Bhattacharya et al. (2022): Bidding and Drilling under Uncertainty: An Empirical Analysis of Contingent Payment Auctions

Hulai Zhang

International School of Finance, Fudan University

Env.Climate

Sep 8, 2025

Motivation: Auction Design and Post-Auction Investment

- The winner's payment in auction is **contingent** on the asset's future cash flows.
  - **Oil & Gas Leases:** Upfront bonus + royalty on production revenue.
  - **Timber Auctions:** Payment based on amount/type of wood harvested.
  - **Procurement:** Contracts with cost-overrun clauses.
- This creates a direct link: **Auction design → Post-auction investment incentives → Bidders' valuations.**

⇒ This link is largely unexplored in the empirical auction literature.

Research Question

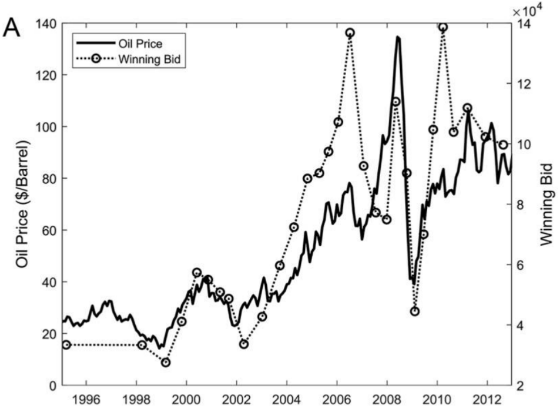
How does auction design affect both seller revenue and the winner's subsequent decision to drill for oil?

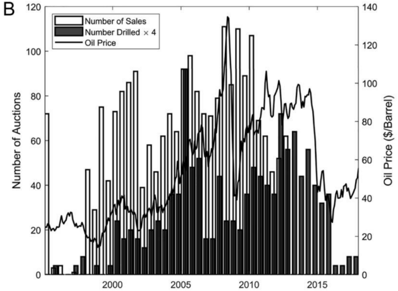
- Cash auction: bid on cash payment
- Bonus auction: bid on cash + a fraction of future cashflow (pre-specified royalty)
- Equity auction: bid on the fraction of future cashflow
- Debt auction: bid on cash payment conditional on drilling

New Mexico Oil Auctions

- New Mexico State Land Office (NMSLO) for oil exploration leases in the Permian Basin
  - Bonus auction with Bid-Bonus and Fixed-Royalty ϕ
  - The highest bidder wins the lease
  - ϕ is fixed by the NMSLO before the auction (typically $1/8$ or $1/6$)
  - If the winner drills and produces oil, they pay $\phi \times$ (Revenue) to the state
  - The lease grants the right, but not the obligation, to drill within a five-year period
- Data sources
  - NMSLO auction data: bids, bidders, location
  - Drillinginfo data: well spud dates, location
  - FRED oil prices

Data Overview: Drilling Activities





- The sample period sees huge fluctuations in oil prices.
- Both winning bids and drilling frequency appear to track the price of oil closely. This motivates a model where prices are a key state variable.

A Two-Stage Model of Bidding and Drilling

Linking the auction (bidding stage) to the subsequent investment problem (drilling stage).

Stage 2: Drilling Decision

- After winning, the firm learns the true oil quantity q and its private drilling cost c_i.
- It then faces an **optimal stopping problem**: when (if ever) to drill before the lease expires at time T.
- The winner chooses a stopping time $\tau \leqslant T$ to maximize expected discounted profit.

Stage 1: Bidding Decision

- Bidders have a common value for the quantity of oil, q.
- Each bidder i receives a private signal $\tilde{q}_i = q\xi_i$.
- Bidders are forward-looking: their value for winning the lease is the expected value from the drilling stage.
- They account for the "winner's curse."

The Drilling Stage: An Optimal Stopping Problem

- The price of oil, P_t, evolves stochastically according to a geometric Brownian motion:

$$\frac{dP_t}{P_t} = \mu_p dt + \sigma_p dB_t$$

- If the winner drills at time τ, her payoff is $(1-\phi)P_\tau q - c_i$.
- The ex-ante value of the drilling option for a winner with cost c_i is:

$$V(q, c_i) = \max_{\tau \leqslant T} \mathbb{E}_{P_0}\left[e^{-r\tau}((1-\phi)P_\tau q - c_i)^+\right]$$

where $(\cdot)^+ = \max(\cdot, 0)$.

Optimal Drilling Rule

The winner drills at the first time t that the oil price P_t hits a time-dependent threshold $P_t^*(c_i/q)$. This threshold is higher for tracts with higher unit costs (c_i/q).

The Bidding Stage: Common Values

- A bidder's value for winning, given true quantity q, is the expected value from the drilling stage, integrated over their private cost distribution $H(\cdot; q)$:

$$v(q) = \mathbb{E}_{c \sim H(\cdot, q)}[V(q, c)]$$

- Bidders submit bids $b(\tilde{q}_i)$ to maximize expected profit, conditional on their signal and on winning the auction. The problem for bidder i is:

$$\max_b \left(\mathbb{E}_q[v(q) - X - b \mid \tilde{q}_i, \text{win}]\right) \cdot \Pr(\text{win} \mid \tilde{q}_i)$$

Key Feature: Value Endogeneity

A bidder's value $v(q)$ is not a primitive. It is an **endogenous** object that depends directly on the auction design (e.g., the royalty rate ϕ).

How Auction Design Changes the Value Function

The paper considers several alternative auction designs, which change the winner's payoff and thus the value of the lease.

- **Bonus Auction (Baseline):** Royalty ϕ is fixed. Bid is an upfront cash bonus.

$$V(q,c) = \max_{\tau \leqslant T} \mathbb{E}_{P_0}\left[e^{-r\tau}((1-\phi)P_\tau q - c)^+\right]$$

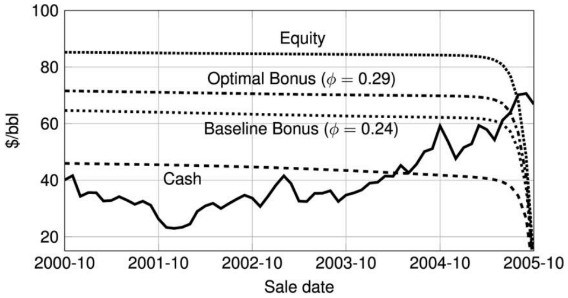
- **Cash Auction:** Fixed Royalty $\phi = 0$. Bid is an upfront cash bonus.
- **Equity Auction:** Bidders bid the royalty rate ϕ^{Equity}. The winner is the one who bids the highest royalty.

$$V(q,c)^{\text{Equity}} = \max_{\tau \leqslant T} \mathbb{E}_{P_0}\left[e^{-r\tau}((1-\phi^{\text{Equity}})P_\tau q - c)^+\right]$$

- **Debt Auction:** Bidders bid a dollar amount d. The winner pays $\min(d, \text{Revenue})$.

$$V(q,c)^{\text{Debt}} = \max_{\tau \leqslant T} \mathbb{E}_{P_0}\left[e^{-r\tau}(P_\tau q - c - d)^+\right]$$

Auction Design Changes the Drilling Decision



- Higher royalty rates (e.g., Bonus $\phi = 0.26$ vs. $\phi = 1/6$) or royalty bids (Equity) raise the price threshold, delaying or preventing investment.
- A pure cash auction ($\phi = 0$) provides the strongest incentive to drill.

Identification Strategy

Intuition from an Affiliated Private Values Model:

(1) **Drilling Delays identify Unit Costs:**

- The optimal drilling rule, $P_t = P_t^*(c/q\xi)$, creates a one-to-one mapping between the drilling delay (τ) and the effective unit cost ($c/q\xi$).
- Thus, the observed distribution of drilling delays identifies the distribution of unit costs.

(2) **Bids identify Total Value:**

- Standard results (Guerre, Perrigne, Vuong 2000; Li et al. 2002) show that the distribution of bids identifies the distribution of bidders' total values, $v_i = b_i + \frac{G(b_i|b_i)}{g(b_i|b_i)}$
- Total Value = (Quantity) × (Per-Unit Profit).

$$v_i = (1 - \phi) q \xi_i \cdot \mathbb{E}[\text{Per-Unit Profit}] - X$$

- Since we identify per-unit profit from delays (step 1) and total value from bids (step 2), we can back out the distribution of quantities $q\xi_i$.

What if New Mexico Used a Different Auction Design?

Alternative Designs Considered:

(1) **Baseline Bonus:** The actual design ($\phi = 1/6$).

(2) **Equity:** Bidders bid the royalty rate ϕ. Winner is highest ϕ.

(3) **Debt:** Bidders bid a dollar amount d. Winner pays $\min(d, \text{Revenue})$.

(4) **Cash:** A bonus auction with $\phi = 0$.

(5) **Revenue-Optimal Bonus:** A bonus auction where the seller sets ϕ to maximize total revenue ($\phi^* = 0.29$).

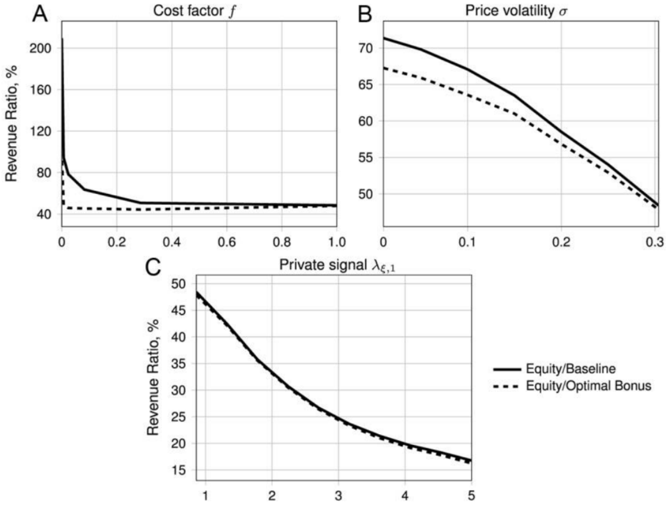
Counterfactual Results: Revenue and Drilling

Security Type	Winning Bid	Revenue ($K) Royalty	Revenue ($K) Total	Pr(Drilling)	Drilling Delay(Days)	Total Oil
Pure cash	$135,400	0	135.4	0.174	1,277	13,396
A. Bonus:						
Baseline bonus	$79,900	129.2	209.1	0.118	1,353	9,273
Revenue-optimal bonus ($\phi^* = 0.29$)	$71,000	140.5	211.6	0.105	1,363	8,319
B. Equity:						
Equity without land fees	38.6%	101.3	101.3	0.060	1,490	4,159
Revenue-optimal equity ($K^* = \$110,000$)	7.8%	91.1	146.8	0.103	1,309	8,438
C. Debt:						
Debt without land fees	$581,400	53.6	53.6	0.023	1,688	3,017
Revenue-optimal debt ($K^* = \$290,000$)	$59,100	49.2	138.4	0.062	1,391	6,286

Key Findings:

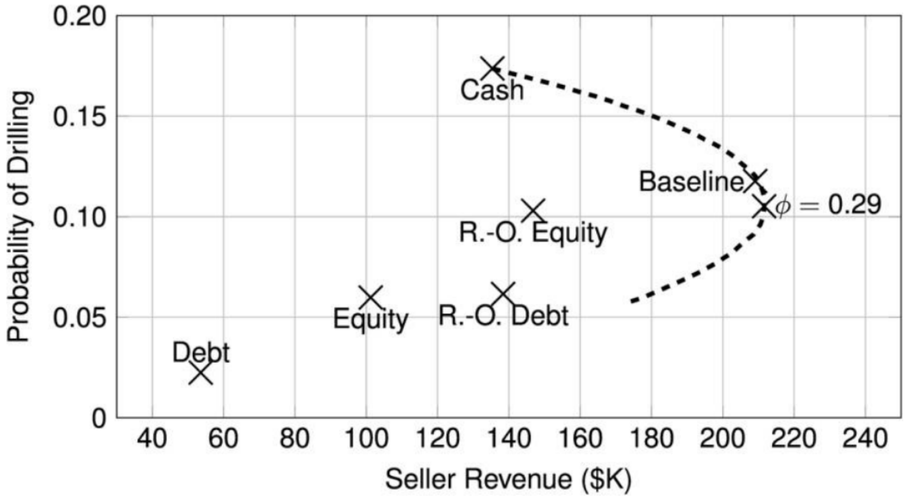
- **Bonus auctions outperform Equity and Debt** in both total revenue and drilling activity.
- **There is a revenue-drilling tradeoff.** The revenue-optimal bonus auction raises more money but leads to a 23% reduction in drilling compared to the baseline.
- The **Cash** auction maximizes drilling but leaves significant revenue on the table.

Revenue and Drilling vs. Winner's Signal (for fixed q)



- The revenue-optimal bonus auction generates the highest revenue across all initial price levels.
- Drilling activity under Equity and Debt is almost completely unresponsive to price, as high bids choke off investment.

Revenue vs. Employment



Conclusion

- This paper provides the first empirical analysis that structurally links contingent payment auction design to endogenous post-auction investment.
  (1) **Auction design has a material impact on real economic activity.** It affects not just revenue, but also the rate and timing of oil drilling.
  (2) **Bonus auctions appear superior to equity or debt auctions** in this setting. They generate more revenue and spur more investment by mitigating the "winner′s curse on moral hazard."
  (3) **A key policy tradeoff exists.** The revenue-maximizing bonus auction involves a higher royalty rate that increases government revenue but reduces drilling activity. The current policy ($\phi = 1/6$) represents a balance between these two objectives.

References I

Bhattacharya, V., A. Ordin, and J. W. Roberts (2022). Bidding and drilling under uncertainty: An empirical analysis of contingent payment auctions. *Journal of Political Economy 130*(5), 1319–1363.