 28 private sealed-bid auctions (source: confidential interviews with four energy advisors).

Fig. 3.3 presents a histogram distribution of index bid data from all 28 private sealed-bid auctions. An index of 1.0 for winning bids was entered only once; however, second bids that had an index of 1.0 (i.e., were entered as many times as they occurred). The statistical tests[4] (Anderson-Darling, Kolmogorov-Smirnov, Chi-Square) of these distributions considered ranked the beta distribution (shown as a continuous green line) as a best fit of the data.

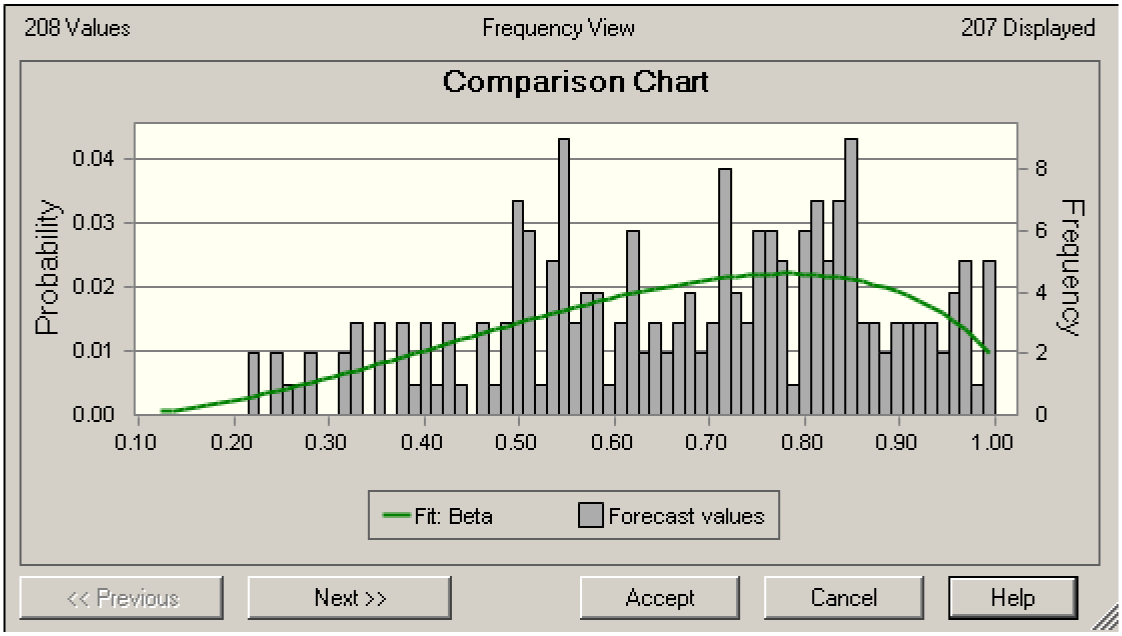


Fig. 3.3—Histogram distribution of private sealed-bid auction index data for 28 auctions with winning bid entered only once.

Fig. 3.4 recreates the fitted beta distribution from Fig. 3.3 with minimum and maximum truncations of 0.10 and 1.0 respectively. Truncation was set as 0.10 because all the data resides above that point, and 1.0 is the index for the winning bids. The P90, P50 (median), P10 are 0.91, 0.69, and 0.40 with a mean of 0.62 and mode of 0.77. Table 3.6 summarizes the beta distribution statistics. This beta distribution is not unique as it comes from a limited sample, but it does offer a distribution type that could be used in stochastic bid models, and resembles the distribution profile of many private bid auctions that I have analyzed. It is interesting that the standard deviation (0.19) of this private auction sample is much less than the federal lease sales statistics (approximately 1.0). This occurs because the properties have historical production associated with the sales.

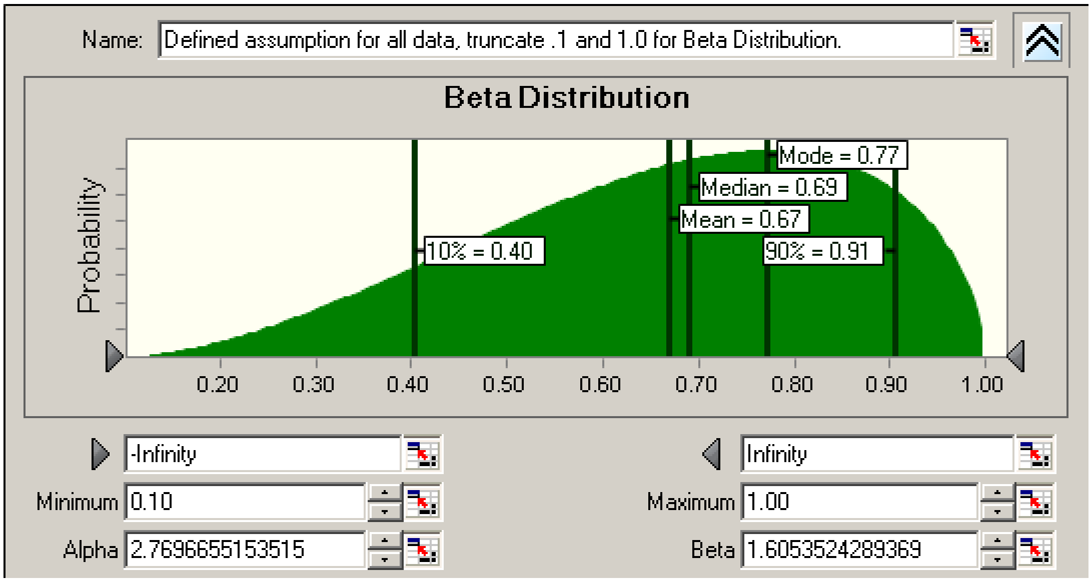


Fig. 3.4—Fitted Beta distribution of 28 auctions with winning bid entered once and minimum and maximum truncations at 0.1 and 1.0.

TABLE 3.6 – BETA DISTRIBUTION STATISTICS OF FIG. 3.4	
Mean	0.67
Median	0.69
P10	0.40
P90	0.91
Mode	0.77
Standard Deviation	0.19
Variance	0.04
Skewness	-0.40
Kurtosis	2.40
Coeff. of Variability	0.28
Minimum	0.10
Maximum	1.00

3.4 Case Studies

3.4.1 Private Sealed-Bid Auctions

I presented data (Nordt 2004) from twenty-four private sealed-bid auctions over a three-year period from 2001 through 2003. These asset auctions ranged between \$4 million to \$40 million. The auctions included properties from most major U.S. producing basins with the highest concentration of properties in Texas, Oklahoma, and Louisiana. Table 3.7 summarizes the transaction parameters. My intent this research was to determine why properties were sold through auctions and the cause of failure in these processes.

Table 3.7 – SUMMARY OF PRIVATE SEALED-BID AUCTION STUDY GROUP (2001-2003)

Category	Parameters
Total Projects	24
Successful Closings	18 (75%)
Closing Prices, \$MM	
High	35.0
Average	11.9
Low	3.6
Average Market Metrics[a]	
Rate	\$21,535/BOEPD
Cash Flow Payout[b]	45 months
Producing Reserves[c]	\$8.10/BOE

[a]6:1 MCF/BO equivalent conversion factor for gas
[b]Closing value/current cash flow per month
[c]Closing value/producing proved reserves

Table 3.8 presents strategic reasons the study group sellers auctioned their properties. Profit-taking strongly topped the list followed by non-core property, developmental risks and operational expenses. The study concluded poor data quality was the most common factor in unsuccessful projects. Poor data quality damages seller credibility and erodes buyer confidence in an auction process. The price received for a property is improved by integrating land, commercial and technical information into a concise historical overview and potential development plans. Buyers have finite resources for evaluating assets, and what is not clearly presented generally receives less value.

Table 3.8 – STUDY GROUP REASONS FOR SELLING PROPERTIES

Reason	Count (percent)
Profit	11 (45.8)
Non-Core Property	5 (20.8)
Developmental Risks	3 (12.5)
Operational Expense	3 (12.5)
Strategic Exit	1 (4.2)
Partner Conflict	1 (4.2)
Total	24 (100)

3.4.2 Lease Sale 206

Central Gulf of Mexico Lease Sale 206 in March 2008 set record winning bids of $3.7 billion on 615 separate blocks. Analysis of LS 206 supports historical lease sale research presented in Section 2 as follows:

- Tract bids tend to exhibit log-normal distributions.
    - *Figures 3.5, 3.6, 3.7, and 3.8 are semi-log graphs of bids values for LS 206 tracts that received seven or more bids. All four tracts follow a log-normal pattern with trend line coefficient of determinations (R^2) greater that 0.93. Although not shown, this pattern holds true for tracts with four to six bids per tract.*
- Winning bids leave significant money on the table (LOT).
    - *In LS 206 LOT (Bs/Bh) averaged 43.2% for the 223 tracts with two or more bids. This represents a significant amount of collective money loss to bid winners.*
- Competition decreases the amount of money left on the table.
    - *In LS 206 LOT averaged 59.3% for five or more bids in 27 tracts and 41.0% for less than five bids in 196 tracts.*
- Competition increases the dispersion of average bid value.
    - *In LS 206 the dispersion of high bids to the geometric mean of bids (Bh/Bg) averaged 3.7 for the 223 tracts. Bh/Bg averaged 6.5 for five or more bids per tract and 3.3 for less than five bids.*
- Bidding jointly does not increase the chances of winning.
    - *Fig. 3.9 compares the highest solo and joint bids of the top 20 winning bid blocks (three blocks did not have a joint bid) from LS 206.*

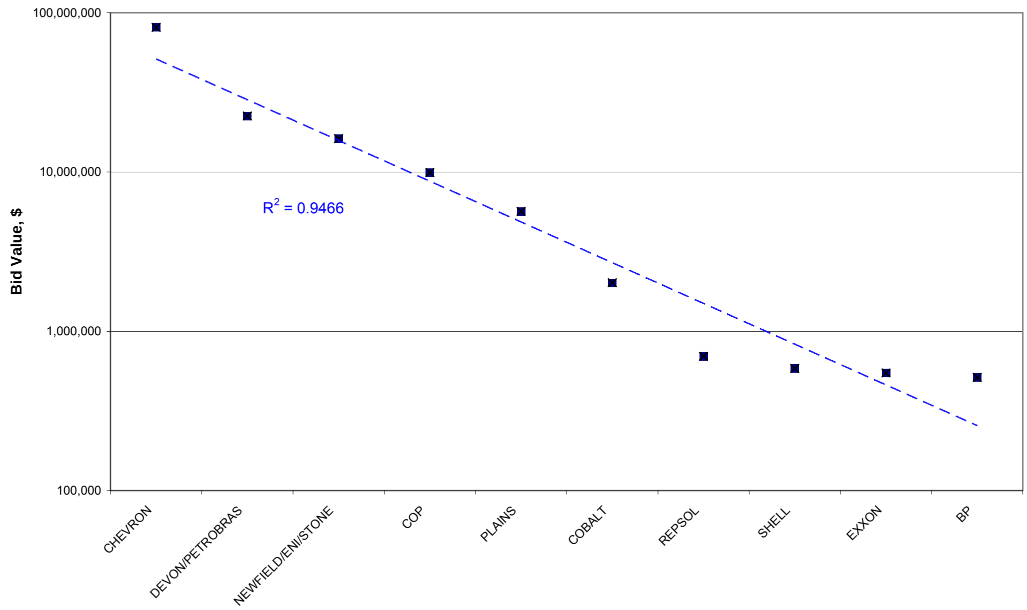


Fig. 3.5—Federal lease sale 206, tract GC 945 bids by company.

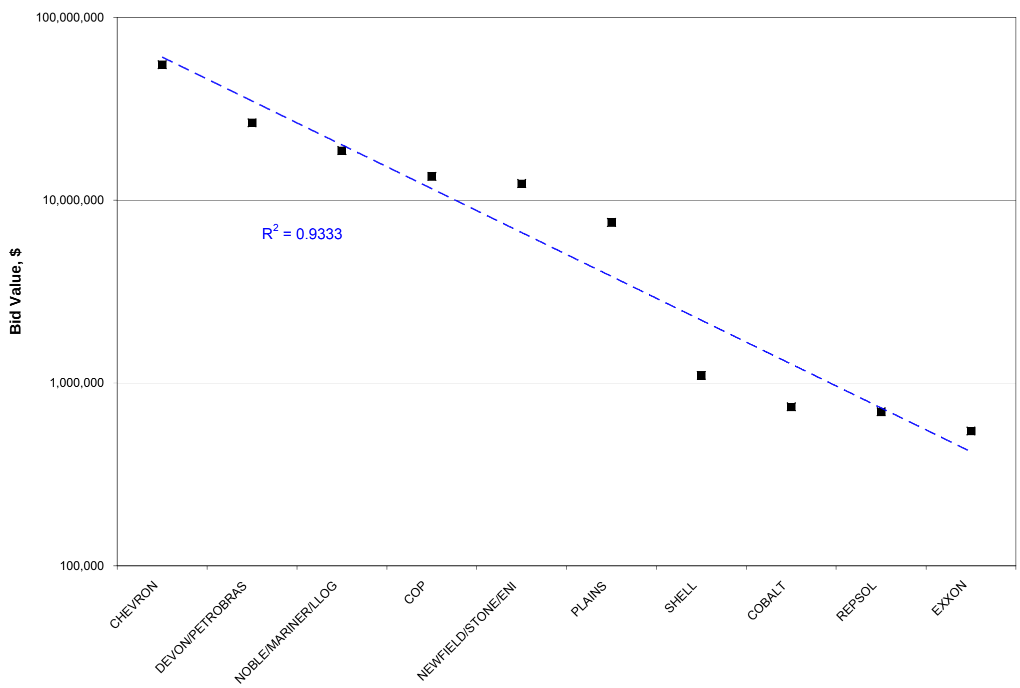


Fig. 3.6—Federal lease sale 206, tract GC 944 bids by company.

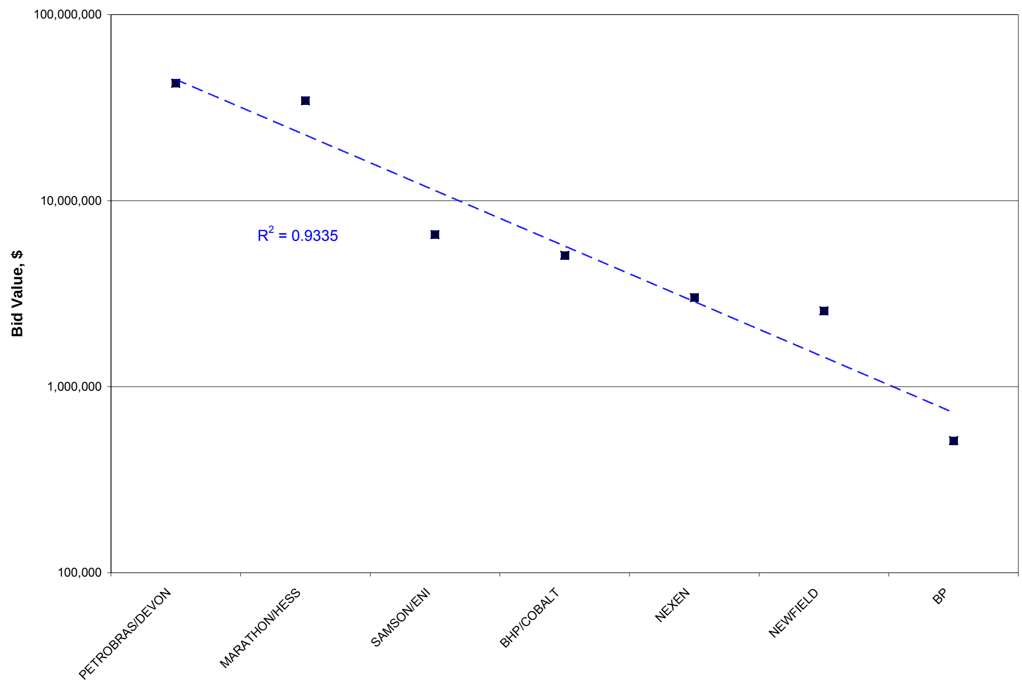


Fig. 3.7—Federal lease sale 206, tract GC 442 bids by company.

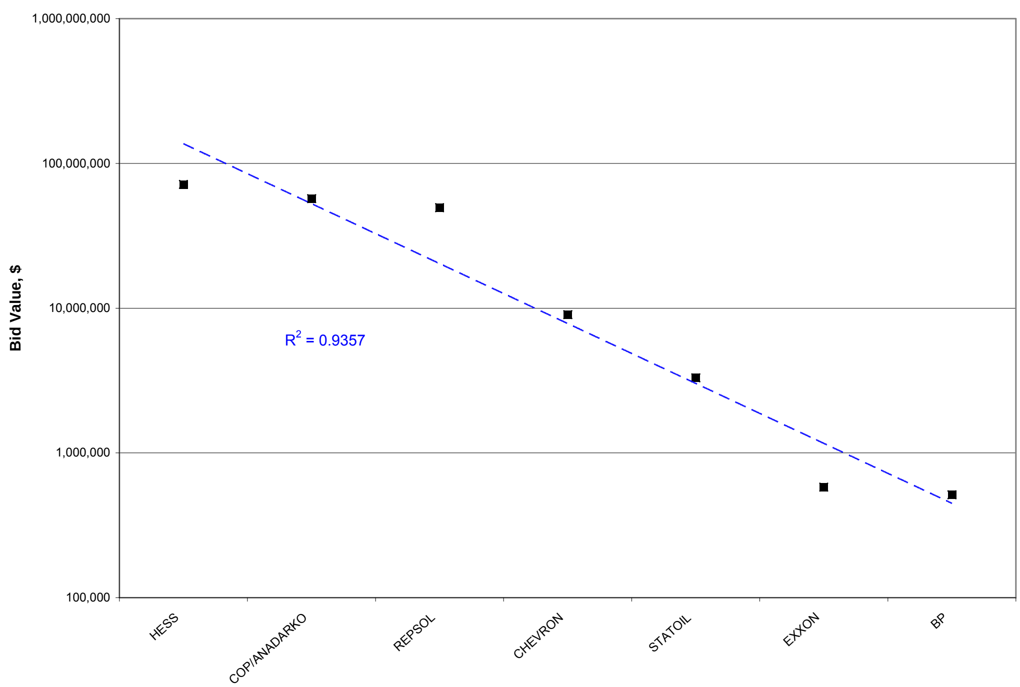


Fig. 3.8—Federal lease sale 206, tract KC 469 bids by company.

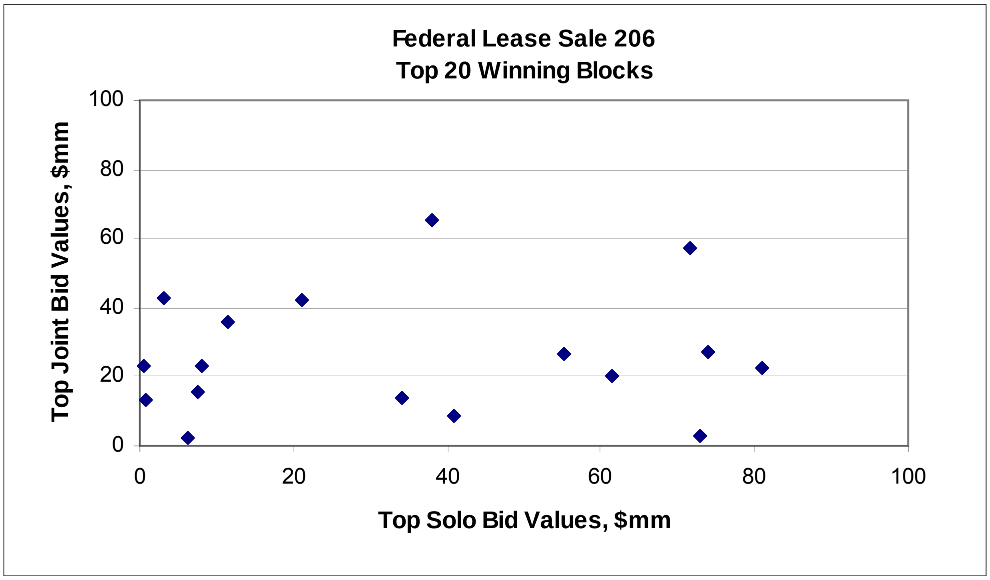


Fig. 3.9—Federal lease sale 206, comparison of the top solo and joint bids for the top 20 winning blocks.

3.5 Summary

The list below recaps a current industry view on auction strategy through interview surveys, confidential private sealed-bid survey results, and a case study of 24 auction projects:

- Competitive bid offers assign more value to non-proved reserves, manipulation of forward commodity price deck, and accepting of lower rate of returns on projects.
- Top risks in valuing properties include commodity price, expenses, reserve ratio, and well concentration; however, commodity price dominates risk as it offers great upside and downside opportunity with its inherent uncertainty.

- Private sealed-bid auctions are perceived to bring better offers than oral-bid auctions when non-producing property value exceeds 30% of the total property value.
- A private sealed-bid auction winner on an average can offer 10% less and retain a high probability of maintaining the winning position.
- In approximately 10% of private sealed auctions an extreme gap in bid values exists between the winner and the competition.
- More money is left on the table on the average in public federal sealed-bid lease sales compared to private sealed-bid auction properties.
- Profit, non-core property, developmental risks and operational expenses are the most frequent reasons the study group properties were sold.
- Poor data quality is a common factor in unsuccessful auctions.

3.6 Notes

1. The collapse in 2008 of the US financial markets and hydrocarbon prices may undo much of the perceived strategy value in reemergence of MLPs in upstream sector of the industry. MLPs once before fell into discredit as an investment tool popular in 1980s with rising commodity prices only to be punished as prices suddenly dropped. The commodity price cycle variance is similar then as it is now.

2. Nordt, D.P. A Commercial Analysis Methodology for Acquisition Evaluations. *Texas A&M Directed Study* (April 2005) 1-17. I have not published this paper and therefore, did not include in the reference section.

3. Another key factor are sealed-bid auctions by the nature of the properties are usually of higher value than oral auctions. Private sealed-bid auctions often use a purchase sales agreement [Nordt 2004] to negotiate the final transaction and allow time for a more thorough due diligence period.

4. Microsoft *Crystal Ball* was used as the evaluation software.

4. AUCTION EXPERIMENTS

4.1 Introduction

Section 4 examines bid behavior through simulated auction game experiments using industry participants. The primary objective is to observe player strategies to changing auction signals (i.e., changes in common knowledge from a base case property). The secondary objective was to establish an experimental approach for future private auction research. The results support a theoretical understanding of general auction behavior and gives additional insight to private oil and gas auctions.

I designed the game experiments and simulation logic. The Texas A&M University Computer Science Department[1] assisted in developing the web-site platform for these experiments. The TAMU IRB Board approved Protocol #2007-0685 to conduct these human subject experiments under Code of Federal Regulations 45 CFR 110(b) (1) as they involved no more than minimal risk to the participants. Following the beta tests, the actual experiments were conducted in 2009.

Eighteen independent players participated in the game experiments out of approximately 120 requests from a community of integrated, independent, and consulting companies. All players volunteered and had some knowledge of industry auction processes. They were contacted through e-mail or verbal invitation to join in the game experiments, and then directed to a website for playing instructions preserving their anonymous participation.

Bid strategies are observed by analysis of composite player mean results between games. The players' challenge was to make an overall profit greater than the simulator competition by bidding on ten separate properties. Bid risk varied between games by changing the common knowledge signals; however, common knowledge did not change between round 1 and round 2 of the same game. Each player had access to equivalent common knowledge; though, competitor bid values could vary based on random number simulator routines that determined the competitor number and each competitor value based on probability distributions.

Players received instruction that a bid value (actual value) exists that yields an acceptable profit within the given range. The common knowledge also gave signals of the percent value by reserve classification (and sometimes competition level or the actual value) to establish the relative risk[2] of submitting an offer. Property utility was assumed neutral to all players. The simulated competition presented the player with three bid outcomes for each auction game and round: 1) win with future profit; 2) win with future negative profit; and, 3) lose with no profit.

4.2 Description

4.2.1 Overview

The experiments consist of ten independent auction games with two rounds per game. Round 1 feature sealed-bids (i.e., the player does not know the simulated competitor bids). Round 2 are oral-bids (i.e., the player observes the current high bid) and player receives a short time to better the current high bid or the auction closes. The highest competitor bid from round 1 remains the high bid for round 2 unless the player bids higher.

Players receive common knowledge for each game shown in Table 4.1. Common knowledge is different for each of the ten games, but it is identical between rounds 1 and 2 of the same game. Game common knowledge includes a range in which the actual bid value lies that yields an acceptable profit[3]. The actual value range includes a lower and upper limit. The actual value is a function of competitor simulation bids and the player's bid unless given in the common knowledge (games 5 and 10). The percent actual value by reserve category sets the initial level of risk in the value range. Games 1 through 5 have 90% of their value in proved producing reserves and should have less value at risk as compared to games 6 through 10 where 50% of value is in proved producing reserves and 50% is in proved undeveloped reserves.

TABLE 4.1—GAME COMMON KNOWLEDGE

Game No.	1	2	3	4	5	6	7	8	9	10
Actual Value, mm$										
Maximum	60	600	60	60	60	60	600	60	60	60
Minimum	30	300	30	30	30	30	300	30	30	30
Known	???	???	???	???	55	???	???	???	???	40
No. of Competitors	???	???	2	9	???	???	???	2	9	???
Reserve Value, %										
Proved Producing	90	90	90	90	90	50	50	50	50	50
Proved Undeveloped	10	10	10	10	10	50	50	50	50	50

4.2.2 Rules

The basic game rules are as follows:

- Player competes against simulated competitors with common knowledge.
- Player inputs round 1 game bids before advancing to round 2.
- Player can not change a game bid in round 1 once he completes the game.
- Player can not change a game bid in round 2 once he completes the game.
- Player and competitor results are displayed after completing all games.

A detail set of rules are given in Appendix A.1—Game Design Rules.

4.2.3 Design Tests

10,000 trials were run on each game to check the simulator logic for expected actual value results. Summary of those trials are shown in Table 4.2. Player bids were set at $45 million for the trial runs. The actual values varied depending on relative uncertainty. There was a ten-fold increase in range of actual values from $30-$60 million to $300-$600 million in games 2 and 7; therefore, results of games 2 and 7 were multiplied by the scale factor of 0.10 to compare results with the other eight games. Games 5 and 9 give the actual value as common knowledge.

Games 1 through 5 (predominately producing reserves) have actual values higher than games 6 through 10 (mixed reserves). The simulator adjusts for the relative uncertainty in valuation as properties move from 90% producing to a 50% mix of producing and undeveloped property value. The actual results of simulation trials agree with expectations for all ten games.

TABLE 4.2—EXPECTED SIMULATION BID BEHAVIOR AND RESULTS				
			Actual Value	
Game	Property Description	Scenario Change	Expected	Results
1	Producing	Base case	n/a	n/a
2	Producing	Ten-fold increase in value range	= Game 1 * 0.10	agree
3	Producing	Two known competitors	< Game 1	agree
4	Producing	Nine known competitors	> Game 1	agree
5	Producing	Actual known value	≈ Game 1	agree
6	Producing + Undeveloped	Undeveloped 50% un-risk value	< Game 1	agree
7	Producing + Undeveloped	Undeveloped 50% un-risk value Ten-fold increase in value range	= Game 6 * 0.10 < Game 1 * 0.10	agree agree
8	Producing + Undeveloped	Undeveloped 50% un-risk value Two known competitors	< Game 6 < Game 1	agree agree
9	Producing + Undeveloped	Undeveloped 50% un-risk value Nine known competitors	> Game 6 < Game 1	agree agree
10	Producing + Undeveloped	Undeveloped 50% un-risk value Actual known value	< Game 6 < Game 1	agree agree

4.2.4 Beta Tests

Beta tests identified potential issues with technical reliability and computer human interaction interface. Final adjustments to the web-site, human game interactions, database functionality, and simulator followed from the results.

4.2.5 Simulator Design

The simulator design provides a mechanism for experimental studies and to keep player interest in a competitive game environment. Table 4.3 outlines the fundamental simulator process. Details are given in Appendix A.2—Simulator Concept Logic.

TABLE 4.3 —SIMULATOR PROCESS
• Player is given common knowledge and simulator constraints for each game. • Player inputs a bid for each sealed-bid auction game. • A random number generator selects game competitors from a uniform distribution. • A random number generator selects competitor bid values from beta distributions. • Actual property value is a function of simulated competitor and player bids. • Player inputs bids for oral auction games. • Database stores game data for analyses.

A player enters the game experiment website where he obtains common knowledge to make bid decisions. A uniform random number generator selects competitors between one and nine, or it is given as common knowledge in games five and ten. The minimum bid is the lower limit in the common knowledge as it guarantees a profit if it is the winning bid. Sealed-bid auction games are played first. A random number generator selects competitor bid values from a distribution. The competitor and player bids are used to calculate an actual property value as a function of geometric mean and a scalar to ensure a reasonable probability of obtaining a profit for each game dependent on relative risk. Player may replay the games; however, only the first participations are used in analyses.

Data collected from player games for analyses includes the following:

- Av = actual value of property
- Bch = highest competitor bid value
- Bcs = second highest competitor bid value
- Bp = player bid value
- Cp = competitor profit = Av - Bw (competitor)
- k = game count
- LOT = money left on table = Bw - Bs

- m = player count
- Mw = player wins
- n = competitor count
- Ncw = competitor wins
- Pp = player profit = Av – Bw (player)
- R1,2 = round 1 or round 2

4.2.5 Web-site Design

Details on are documented in Appendix A.3—Website Design Logic.

4. 3 Results

4.3.1 Overview

The common knowledge for these auction games is the same for all players. The games represent theoretical populations of different property types presented in the experiment. The objective of the experiments is to determine how a sample of industry players perceives changing risk and uncertainty by analyses of bids for the theoretical populations. Protocol requirements, website platform, time requirements, game complexity (design and application), and potential of learning bias required a single experiment trial. This requirement added a tremendous pressure to the designer. The game design, logic, and website platform evolved over a year of design and beta tests.

Eighteen unique players participated in 360 games (i.e., 10 games x 2 rounds x 18 players). It takes each player 10 to 15 minutes to complete the game experiments as determined from beta tests. The eight participants in the various beta tests were excluded from the actual experiment results.

Table 4.4 shows the eighteen players won 24% of the total 360 games against simulated competition. Players made a profit (i.e., not losing money) in 54% of the games they won. They won fewer times in round 1 (19%) and made less profit (30%) versus round 2 games.

TABLE 4.4—PLAYER WIN AND PROFIT GAME COUNT			
	Round 1	Round 2	Total
Game Count	180	180	360
Win Count (%)	34 (19%)	54 (30%)	88 (24%)
Profit Count (%)	16 (47%)	32 (59%)	48 (54%)

4.3.2 Analysis Process

I use the averages of the mean player values for each game to review trends in bid behavior. Additional detail appears in Appendix B—Statistical Analysis of Game Results.

4.3.3 Results

Fig. 4.1 presents the average player bids for each game. Games 1 through 5 are producing properties and Games 6 through 10 are a mixture of producing and undeveloped properties. Rounds 1 and 2 are shown side by side for each game. The changes in common knowledge are annotated above each game; the reader can reference Table 4.1 for a complete description. Observations for this set of experimental games include:

- Producing properties received higher bids than mixed properties.
    - *Producing properties are assumed to have less uncertainty as their valuation is based on historical production and cash flows.*

- Oral auctions with the same common knowledge increased bids.
    - *Oral auctions can drive bids higher through emotional involvement, and the assurance that the property is being valued similarly by competition. The experiments show support in using a hybrid process for traditional private sealed-bid auctions to include an oral auction component.*
- Competition increased bids in sealed-bid auctions.
    - *The normal reaction in sealed-bid auctions is to increase bids in strong competition. As we have seen from historical lease sales and theoretical studies this increases the chance of winner's curse.*
- Property size did not change relative bids in the sealed-bid auctions.
    - *A relative magnitude change will not change the rate of return on a property in theory; however, in the real world economy of scale may lower expenses which impacts rate of return.*
- A known value reduced uncertainty and variance of bids and increased or decreases bids depending on the known value bias.
    - *If auction players know the actual value, then there would be less uncertainty and the bids would consistently center on the true value. In the real world the actual value is never really known until abandonment, but this exercise emphasizes that reducing uncertainty in any parameter increases value.*

Figs. 4.2 and 4.3 review the same data as a function of bid ratios to compare different games for producing and mixed properties.

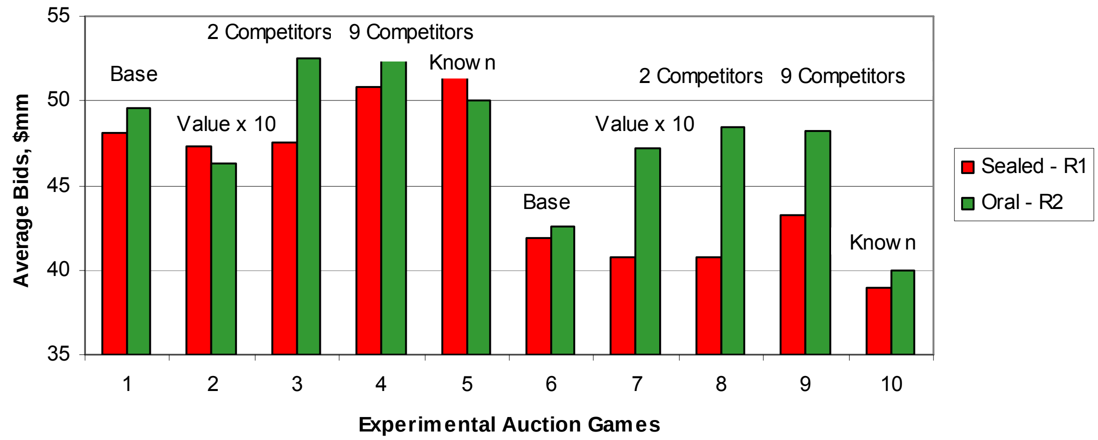
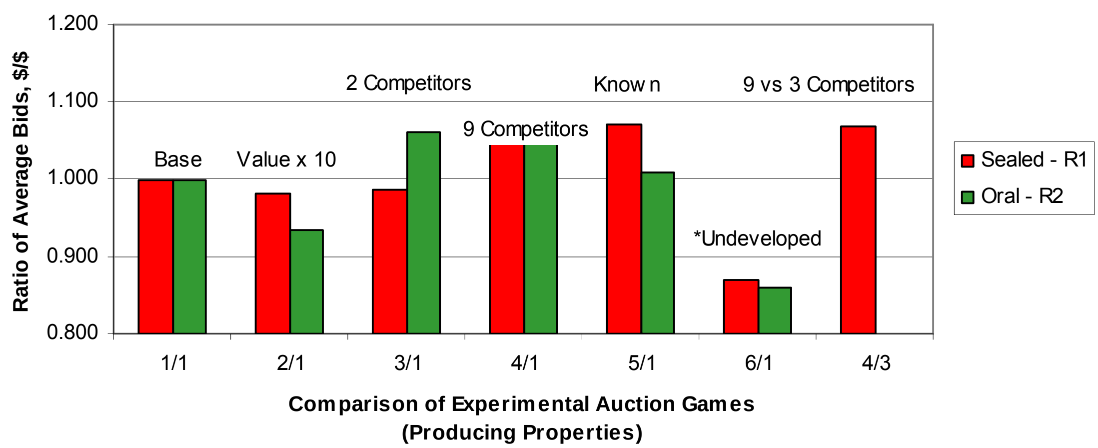


Fig. 4.1—Common knowledge changes average bids for experimental auction games.



**This compares the base case as an undeveloped versus a producing property.*

Fig. 4.2—Common knowledge impacts average bid ratios for producing properties.

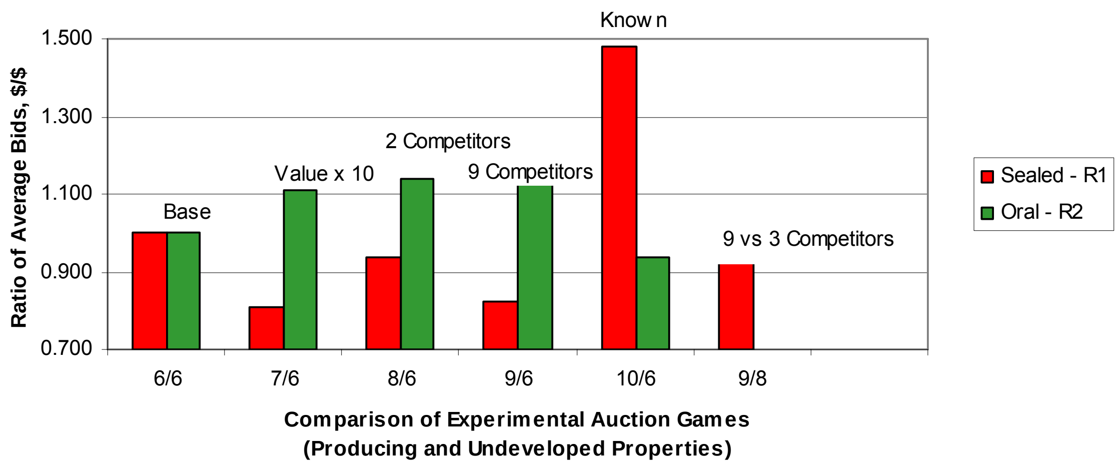


Fig. 4.3—Common knowledge impacts average bid ratios for producing and undeveloped properties.

4.4 Summary and Comment

These game experiments generally support what we learned from auction theory in Sections 2 and 3, and emphasize concepts to formulate winning and profitable auction strategies.

Sellers should consider the sealed-bid process for properties that include a large component of undeveloped value. Sellers should consider the oral auction for producing properties, and perhaps not be so concerned about size of the property. Uncertainty reduces value: therefore, reasonable efforts should be made to provide good support data to potential buyers.

Buyers should consider: 1) holding fast on their property valuations to avoid the herd mentality to increase bids in face of strong competition, 2) increasing value by reducing parameter uncertainties, 3) taking a long term portfolio strategy to avoid the winner's curse, and 4) reviewing competition level and changing market conditions prior to making a bid.

4.5 Notes

1. Marlo Nordt, PhD Computer Science TAMU [2008)] developed the operational website.

2. A producing property normally has less risk than a proved undeveloped property and increased competition generally increases the chance of overbidding.

3. The actual value is calculated from an algorithm based on the geometric average of the bidder and competitors, and then multiplied by a scalar (based on calibration stochastic runs) dependent on the game and number of competitors.

5. VALUATION MODELS

5.1 Introduction

This section examines bid valuation processes. A valuation process should offer a consistent system valuing auction properties. Auctions often occur over short durations[1] from market to sale which can create an evaluation dilemma for buyers. Winning an auction is not hard, winning and making a profit is a more difficult proposition. An opportunity could be by-passed through inadequate review, or hasty participation may lead to a bad investment decision. The emphasis in this section is from a buyer's prospective; however, a seller uses the same approaches in determining an acceptable reserve price for a auction property.

5.2 Property Valuation

5.2.1 Discounted Net Cash Flow

The first step in setting a bid value is to determine the value of the property. Megill [1979] discusses converting exploration and development opportunities into cash flow streams as the basic analysis tool. A cash flow stream charts inflow and outflow of all related funds over the life of an investment. This cash flow model relates internal expenditures and revenue of a property, and provides a comparison with other properties. Capan, Clapp, and Campbell [1971] comment on this method:

> *We believe that methods involving the discounting of the cash flow stream are effective for the decision maker. The criterion we prefer is present worth or present value (PW), using as the discount rate the Internal or Investor's Rate of Return (IRR) expected to be earned by the investor in the future. The very essence of PW is that it is the value or worth we place on an investment opportunity at the present time.*

Acquisitions through auctions are typically based on reserve reports generated from a discounted net cash flow approach. Once the property value is determined a preliminary bid value can be established as a fraction of the estimated value. Acceptable risked economics can be finalized with the bid price included.

5.2.2 Market Metrics

The discounted cash flow model is the most widely used valuation approach, but market metrics can provide good estimates for property value as they measure the most current auction results. Nordt [2004] notes market metrics assist in estimating value before expending resources in a more rigorous cash flow valuation. Stevrig [1989] states the advantages of market metrics (valuation metrics) over the discounted net cash flow model are benchmarking from actual transactions, and the emphasis of market metrics follows the generally accepted concept of fair market value. He observes that the primary disadvantage is they have not been used as much as discounted net cash flow, and they tend to overvalue long-life reserves[2].

Table 5.1 defines the three most common market metrics. They include metrics based on reserves, production rate, and cash flow. Market metrics depend on the most recent transactions.

TABLE 5.1 – COMMON MARKET METRICS

Metric	Description
Net Reserves	Property value / net reserve classification
Net Rate	Property value / net current production
Net Cash Flow Multiple	Property value / net yearly cash flow

Table 5.2 demonstrates an example using market metrics. In this example average market metrics of similar properties from East Texas and South Texas are available from recent sales. Assume the discounted cash flow models yields a combined property risked proved present value of $280 million. The average market value estimate in Table 5.2 is $285 million with a range of $267 to 298 million. The market value is consistent with the cash flow model.

TABLE 5.2 – EXAMPLE OF MARKET METRIC VALUATIONS

Asset	Area	Property Characteristics			Average of Recent Sales Similar Properties			Market Value Estimates			
		PRV mmboe	Rate boepd	CF $mm/yr	PRV $/boe	Rate $/boepd	CF Yrs	PRV $mm	Rate $mm	CF $mm	Avg $mm
1	ETX	6.2	1,135	19.5	16.25	85,000	4.8	100.8	96.5	93.6	97.0
2	STX	9.8	1,790	35.6	20.10	95,000	5.6	197.0	170.1	199.4	188.8
Total								297.8	266.6	293.0	285.8

Net cash flow multiples for oral auctions tend to be more constant over time and commodity price fluctuations [Nordt 2005]. Net value per reserve unit and net value per unit production tend to follow commodity price changes over time. I hoped that after completing preliminary research[3] that it might be possible to develop universal correlations of market metrics to commodity prices over a range of prices and time for both producing and undeveloped properties. The original study correlated a time period with moderate variation in commodity prices and predominately producing properties. However, Figs. 5.1 and 5.2, using data from 370 US transactions [J.S. Herold 2008], show that universal market metric correlations for mixed properties[4] are not possible without detailed knowledge of other factors that influence these relationships (i.e., the coefficients of correlation are very low).

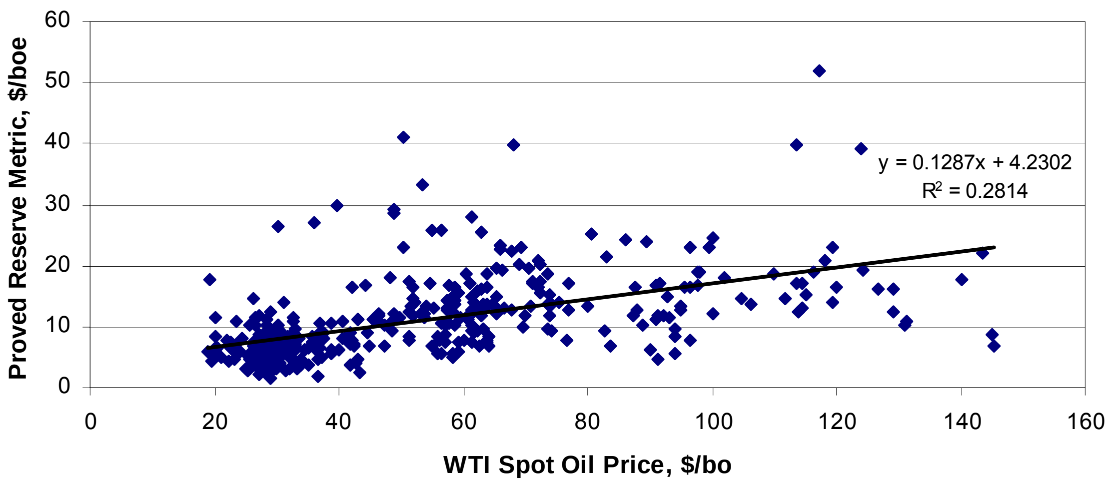


Fig. 5.1—Correlation oil price (WTI) to proved reserve market metrics, \$/boe, from 370 US transactions 2000-2008 (data from John S. Herold, Inc. 2008).

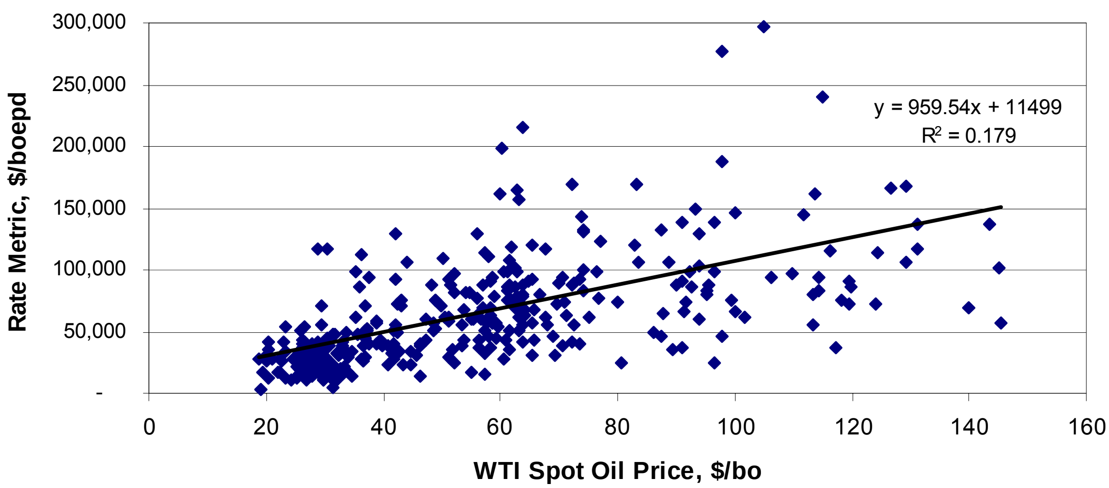


Fig. 5.2—Correlation of oil price (WTI) to rate market metrics, \$/boepd, from 381 US transactions 2000-2008 (data from John S. Herold, Inc. 2008).

Despite their limitations market metrics are valuable in valuation analysis if market conditions, risks, and buyer/seller expectations are understood. So *how can we compensate for factors not in the market metrics?* I propose use of risk factors, illustrated by example in Table 5.3. A property is initially assigned a neutral risk with index 1.0. Risk factors less than one have a negative impact on values, and risk factors greater than one have a positive impact on values. The evaluator considers each incremental risk factor as decreasing or increasing the index number. A total risk factor is calculated using Eq.1. The total risk factor is then multiplied by the un-risked property value in Eq. 2 to yield a risked value.

TABLE 5.3 – EXAMPLE OF MARKET METRIC RISK FACTORS

Tactical		Strategic	
Description	Incremental Factor	Description	Incremental Factor
Operational costs	n/a	Price volatility	-0.2
Development costs	-0.1	Regulator issues	n/a
Reserves to production ratio	-0.1	Regional infrastructure	+0.2
Single well concentration	n/a	Entry decision	n/a
Environmental issues	n/a	Competition	-0.1
Sub Total	-0.2	Sub Total	-0.1

Total Risk Factor = 1 + Tactical Sub Total + Strategic Sub Total ………... (1)

Risk Value = (Value) x (Total Risk Factor) ………………………………. (2)

This approach is shown in the case history presented in Section 5.4, and it is analogous to the procedures of risking reserve input or reserve value output in a deterministic cash flow model.

5.3 Bid Models

Oil and gas auction bid models in the literature vary from simple to complex, and their focus has been lease sales for undeveloped acreage. Table 5.4 summarizes several representative models that have been published.

TABLE 5.4—REPRESENTATIVE BID MODELS PRESENTED IN THE LITERATURE

Year	Investigator	Model Description	Type
1956	Friedman	Contract model uses historical data for probability distribution of true cost as fraction of estimated cost, probability distribution of bidding, probability distribution of winning, and expected profit from integration of distributions at a given bid level.	Sealed-bid General
1965	Arps	Lease model estimates property value with deterministic and stochastic analyses of common information. Statistical analysis assumes log normal distribution to determine mean value and standard deviation of previous lease sales. Assumes geometric mean value as good indicators of the future value. Probability distribution derived empirically relating historical mean bids to the winning bids.	Sealed-bid Lease
1966	Brown	Lease model estimates the probability that any proposed bid will be the winning bid for a tract. Three variables of focus are estimated present value of the tract, the likely number of competing bidders, and the probability distributions of possible competitor bids.	Sealed-bid Lease
1971	Capan, Clapp, Campbell	Lease model assumes a log normal distribution of value estimates. True property value (expected value) is geometric mean. Estimate of competitors and probability of bidding needed. Set bid fractions to calculate bids and determine winner and profit/loss.	Sealed-bid Lease
1975	Dougherty, Nazaki	Lease model analogous to Capen, Clapp, and Campbell. Study variable parameters of standard deviation of estimates, competitor estimates, number of competitors, and bid fraction of competitors. Vary parameters to find optimum bid fractions for maximizing profit/loss.	Sealed-bid Lease
1977	Hartstock	Lease model to compute the probability of winning with a given bid. A Pearsonian analysis was performed on lease sales to identify functional forms of probability density functions, and regression analyses of past lease sales to provide estimate of model parameters.	Sealed-bid Lease
2008	Furtado, Suslick, Rodriguez	Lease model assumes bid value as fraction of the estimate reserve value. Value estimate is calculated through bid fraction probability distribution.	Sealed-bid Lease

Reoccurring elements in these models include estimates of:

- Property present value
- Variance of present value
- Bidder bid fraction
- Number of competitors
- Probability distribution of bidding
- Probability distribution of winning

The Capan, Clapp, and Campbell [1971] simulation model is the most referenced lease sale model. Fig. 5.3 presents the logic and essential elements in their model. I have changed some of their nomenclature to align with this dissertation. These models are helpful in formulating general lease sale strategies discussed in Section 2, but are difficult to apply because of historical information and assumptions necessary to estimate model elements.

Step	Process	Element
1	Set number of competitors (n)	historical data
2	Set bid fraction (Bfn) for each (n)	historical data
3	Actual property value (Av) equal to 1.0	assumption
4	Determine standard deviation (S) for each (n)	historical data
5	*START OR EXIT SIMULATION TRIAL*	
6	Select if (n) bidding	distribution
7	Select competitor value (Vc) as f(Av,S)	distribution
8	Calculate each (n) bid value (Bn) = (Vc) * (Bfn)	
9	Determine highest bid (Bh) of (Bn)	
10	Start with your bid fraction (Bf) = 1.5	
11	Calculate your bid value (Bp) = (Bf) * Av	
12	If (Bp) > (Bh), continue at next step 13 Else record loss count Return to next trial at step 5	
13	Record win count and profit (Pw) = (Av) - (Bp)	
14	If (Bf) = 0, return to next trial at step 5 Else continue at next step 15	
15	New (Bf) = (Bf) - 0.1	
16	Return to step 11 to calculate new (Bp)	

Fig. 5.3—Example of simulation logic and essential elements adapted from the Capan, Clapp, Campbell (1971) lease sale bid model flowchart.

5.4 Case Study

I use a case study below to present a process for developing a bid model for private seal-bid auctions with data that obtained from sellers and other sources available to buyers. The company names are not provided to preserve confidentiality. Production, reserves, cash flow, and transaction values are slightly scaled for the same reason.

> *An established private energy company offers to sell a field with eight wells producing at a combined rate of 500 net barrels of oil per day with less than 10% decline the last two years. A structural closure contains the reservoir with a moderate water drive mechanism from the flanks. 75% of the production comes from two wells, and there is spacing above the oil/water contact to infield drill one to two undeveloped proved reserve locations to increase and accelerate oil recovery. The net production to proved reserve ratio is 12.4 years. WTI index oil price is currently at $35 per barrel oil with an average annual increase of 20% for the last two years. The net cash flow averages $400 thousand per month. The company wants to monetize a portion of its assets to distribute to the partners, but will not sell unless they can receive at least fair market value. They have been advised by their auctioneer that the potential value of the reserves, uncertainty of the undeveloped reserves, and risk of down-dip production increasing water cut makes this property a candidate for a sealed-bid auction.*

An independent risked reserve report summarized in Table 5.5 values the property at $18 million dollars before federal income tax. This equals $7.94/bo for net proved reserves and $36,000/bopd net production rate. The risked undeveloped reserves are 179 mbo (600 mbo unrisked). Prior to the auction buyers have access to the same evaluation data used in preparing the risked reserve report; however, they are not given actual risked expected NPV of $18 million of the seller and auctioneer. The high bid was $23 million which equates to $10.15/bo net proved reserves and $46,000/bopd net production. The second bid was $17 million so the winner left $6 million on the table.

TABLE 5.5—SUMMARY OF NET RISKED RESERVES AND PRESENT VALUE				
Net Risked Proved Reserves, mbo		NPV_{10} BFIT	Net Production	Net Cash Flow
Producing	Undeveloped	$mm	boepd	$m/month
2,088	179	18.0	500	400

Did the winner in this case study have a strategy? A review of the average US transactions six months leading to this auction yields average market metrics of $9.73/bo and $42,944/bopd with an average R/P ratio of 13.4 years. With these market metrics the property a fair market value would be calculated at $22.1 million on a $/bo basis and $21.5 million on $/bopd basis; however, these average metric values are not risked for this property.

Table 5.6 presents the market metric approach adjusted for risk. Most of the factors are considered risk neutral; however, the uncertainty of reserves and well concentration of production are negative factors. When these factors are considered the risked adjusted metric values equals $15.3 million using equations 1 and 2:

- Total Risk Factor = 1 + (-0.3) + (0.0) = 0.7
- Risk Value = ((22.1 + 21.5) / 2) x (0.7) = $15.3 million

Assuming a knowledgeable buyer's reserve report is similar to the independent report in Table 5.5, and using a strategy of bidding 90% of $18 million yields a value of $15.5 million. Here a risked market metric value and a strategy of reducing a bid on a reserve report give very similar results. The second bidder with an offer of $17 million appears to a reasonable bid, but the high bid of $23 million is a candidate to experience the winner's curse.

TABLE 5.6 – ASSESSMENT OF RISK FACTORS			
Tactical		Strategic	
Description	Incremental Factor	Description	Incremental Factor
Operational costs	n/a	Price volatility	n/a
Development costs	n/a	Regulator issues	n/a
Reserves to production ratio	-0.2	Regional infrastructure	n/a
Single well concentration	-0.1	Entry decision	n/a
Environmental issues	n/a	Competition	n/a
Sub Total	-0.3	Sub Total	0.0

The above strategy methodology would have lost this competitive auction; however, the objective is not to win at the expense of making a future profit. If the second sealed bid had been the highest offer, then there is high probability the auctioneer would have invited us a chance to resubmit a second round sealed-bid. This informal second round is common industry practice in private sealed-bid auctions. This practice is potentially inefficient as some companies reduce their offers in anticipation of this occurrence. I believe a better way is a hybrid auction consisting of a first round sealed-bid auction, followed by a playoff round of the top sealed-bid qualifiers.

5.5 Notes

1. Review of top Energy Advisors websites for private sealed-bid auctions indicates that time from availability of evaluation materials to bid offers is about five weeks. This period normally includes three to four weeks of data room presentations for potential buyers.

2. The cash flow stream mirrors the longer life production. When the stream is discounted from the future to the present it will be a smaller value as compared to market metrics without a discount factor.

3. Nordt, D.P. 2006. Market Value Metric Correlations. *Texas A&M Directed Study Presentation, 1-15* (May). Not published.

4. Mix properties from this transaction database have a wide range of oil and gas reserves with different reserve classifications and production profiles.

6. CONCLUSION

6.1 Section Review

Section 1 framed the importance of a contemporary study on oil and gas auction strategies. Auctions transact billions of dollars in property sales each year. The majority of these transactions are through private auctions. Federal lease auctions have been extensively studied from public data, but published work on private sealed-bid auctions essentially does not exist because of confidentiality requirements which make collecting data difficult.

Section 2 examined game theory, federal lease sales and other studies for potential strategic application. The published literature tends to be obscure and narrowed to lease sales. I distilled the eclectic nature of the literature into a summary of key points for potential strategic application.

Section 3 summarized the results of interviews conducted with industry professionals to present a current view of auction strategies. The first group of interviews concentrated on the questions framed in the introduction. The second group of interviews obtained samples of private sealed-bid results and indexed for confidentiality. In addition, case studies for private sealed-bid auctions and record setting federal lease sale 206 were presented.

Section 4 validated certain historical and current views through simulated auction game experiments using industry participants. The experiments investigated relations between oral and sealed bid auctions, relations between producing and undeveloped properties, and the influence of uncertainty on bid results.

Section 5 presented bid valuation processes and applications. The emphasis was on a consistent system for screening and valuing auction properties using cash flow models and market metrics. Literature on lease sale models was summarized to demonstrate difficulties in obtaining data support. A case history on a private sealed-bid auction was reviewed to illustrate application of techniques to set a competitive, but potentially profitable bid level.

6.2 Framing Questions and Findings

1. What auction strategies are currently used to acquire or divest of properties?

Hypothesis 1a–auction players often participate in auctions without clearly defined strategies.

Most interviewees believe their companies have clearly defined auction strategies; however, a smaller, but significant group of companies do not have consistent auction strategies.

Hypothesis 1b–primary drivers in winning bids are tactical versus strategic: aggressive forward price deck, inclusion of probable/possible reserves, and acceptance of lower project rate of returns.

The top three winning strategies perceived by interviewees are aggressive valuation of non-proved reserves, an aggressive price deck, and acceptance of lower rate of returns.

Hypothesis 1c–Well concentration risk, lack of development potential, and data quality are the most common reasons that properties fail to sell in auctions.

> *A case study of sealed-bid auctions concluded properties that did not sell at reserve value suffered primarily from poor quality data. Bids are improved by integrating land, commercial and technical information into a concise historical overview and a future development plan.*

2. Do bidding strategies from earlier research on federal offshore lease sales apply to contemporary private auctions?

Hypothesis 2a–some auction research strategies developed for offshore federal leases apply to contemporary private property auctions.

> *A review of auction game theory and federal offshore leases sale studies yielded common strategies applicable to private auctions:*
>
> - *Reducing uncertainty can increase bid levels.*
> - *Uncertainty causes greater variation in property values.*
> - *Reducing bid fraction with increased competition increases buyer profit.*
> - *Aggressive bidding results in a subpar buyer portfolio performance.*
> - *Joint bidding encourages aggressive bidding.*
> - *Inexperience encourages aggressive bidding.*
> - *Competition encourages aggressive bidding.*
> - *Increased competition contributes to the winner's curse.*

Hypothesis 2b–bid models from theory and lease sales research require modification to accommodate uncertainty in value.

Lease models are helpful in formulating general auction strategies discussed, but are difficult in adapting to private sealed-bid auctions because of historical information and assumptions necessary to estimate model parameters. Sufficient data to develop private auction models are not available. A combination of a risked cash flow and market metric models appear to yield good results and are favored by the industry.

3. Which auction process, sealed-bid or oral, brings more value to the seller?

Hypothesis 3a–The sealed-bid auction process brings more value to seller when development potential exceeds 30% of the total property value.

Interviewees believe properties that exceed 30% in undeveloped reserves receive higher bids in a sealed-bid process.

4. Can market metrics correlate to commodity price and risk?

Hypothesis 4a–market metrics based on $/BOE, $/BOEPD, and annual cash-flow multiples can correlate to historical commodity price and risk.

I was not successful in finding meaningful correlations of market metrics with historical commodity prices. Universal market metric correlations for mixed properties are not likely without detail knowledge of other factors that influence these relationships.

Hypothesis 4b–Risked market metric correlations can yield valuations similar to more rigorous risked cash-flow modeling.

The results of Hypothesis 4a fails this hypothesis by association; however, I present a case study that demonstrates a process of risking universal market metrics for a specific time period that matches well with cash-flow modeling.

6.3 Future Research

This dissertation touched on numerous areas that could use additional study, but I believe three areas particularly need further research. These are refinement of simulated bid models for private auctions, a comparative study of e-bay styled internet versus live oral auctions, and investigation of hybrid private auctions.

I approach development of a simulated bid model for website research experiments used in this dissertation. The biggest challenge to private sealed-bid research is getting confidential data to analyze. This study demonstrates it is possible to gain knowledge in this area by interactive auction experiments with practicing professionals.

I did not investigate internet versus live oral auctions. This auction type is dominated by a few auctioneers because of the relatively low profit margins and high entry costs; however, as more US properties reach full development and offer only decline curve value, internet auctions offer cost effective liquidity.

I did not investigate hybrid auctions. To my knowledge it is has not been used by the industry. Auctioneers that sell properties through the sealed-bid process typically receive bids, and then they re-approach the top bidders to consider resubmitting a higher bid. Although this is standard practice, in my opinion a hybrid auction using a combination of sealed bid and play-off oral auctions could be more efficient and perhaps more professional.

6.4 Final Comment

I surmise from this assorted work that the most essential strategic ingredients to successful oil and gas auction participation include:

- Knowledge and recognition of current market conditions.
- Unbiased appraisal of property value and associated risks.
- Recognition of portfolio impact and constraints.
- Reasonable intelligence on potential competitors.
- Selection of the appropriate auction process.
- Discipline to believe in basic auction strategies.
- Participation on a regular basis.

Box [2008], writing on investment portfolios in petroleum ventures, asserts "*too much risk in a series of investments can lead to spectacular ruin, and alternatively, too little risk leads to unspectacular defeat overtime.*" Auction players bear this burden and for those that play the game I offer you my reflections on the subject:

- The frequent auction player with a consistent bid strategy constraining himself to a risked profit bid can win on occasion and has a better chance of sustaining a profitable portfolio over time.
- A frequent auction player without strategy or profit constraints has a low chance of a profitable portfolio over time.

- The infrequent player, with or without a strategy, plays a high risk game as he often struggles with inexperience in analyses, processes, and bid strategies.
- The infrequent player tends to buy high and sell low with underperforming assets.

Frequent players that have strategic discipline can be successful in the oil and gas auction game, as buyer or seller, over the long haul. All other categories of auction players rely on a probabilistic event called “dumb luck”. It is analogous to a trip to Las Vegas and coming back significantly richer. It happens, but rarely.

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APPENDIX A

SIMULATED AUCTION GAME DESIGN

A.1 Game—Design Rules

Player objective is to make a *profit* by submitting bids on oil and gas auction properties.

1. There are *ten independent auction games* with *two rounds per game.*
2. *Round 1 are sealed-bid auctions* . . . player does not know competitor bids.
3. *Round 2 are oral-bid auctions* . . . player knows the current high bid.
4. Each game has a *different set of common knowledge (Table A1, signals)***.**

TABLE A1—GAME COMMON KNOWLEDGE SIGNALS

Game No.	1	2	3	4	5	6	7	8	9	10
Actual Value, mm$										
Maximum	60	600	60	60	60	60	600	60	60	60
Minimum	30	300	30	30	30	30	300	30	30	30
Known	???	???	???	???	55	???	???	???	???	40
No. of Competitors	???	???	2	9	???	???	???	2	9	???
Reserve Value, %										
Proved Producing	90	90	90	90	90	50	50	50	50	50
Proved Undeveloped	10	10	10	10	10	50	50	50	50	50

5. Common knowledge always includes a *range in which the actual value exists.*
6. Common knowledge always includes *percent un-risked reserve category values.*
7. Common knowledge includes the *number of competitors in games 3, 4, 8, and 9.*
8. Common knowledge includes the *actual value of the property in games 5 and 10.*
9. Player competes against *simulated competitors.*
10. Player submits *no-bid* with *zero.*

11. *Bid it cannot be changed* after submitted as final bid.

12. *Bid results will be displayed* after completing all the games in rounds 1 and 2.

A.2 Simulator—Concept Logic

Step 1—Use Beta distribution from sample industry sealed-bid results to determine competitor bids.

TABLE A1—BETA DISTRIBUTION

Percent	Cum Prob.
0%	0.12
5%	0.34
10%	0.41
15%	0.46
20%	0.50
25%	0.54
30%	0.57
35%	0.61
40%	0.64
45%	0.66
50%	0.69
55%	0.72
60%	0.74
65%	0.77
70%	0.80
75%	0.82
80%	0.85
85%	0.87
90%	0.90
95%	0.94
100%	1.00

TABLE A2—BID LOOKUP TABLE

Fraction	Cum Prob.	\$30mm<Bid<\$60mm
0.000	0.12	*33.54330*
0.050	0.34	*40.16390*
0.100	0.41	*42.16940*
0.150	0.46	*43.76350*
0.200	0.50	*44.96410*
0.250	0.54	*46.06640*
0.300	0.57	*47.16750*
0.350	0.61	*48.20530*
0.400	0.64	*49.08300*
0.450	0.66	*49.89910*
0.500	0.69	*50.68930*
0.550	0.72	*51.54060*
0.600	0.74	*52.28870*
0.650	0.77	*53.06330*
0.700	0.80	*53.85930*
0.750	0.82	*54.61580*
0.800	0.85	*55.38970*
0.850	0.87	*56.23120*
0.900	0.90	*57.12040*
0.950	0.94	*58.12760*
1.000	1.00	*59.98930*

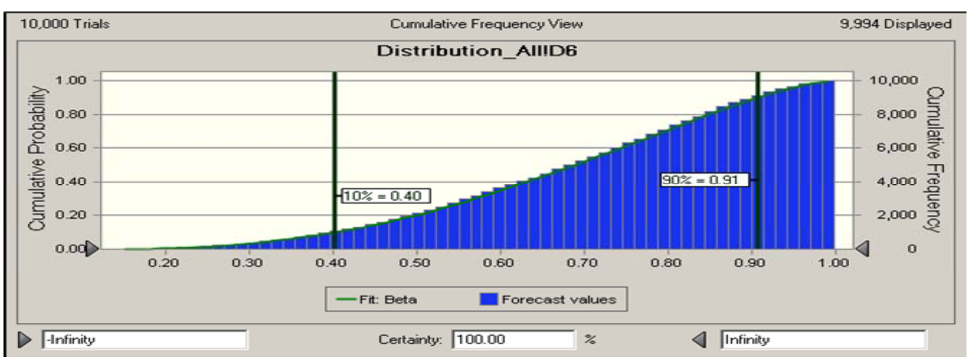

Fig. A1—Cumlative beta distribution from sample industry sealed-bid results.

Step 2—Generate random numbers (0.0-1.0) for nine potential competitors.

Competitor	Random No.
B1	0.782
B2	0.580
B3	0.274
B4	0.629
B5	0.699
B6	0.665
B7	0.719
B8	0.563
B9	0.057

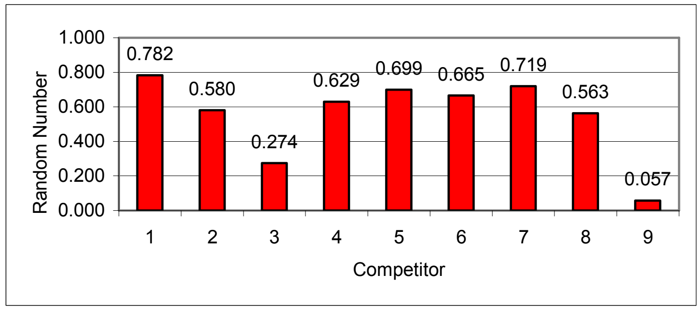

Fig. A2—A random number is generatated to match each competitor.

Step 3—Match each potential competitor random number with an interpolated bid from lookup table (Table A2).

Competitor	Random No.	Bid, $mm
B1	0.782	53.063
B2	0.580	47.168
B3	0.274	33.543
B4	0.629	48.205
B5	0.699	50.689
B6	0.665	49.899
B7	0.719	51.541
B8	0.563	46.066
B9	0.057	49.083

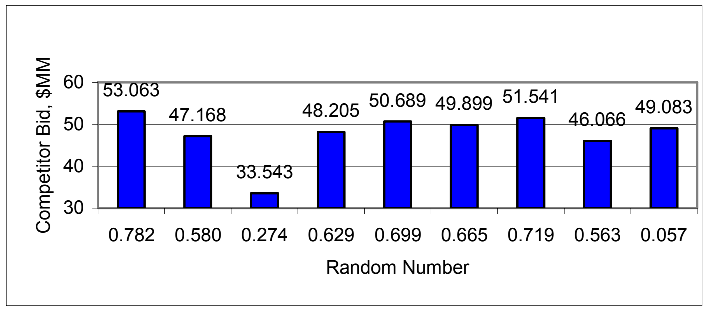

Fig. A3—Each competitor bid is matched to a random number.

Step 4—Player enters game bid.

Bp, $mm	Game (k)	Actual Value Low	Actual Value High	Actual Value Given	Competitors
45.000	1	30	60	???	6

If games 2 or 7 divide by 10 to normalize range of bids to other games.

Step 5—Determine number of simulated competitors from random number (0.0-1.0).

Random No.	Competitors (n)
0.72112	6

Step 5—Register bids.

Bidder	Bid, $mm	Rank
Bp	45.000	
B1	53.063	1
B2	47.168	5
B3	*33.543*	6
B4	*48.205*	4
B5	*50.689*	2
B6	*49.899*	3
B7	*no bid*	no bid
B8	*no bid*	no bid
B9	*no bid*	no bid

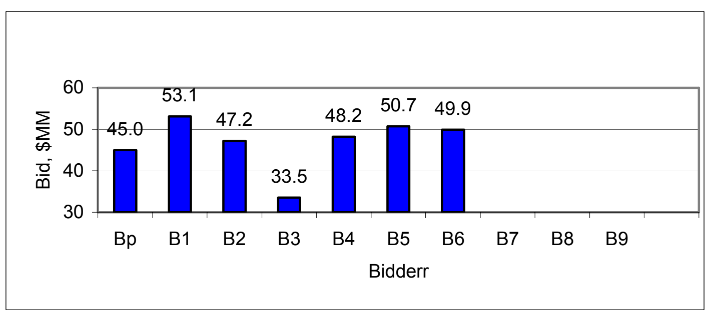

Fig. A4—Simulated competitors determined.

Step 7—Calculate geometric mean of bids.

Būg, \$mm 46.365 = (Bp x B1 x B2 x . . . x Bn)1/(n+1)

If Bp is less than \$45.000 mm, use \$45.000 mm to calculate geometric mean.

Step 8—Scalars for calculating actual value to optain a probability of profit.

	Scalars		
No. of Competitors	1-3	4-6	7-9
Games 1-5	1.300	1.250	1.195
Games 6-10	1.200	1.180	1.100

Step 9—Calculate results actual value and profitability.

-

	Actual Value, \$mm		
No. of Competitors	1-3	4-6	7-9
Games 1-5	0.000	57.957	0.000
Games 6-10	0.000	0.000	0.000

No. of Competitors	6	
Player bid (Bp)	45.000	
Competitor High Bid (Bch)	53.063	
High bid, \$mm	53.063	*Competitor Wins*

	Profit, \$mm		
No. of Competitors	1-3	4-6	7-9
Games 1-5	0.000	4.894	0.000
Games 6-10	0.000	0.000	0.000

-

Step 10—Store data for analysis.

Av	actual value
Bch	highest competitor bid
Bcs	second highest competitor bid
Bp	player bid
Cp	competitor profit
k	game count
LOT	money left on table
m	player count
Mw	player wins
n	competitor count
Ncw	competitor wins
Pp	player profit
R1,2	round 1 or 2

Step 11—Demonstrate example of data for Bp parameter.

	Round 1—Player Bids, \$mm		
Game	**1**	**2**	**3**
Player			
1	47.422	44.128	43.500
2	42.861	40.398	41.320
3	47.975	43.898	42.341
4	38.852	45.543	33.000
5	45.441	46.653	42.031
6	50.696	50.303	42.310
7	38.388	41.112	37.000
8	47.261	48.886	45.000
9	47.261	50.206	44.000
10	44.778	48.865	43.213
Pū	45.094	45.999	41.372
$P\sigma$	3.995	3.599	3.643
$P\sigma^2$	15.96	12.953	13.271
m	10	10	10
SE	1.263	1.138	1.152

Step 12—Analyze composite player behavior by significance of the difference of means.

Pū	mean of all player bid values each game
$P\sigma$	standard deviation of all player bid values each game
m	player count
SE	standard error of all player bid values for each game [$P\sigma \div (m^{1/2})$]
z (two tail)	z ratio of differences [(Pū2-Pū1) ÷ $(SE2^2 - SE1^2)^{1/2}$]

	Round 1			
Game	Pū	Ps	m	SE
1	45.094	3.995	10	1.263
2	45.999	3.599	10	1.138
3	41.372	3.643	10	1.152

	Round 1		
Compare Games	**1-2**	**1-3**	
z (two tail)	-0.533	2.177	*If z>±1.96 reject null hypothesis at 95% confident level.*
Ho		Reject	

A.3 Website—Design Logic

A website was created to host the game experiments described in Section 5. Fig. A5 illustrates the website design logic.

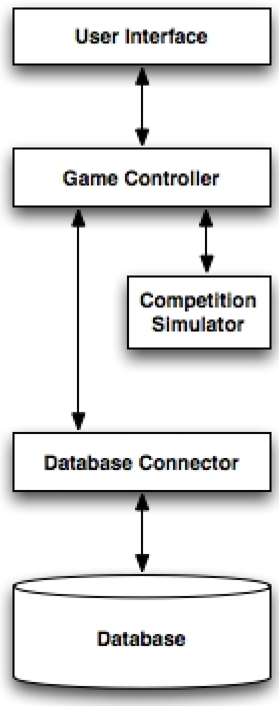

Fig. A5—Website logic design of the simulated auction games.

The database, MySQL, stores the user (player) input simulator bids, match settings (i.e., common knowledge, game order, etc.), and player/group login information (i.e., password; group name). The database connector is written in PHP. It includes all the logic for getting information from and to the game controller and storing information in the database. The game controller is written in PHP, and it acts as the game logic, central controller for handling game flow. The competition simulator is written in PHP, and all the simulation logic resides there. The user interface is written as a combination of HTML, CSS, and Javascript which includes the JQuery library. HTML = basic web page; CSS (cascading style sheets) = basic look and feel; and, Javascript = interactive page with advanced look and feel. JQuery is written in Javascript that the code accesses.

Game logic, simulator logic, and interface designs are unique. Website technology and general design are common. The website design followed a "user-centric design process". We started with a user interface prototype to help focus on the user experience before coding the program logic. The entire process was beta tested several times to determine user-interaction difficulties. We practice good design principles by keeping interface and game logic simple to prevent overloading users with too much information. Visual cues were used to emphasize certain information (e.g., common knowledge changes between rounds is highlighted in blue and the timer changes colors from green to red when oral auctions get to final five seconds). Finally, the most important feature is the interactive website to make experiment participation more enjoyable and realistic.

APPENDIX B

STATISTICAL ANALYSIS OF GAME RESULTS

I reference Longnecker and Ott [2001] for the analysis parameters[1] below:

- df = degrees freedom
- m = player count (sample size)
- Pū = mean of all player bid values for each game
- p-value = probability level of significance
- Pσ = standard deviation of all player bid values for each game
- Sp = common standard deviation of two populations
- t-test = test statistic

Table B1 summarizes the parameters derived[2] from the experimental data. The assumptions under which tests are valid are: 1) random, independent player samples, 2) normal population distributions with approximately equal variances, and 3) sufficient sample sizes.

Assumptions one and two are believed to be satisfied. I am not sure on the sample size. In a controlled experiment with unlimited supply of subjects that is possible, but in the private auction world data is hard fought. Finding qualified candidates for participation was the first hurdle. The next hurdle was equally hard; it depended on the good will of very busy participants to allow a half of hour to play the games. The intent of the experiments was support (or at least not refute) conclusions reached in general auction theory and the limited focus of federal lease studies. To that extent the objective was met as described in Section 4.

TABLE B1—SUMMARY OF STATISTICAL PARAMETERS DERIVED FROM EXPERIMENTAL DATA

	Round 1			Round 2		
Game	Pū	Pσ	M	Pū	Pσ	m
1	48.139	7.768	18	49.567	6.918	9
2	47.294	6.666	17	46.301	9.542	14
3	47.522	9.057	18	52.569	5.027	13
4	50.788	9.665	17	52.694	6.633	16
5	51.583	6.208	18	49.973	9.131	15
6	41.889	8.203	18	42.553	8.927	16
7	40.800	6.625	15	47.216	8.873	15
8	40.813	8.750	16	48.400	6.507	16
9	43.281	9.957	16	48.253	6.947	15
10	38.917	5.542	18	39.950	3.706	16

Tables B2 and B3 compare combinations of mean differences between game bids for proved producing and proved undeveloped properties. Table B2 also compares a proved producing (game 1) to proved undeveloped (game 6) property. The t-test and p-values are listed.

TABLE B2—COMPARISON OF PROVED PRODUCING PROPERTY BIDS

	Round 1						Round 2					
Games:	2-1	3-1	4-1	5-1	4-3	*6-1	2-1	3-1	4-1	5-1	4-3	*6-1
t	.38	.20	.81	1.67	1.00	2.27	.80	1.38	1.13	.11	.05	.73
p	.71	.84	.42	.11	.33	.00	.43	.18	.14	.92	.96	.47

*comparison of producing and undeveloped properties

TABLE B3—COMPARISON OF PROVED UNDEVELOPED PROPERTY BIDS										
	Round 1					Round 2				
Games:	7-6	8-6	9-6	10-6	8-9	7-6	8-6	9-6	10-6	8-9
t	.47	.36	.41	1.61	1.22	1.46	2.54	2.28	1.99	.21
p	.53	.72	.69	.12	.23	.15	.02	.03	.06	.83

Table B3 compares mean differences between sealed bid and oral auction games of rounds 1 and 2.

TABLE B3—COMPARISON OF SEALED BID AND ORAL AUCTION PROPERTY BIDS										
	Round 1 – Round 2									
Games	1	2	3	4	5	6	7	8	9	10
t	.51	.29	2.76	.83	.50	.22	1.98	3.30	1.99	.81
p	.62	.78	.00	.42	.62	.83	.06	.00	.06	.42

Notes:

1. Some of the nomenclature abbreviations are different from Longnecker and Ott (2001) to provide consistency within this dissertation.

2. I used *Excel ToolPak* add-in and a university website calculator for independent verification of the calculations.

VITA

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