Vreugdenhil (2025): Booms, Busts, and Mismatch in Capital Markets: Evidence from the Offshore Oil and Gas Industry

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Motivation and Core Idea

- Capital reallocation over the business cycle is a key driver of aggregate productivity
  - However, micro-level mechanisms within industries are not well understood
  - This is primarily due to the lack of data on firm-to-firm contracts
- This paper investigates one such mechanism: **matching** in decentralized capital markets
- **Core Idea: The "Sorting Effect"**
  - During booms, markets become "thicker," increasing the **option value of searching** for good matches
  - Agents become more selective and avoid low-surplus matches
  - This leads to stronger positive assortative matching (less mismatch) during booms

$\Rightarrow$ Research Question: quantifying the welfare importance of the sorting effect

Background: Offshore Oil & Gas Drilling

- A decentralized market ideal for studying search and matching
- **Setting:** 2000-2009, shallow water US Gulf of Mexico

- **Two sides of the market with vertical heterogeneity:**
  - **Projects (Demand):** Oil and gas companies (BP, Chevron) rent rigs to drill wells
    - Heterogeneity in **complexity**: Mechanical Risk Index (MRI)
  - **Capital (Supply):** Rig companies own drilling rigs
    - Heterogeneity in **efficiency**: maximum drilling depth
  - Neither side of the market is concentrated

- **Data:** Novel dataset combining:
  - Contract data (IHS, Rigzone): prices (dayrates), duration, contracting parties
  - Well characteristics (BSEE): depth, complexity factors
  - Lease auction data: proxy for expected project value

Stylized Facts in the Decentralized Market

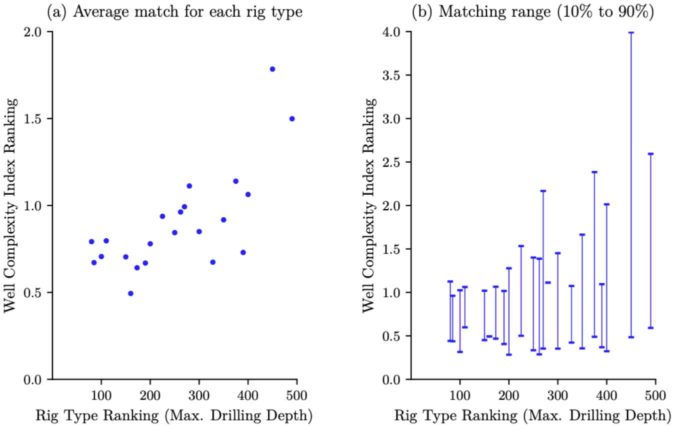
(1) Positive assortative matching with imperfect sorting

(2) Strong cyclicality driven by oil and gas prices

(3) Evidence of search frictions

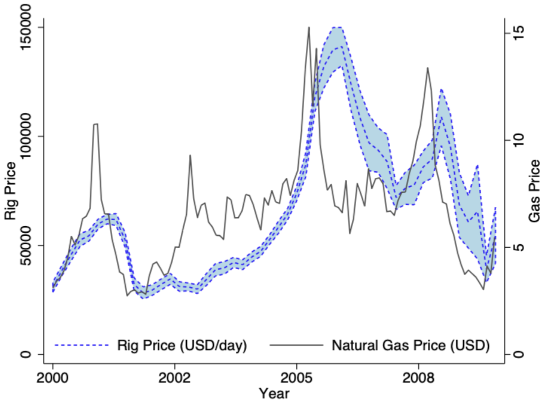
Stylized Fact 1: Positive Assortative Matching

Higher-efficiency rigs consistently match with more complex wells, but sorting is imperfect.



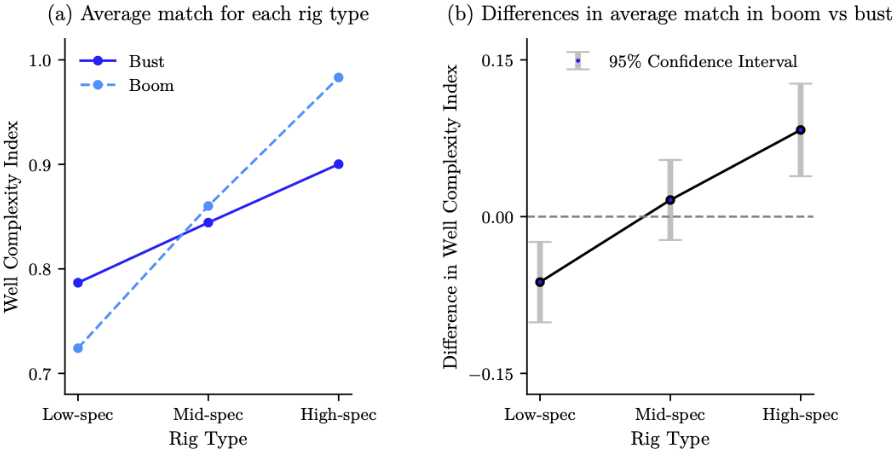
Stylized Fact 2: Strong Cyclicality

The market experiences large exogenous shocks driven by global energy prices. Rig prices and utilization are strongly pro-cyclical.



Cyclical Patterns in Matching Quality

The strength of assortative matching is pro-cyclical.



Stylized Fact 3: Search Frictions

(1) Price dispersion

	(a) Using aggregated rig types	(b) Using disaggregated rig types
$1 - R^2$	0.37	0.27
$SD(\tilde{p}_{it})$	11	9
$SD(\hat{p}_{it})$	18	18

(2) Evidence of mismatch

	Change in Match Value (Millions USD)		
	Bust	Boom	Difference: Bust vs Boom
Optimal Match vs Empirical Match	0.758	0.594	0.164
T-test	0.002***	0.01***	0.029**

Model Setup: Agents and Environment

Capital Owners (Rigs): Type $y \in Y = \{low, mid, high\}$

- Efficiency categorized by maximum drilling depth
- Available capital: n_{yt} rigs of type y at time t

Projects (Wells): Characteristics $x = (x_{complexity}, x_{quantity}, \tau)$

- $x_{complexity}$: complexity index (Mechanical Risk Index)
- $x_{quantity}$: expected hydrocarbon value
- τ: contract duration in months
- $K_t = k_0 + k_1 g_t$ potential projects drawn each period

State Space: $s_t = [g_t, n_{low,t}, n_{mid,t}, n_{high,t}]$

- State evolution: $s_t = R_0 + R_1 s_{t-1} + \varepsilon_t$
- Only gas price g_t is stochastic

Timing and Decision Sequence

Within Each Period (Monthly):

(1) **Contract Extensions:** Existing matches extend with probability

$$\eta_{xy,t+\tau} = \eta \cdot \mathbf{1}[S_{xy,t+\tau} \geqslant 0]$$

(2) **Entry Decision:** Each potential project enters with probability

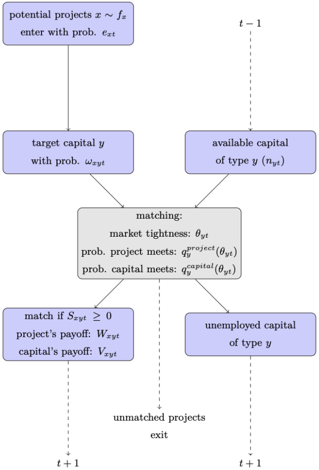
$$e_{xt} = \frac{\exp\left[\sum_{k \in Y} \omega_{xkt} \pi_{xkt} - c\right]}{1 + \exp\left[\sum_{k \in Y} \omega_{xkt} \pi_{xkt} - c\right]}$$

(3) **Partially Directed Search:** Projects target capital submarkets with probability

$$\omega_{xyt} = \frac{n_{yt} \exp[\gamma_0(\pi_{xyt} - \gamma_1 \mathbf{1}[x \notin A_{yt}])]}{\sum_{k \in Y} n_{kt} \exp[\gamma_0(\pi_{xkt} - \gamma_1 \mathbf{1}[x \notin A_{kt}])]}$$

(4) **Matching:** Meet with probabilities $q_y^{capital}(\theta_{yt})$, $q_y^{project}(\theta_{yt})$

Timing and Decision Sequence



Value Functions: Project Owners

Project Owner's Value from Matching:

$$W_{xyt} = \sum_{k=0}^{\tau-1} \beta^k [v_{xyt,k} - p_{xyt}] + \beta^\tau \mathbb{E}_t[\eta_{xy,t+\tau} W_{xy,t+\tau}]$$

Where Per-Period Match Value:

$$v_{xyt,k} = m_{0,y} + m_{1,y} \cdot x_{complexity} + m_2 \cdot \mathbb{E}_t[g_{t+k}] \cdot x_{quantity}$$

Key Parameters:

- $m_{0,y}$: Base match value for rig type y
- $m_{1,y}$: Complementarity parameter (sorting incentive)
- m_2: Weight on expected hydrocarbon value

Supermodularity Condition for Sorting: $m_{1,high} > m_{1,mid} > m_{1,low}$

Value Functions: Capital Owners

Capital Owner's Value from Matching:

$$V_{xyt} = \sum_{k=0}^{\tau-1} \beta^k p_{xyt} + \beta^\tau \mathbb{E}_t[\eta_{xy,t+\tau} V_{xy,t+\tau} + (1 - \eta_{xy,t+\tau}) U_{y,t+\tau}]$$

Capital Owner's Value of Searching Again:

$$U_{yt} = \int_z \max\{V_{zyt}, \beta \mathbb{E}_t U_{y,t+1}\} h_{zyt} dz + h_{\emptyset yt} \beta \mathbb{E}_t U_{y,t+1}$$

Where Contact Probabilities:

$$h_{xyt} = q_y^{capital}(\theta_{yt}) \cdot \frac{\omega_{xyt} e_{xt} f_x}{\int_z \omega_{zyt} e_{zt} f_z dz} \tag{1}$$

$$h_{\emptyset yt} = 1 - q_y^{capital}(\theta_{yt}) \tag{2}$$

Matching Technology and Market Tightness

Market Tightness:

$$\theta_{yt} = \frac{n_{yt}}{K_t \cdot \int \omega_{xyt} e_{xt} f_x dx}$$

Meeting Probability Functions:

$$q_y^{capital}(\theta_{yt}) = \min\left\{1 - \exp\left(-\frac{a_y}{\theta_{yt}}\right), \frac{1}{\theta_{yt}}\right\} \tag{3}$$

$$q_y^{project}(\theta_{yt}) = \min\left\{\theta_{yt}\left(1 - \exp\left(-\frac{a_y}{\theta_{yt}}\right)\right), 1\right\} \tag{4}$$

Parameter a_y: Controls matching efficiency for rig type y

Functional Form Properties:

- As $\theta_{yt} \to 0$: $q_y^{capital} \to 1$, $q_y^{project} \to 0$ (thick capital market)
- As $\theta_{yt} \to \infty$: $q_y^{capital} \to 0$, $q_y^{project} \to 1$ (thin capital market)

Equilibrium: Nash Bargaining and Acceptance

Nash Bargaining Solution:

$$p_{xyt} = \arg\max_{p_{xyt}} [V_{xyt} - \beta \mathbb{E}_t U_{y,t+1}]^{\delta} [W_{xyt}]^{1-\delta}$$

Total Surplus:

$$S_{xyt} = W_{xyt} + V_{xyt} - \beta \mathbb{E}_t U_{y,t+1}$$

Acceptance Set:

$$A_{yt} = \{x : S_{xyt} \geqslant 0\}$$

Rearranged Price Equation (for identification):

$$p_{xyt} = (1-\delta) z_{xyt} + \delta m_{0,y} + \delta m_{1,y} x_{complexity} + \delta \left[\frac{\sum_{k=0}^{\tau-1} \beta^k \mathbb{E}_t [g_{t+k}]}{\sum_{k=0}^{\tau-1} \beta^k} \right] x_{quantity}$$

where z_{xyt} captures outside option effects

Identification Challenge and Strategy

Central Challenge: Separate sorting effect from compositional changes in demand

- Observed stronger sorting in booms could reflect:
  1. **Sorting Effect:** Agents become more selective (behavioral)
  2. **Composition Effect:** Different types of projects enter in booms

Key Innovation - Price-Based Identification:

$$p_{xyt} = (1-\delta)z_{xyt} + \delta m_{0,y} + \delta m_{1,y} x_{complexity} + \delta \left[\frac{\sum_{k=0}^{\tau-1} \beta^k \mathbb{E}_t[g_{t+k}]}{\sum_{k=0}^{\tau-1} \beta^k} \right] x_{quantity}$$

Auxiliary Regression:

$$p_{xyt} - (1-\delta)z_{xyt} = \hat{\beta}_{0,y} + \hat{\beta}_{1,y} x_{complexity} + \hat{\beta}_2 g_t x_{quantity} + \varepsilon_{xyt}$$

This separates match values from outside option values, enabling identification of true complementarities

Two-Step Estimation Procedure

Step 1: State Transitions and Value Functions

- Estimate state transition parameters $(R_0, R_1, \sigma_\varepsilon)$ via Maximum Likelihood
- Construct search value functions U_{yt} non-parametrically using forward simulation:

$$U_{yt} = \mathbb{E}\left[\sum_{s=1}^{\infty} \beta^{s-1} \text{Flow Value}_{y,t+s}\right]$$

- Calibrate bargaining parameter $\delta = 0.37$ from industry operating margins

Step 2: Simulated Method of Moments

- Estimate remaining parameters $\Theta = \{m_{0,y}, m_{1,y}, m_2, \gamma_0, \gamma_1, a_y, \eta, k_0, k_1, f_x\}$
- Minimize: $\min_\Theta [\mathbf{m}_{data} - \mathbf{m}_{model}(\Theta)]'\mathbf{W}[\mathbf{m}_{data} - \mathbf{m}_{model}(\Theta)]$
- Optimal weighting matrix $\mathbf{W}$ from efficient GMM

Moment Conditions and Identification Sources

Match Value Parameters $(m_{0,y}, m_{1,y}, m_2)$ **- 7 parameters:**

- *Source:* Price regression coefficients (4 moments)
- *Variation:* Cross-sectional complexity, time-series gas prices

Targeting Parameters (γ_0, γ_1) **- 2 parameters:**

- *Source:* Sorting patterns by rig type in booms/busts (6 moments)
- *Variation:* Cyclical changes in match patterns

Meeting Technology (a_y) **- 3 parameters:**

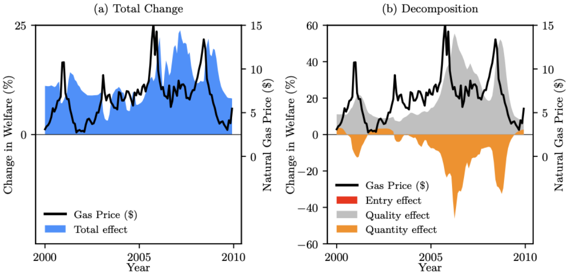
- *Source:* Mean utilization rates by rig type (3 moments)
- *Variation:* Cross-sectional differences in capacity utilization

Demand Parameters (k_0, k_1, f_x) **- 8 parameters:**

- *Source:* Utilization variance, cyclicality, match distribution (8 moments)
- *Variation:* Time-series correlation with gas prices

Counterfactual 1: Quantifying the Sorting Effect

Counterfactual 1: No sorting (agents cannot be selective; $\gamma_0 = 0$, wider acceptance sets).



(c) Summary of changes

	Boom	Bust	Average
Quality Effect	15.4%	4.8%	20.2%
Quantity Effect	-8.1%	-0.1%	-8.2%
Entry Effect	0.0%	0.0%	0.0%
Total	7.3%	4.7%	12.0%

Result:

- The sorting effect increases total welfare by **12.0%**.
- This is approximately $536 million

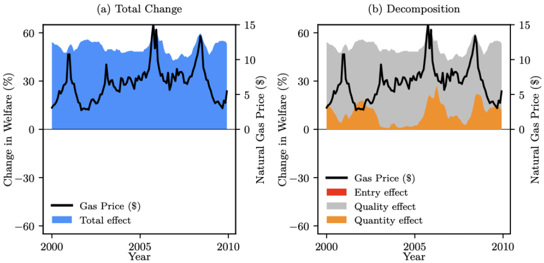
Decomposition:

- Quality Effect: +20.2%
- Quantity Effect: -8.2%

The quality effect dominates

Counterfactual 2: An Intermediary

Counterfactual 2: Introduce a "greedy" intermediary that improves the search technology, assigning wells to the statically optimal rig submarket.



(c) Summary of changes

	Boom	Bust	Average
Quality Effect	23.2%	17.9%	41.1%
Quantity Effect	5.2%	4.7%	9.9%
Entry Effect	0.0%	0.0%	0.0%
Total	28.4%	22.6%	51.0%

Result:

- The intermediary increases welfare by **51.0%** over the baseline.

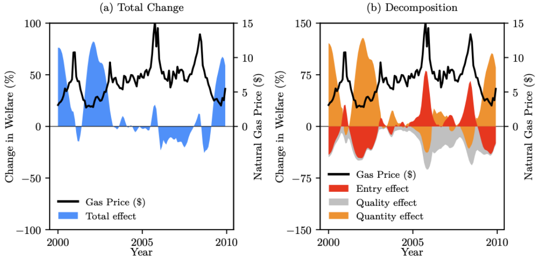
Decomposition:

- Quality Effect: +41.1%
- Quantity Effect: +9.9%

Substantial search frictions remain.

Counterfactual 3: Demand Smoothing

Counterfactual 3: Gas price at its long-run average.



(c) Summary of changes

	Boom	Bust	Average
Quality Effect	-10.2%	-2.4%	-12.6%
Quantity Effect	-2.4%	30.5%	28.1%
Entry Effect	10.4%	-11.0%	-0.6%
Total	-2.1%	17.0%	14.9%

Result:

- A surprisingly modest welfare gain of **14.9%**.

Why?

- It shifts drilling from booms to busts.
- But it **blunts the sorting effect**.

Conclusion

- A dynamic search model with two-sided heterogeneity
  - Provides a detailed picture of the "inner workings" of capital reallocation
- Novel evidence of pro-cyclical sorting in a major decentralized capital market
  - The sorting effect is a quantitatively important mechanism, increasing welfare by 12%.
  - Significant search frictions remain; an intermediary could boost welfare by a further 51%.
  - Demand smoothing policies may be less effective than commonly thought because they eliminate the pro-cyclical efficiency gains from better matching.

References I

Vreugdenhil, N. (2025). Booms, busts, and mismatch in capital markets: Evidence from the offshore oil and gas industry. *Journal of Political Economy, Forthcoming*.