Impacts of Mineral Right Regime on China’s Shale Gas Market Structure

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China University of Petroleum, Beijing
Outline

1. Introduction
2. A Three-stage Common Value Auction Model
3. Experience From the Two Auction Rounds for Shale Gas Prospecting Right
4. Another Example Demonstrating the Importance of Initial Signal
5. Conclusions and Suggestions
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5. Conclusions and Suggestions
Resources

Sichuan Basin and the fringe areas
Resources

- The ministry of land and resources, Chinese Academy of Engineering, and the EIA has evaluated the potential of shale gas resource in China independently.
- The latest estimate of technically recoverable reserves in China is 12.85 trillion cubic meters by China National Petroleum Corporation (CNPC).

<table>
<thead>
<tr>
<th>Institution</th>
<th>Year</th>
<th>Technical Recoverable Resource (trillion cubic meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLR</td>
<td>2012</td>
<td>25.1</td>
</tr>
<tr>
<td>Chinese Academy of Engineering</td>
<td>2012</td>
<td>10</td>
</tr>
<tr>
<td>EIA</td>
<td>2014.6</td>
<td>31.2</td>
</tr>
<tr>
<td>CNPC</td>
<td>2014</td>
<td>12.85</td>
</tr>
</tbody>
</table>
Chinese shale gas policies

- China- USA cooperation plan
- MLR set the first leading tentative area

National Geological survey mentioned exploring shale gas

- China sign a cooperation agreement with the USA
- National financial support for shale gas survey

- Shale gas became an independent mineral resource
- The 12th Five Year Plan include directions for foreign investors in industry
- The first round shale gas auction

- Shale gas development plan 2011-2015
- Subsidize policy for shale gas development
- Regulations on Shale gas exploration and development

- Same payment standards of value-added tax for shale gas as conventional gas
- Publish shale gas industrial policy
- The second round of shale gas auction
- 4 national shale gas demonstration areas are permitted
- Reserve calculation and evaluation requirement

Investment and development

- 10-year investment: 23 Billion RMB
- Wells drilled: 780
- Cumulative production: 1.3 BCM
- Average single well production: 0.1 MMCM/d

**Fuling field (By Sep. 30, 2015)**
- 227 wells completed,
- 146 wells under production
- Accumulated output 3 BCM, building capacity of 4.325 BCM per year
Auction and competition

- Auction is a kind of trading mechanism to ensure fair competition, and is commonly used to allocate public resources by the government
  - private value auction model
  - common value auction model

- It is very controversial whether auction is an efficient mechanism to guarantee bidder the maximized profit
  - Capen, Cpapp and Campbell (1971)
  - Lorenz and Dougherty (1983)
  - Hendricks, Porter and Boudreau (1987)

- In dynamic bidding process, the existence of winner’s curse will affect bidders’ strategy, so the equivalent solution is likely to pass a slow process of learning and adjustment, and gradually evolving, rather than achieve immediately in the game.
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Assumptions

- The qualification of bidders, \( i \in \{1, 2, 3, \ldots, K\} \), the probability of successful finding is positively correlated with their qualification.
- \((i, b)\) describes bidder \(i\)'s strategy.
- Tenderee’s utility function:
  \[
  U = w(i, \theta) + b
  \]
  where \(\theta\) is the state of the asset; \(w(i, \theta)\) means the utility brought by the outcome that bidder with capacity \(i\) winning the game. And,
  \[
  \frac{\partial U}{\partial w} > \frac{\partial U}{\partial b} = 1
  \]
The 1st Stage

- The expected profit of bidder \( i \) as follows:

\[
\pi_{i1} = \begin{cases} 
V(\hat{\theta}_i) - c(x_i) - b_i & \text{if } b_i > \max b_{j, j \neq i} \\
0 & \text{if } b_i < \max b_{j, j \neq i}
\end{cases}
\]

Where:
- \( V(\hat{\theta}_i) \) the estimated value of the mining right, \( V(\hat{\theta}_i) = \sum_{j=1}^{n} p(\theta_j) \times v(\theta_j) \)
- \( p(\theta_i) \), the prior probability of state \( \theta \)
- \( c(x) = mx \), of which \( m \) is the unit exploration cost, \( x \) measures the input of exploration investment

- Bidders should determine \((b^*, x^*)\), that is how much to offer and the number of inputs to maximize their profits: \((b^*, x^*) \in \arg \max \pi_{i1} \).
The 2nd Stage

Possible Outcomes Observed From the First Stage

- **Qualification**
  - Experienced
  - Inexperienced

- **Bid**
  - Win
  - Loss

- **Findings**
  - Success
  - Failed

- **Success**
  - Win
  - Loss

- **Failed**
  - Win
  - Loss

**So the value of the adjacent blocks is:**

\[
V(\hat{\theta}_i) = \sum_{j=1}^{n} p(\theta^j_i | d(\theta^j_i)) \times v(\theta^j_i)
\]

Where, \( p(\theta^j_i | d(\theta_i)) \) is the posteriori probability and \( d(\theta_i) \) indicates the incremental signal

\[
d(\theta_i) = \begin{cases} 
1, & \text{findings} \\
0, & \text{no finding}
\end{cases}
\]
The 2nd Stage

Possible Outcomes Observed From the First Stage

<table>
<thead>
<tr>
<th>Qualification</th>
<th>Bid</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experienced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inexperienced</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the second round of auction, bidders should determine \((b^*, x^*)\) on the basis of signals obtained from the first stage to maximize their profits: \((b^*, x^*) \in \text{arg max } \pi_{i2}

- So the value of the adjacent blocks is:
  \[
  V(\hat{\theta}_i) = \sum_{j=1}^{n} p(\theta^j_i | d(\theta^j_i)) \times v(\theta^j_i)
  \]

  Where, \(p(\theta^i | d(\theta^i))\) is the posteriori probability and \(d(\theta^i)\) indicates the incremental signal
  \[
  d(\theta^i) = \begin{cases} 
  1, & \text{findings} \\
  0, & \text{no finding} 
  \end{cases}
  \]
The 2nd Stage

- Given the results of the first round observable, new entrant $j (j \neq i)$ will determine his bidding strategy after comparing his capacity and the winner $i$ of the first round auction.

Bidder $i$

$d(\theta_i) = 0$  

Bidder $j$

<table>
<thead>
<tr>
<th>$j &gt; i$</th>
<th>(Normal, Conservative)</th>
<th>(Aggressive, Aggressive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$j &lt; i$</td>
<td>(Conservative, Conservative)</td>
<td>(Aggressive, Aggressive)</td>
</tr>
</tbody>
</table>

- When it is observed by a more experienced bidder $j (j > i)$ that the outcome of no finding after the input of bidder $i$, then bidder $j$ will follow its original bidding strategy because this information has no influence on his estimation.
- The winner in this round will be bidder $j$ because $U_i < U_j$
The 2nd Stage

- Given the results of the first round observable, new entrant \( j(j \neq i) \) will determine his bidding strategy after comparing his capacity and the winner \( i \) of the first round auction.

  Bidder \( i \)

  \[
  d(\theta_i) = 0 \quad \text{or} \quad d(\theta_i) = 1
  \]

<table>
<thead>
<tr>
<th>Bidder ( j )</th>
<th>( j &gt; i )</th>
<th>( j &lt; i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Normal, Conservative)</td>
<td>(Aggressive, Aggressive)</td>
<td>(Conservative, Conservative)</td>
</tr>
</tbody>
</table>

- When it is observed by a more experienced bidder \( j \) \( (j > i) \) that the outcome of successful findings after the input of bidder \( i \), then bidder \( j \) will be more aggressive because of lower uncertainties of exploitation and a larger capacity than bidder \( i \).
- The winner in this round will be bidder \( j \) because \( U_i < U_j \).
The 2nd Stage

- Given the results of the first round observable, new entrant \( j (j \neq i) \) will determine his bidding strategy after comparing his capacity and the winner \( i \) of the first round auction.

\[
\begin{array}{c|c|c}
\text{Bidder } i & d(\theta_i) = 0 & d(\theta_i) = 1 \\
\hline
\text{Bidder } j & \begin{array}{c}
\text{(Normal, Conservative)} \\
\text{(Aggressive, Aggressive)}
\end{array} & \begin{array}{c}
\text{(Conservative, Conservative)} \\
\text{(Aggressive, Aggressive)}
\end{array}
\end{array}
\]

- When it is observed by a less experienced bidder \( j \ (j < i) \) that the outcome of no finding after the input of bidder \( i \), then bidder \( j \) will be more conservative because of large uncertainties of exploitation and huge volume of sunk cost.
- The winner in this round will still be bidder \( i \) because \( U_i > U_j \)
The 2nd Stage

- Given the results of the first round observable, new entrant \( j(j \neq i) \) will determine his bidding strategy after comparing his capacity and the winner \( i \) of the first round auction.

\[
\begin{align*}
\text{Bidder } i & \\
& \begin{array}{ll}
\quad d(\theta_i) = 0 & \quad d(\theta_i) = 1 \\
\text{Bidder } j & \\
& \begin{array}{ll}
\quad j > i & \quad \text{(Normal, Conservative)} \quad \text{(Aggressive, Aggressive)} \\
\quad j < i & \quad \text{(Conservative, Conservative)} \quad \text{(Aggressive, Aggressive)}
\end{array}
\end{array}
\end{align*}
\]

- When it is observed by a less experienced bidder \( j \) (\( j < i \)) that the outcome of successful findings after the input of bidder \( i \), then bidder \( j \) will be more aggressive because of lower uncertainties of exploitation and a higher chance of speculation.
- The winner in this round will be bidder \( i \) because \( U_i > U_j \)
- Unless \( b_j \gg b_i \), which means bidder \( j \) has to deduct its capital expenditure in exploitation to maximize its expected profit.
The 2nd Stage

- Two factors affect the prior probability density:
  - the comparative advantage of the incumbent company
  - the exploitation result by the incumbent company
The 3rd Stage

- After two rounds of auction, the potential new comers (bidder $k$) can observe the entry and exit of the incumbent companies.
- The possible combinations of the incumbent firms:

<table>
<thead>
<tr>
<th></th>
<th>$i$</th>
<th>$j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(1, 1)</td>
<td>(0, 0)</td>
</tr>
<tr>
<td>2</td>
<td>(1, 0)</td>
<td>(0, 1)</td>
</tr>
<tr>
<td>3</td>
<td>(1, 0)</td>
<td>(0, 0)</td>
</tr>
</tbody>
</table>

- If $i>j$
  - $i$ (1, 1), $j$ (0, 0), the consistence of the behavior of experienced company $i$ will be a strong signal of economic benefits.
  - $i$ (1, 0), $j$ (0, 1), the reversed action of experienced early bird matters, which send insights that the breakthrough is not as satisfying.
  - $i$ (1, 0), $j$ (0, 0), the reversed action of experienced early bird together with the failure of second round auction can be understood as signal that the exploitation of shale gas is far from technical or financial economical.
The 3rd Stage

- The possible combinations of the incumbent firms:

<table>
<thead>
<tr>
<th></th>
<th>i</th>
<th>j</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1, 1)</td>
<td>(0, 0)</td>
<td></td>
</tr>
<tr>
<td>(1, 0)</td>
<td>(0, 1)</td>
<td></td>
</tr>
<tr>
<td>(1, 0)</td>
<td>(0, 0)</td>
<td></td>
</tr>
</tbody>
</table>

- If i<j
  - i(1, 1), j(0, 0), the reinforcement strategy of inexperienced company i may be considered as blowing his own horn because the experienced late comer j take no action. So the optimum strategy of inexperienced winners might be “enclosure without exploration”, leading to a speculator-dominated market structure;
  - i(1, 0), j(0, 1), the positive action of experienced late comer j and the loss of the low-competence bidder i convey significant positive signals to the market. It may thus be optimal for companies with ability stronger than firm i to employ more aggressive strategies to compete. The ultimate winner standing out in the third round auction will be an Pareto improvement for the tenderee.
The 3rd Stage

- the number of post market players and the types of participants depend on the finding results in the previous stages and the type and behavior of the incumbents.

- However, even in the “low-competence incumbent” situation, with increasing expansion and awakening of market participants, the number of companies with high ability will get larger and eventually occupy more market share.

- The worst situation will be no findings in the initial stage and high capacity of bidders’ inaction or even employment of a reversed action, which will make the late entrants more cautious and more conservative.
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### Experience From the Two Auction Rounds

#### The 1st Round

- The MLR adopted the form of invitation to tender in the first round of shale gas bidding in June 2011. Four shale gas blocks are listed and six firms are invited.

<table>
<thead>
<tr>
<th>Block</th>
<th>Chongqing-Guizhou-Nanchuan block</th>
<th>Chongqing-Guizhou-Hunan-Xiushan block</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bid Winner</strong></td>
<td>East China branch of Sinopec</td>
<td>Henan Provincial Coal Seam Gas Development and Utilization Co., I, TD</td>
</tr>
<tr>
<td><strong>Firm types</strong></td>
<td>Central SOE</td>
<td>Local SOE</td>
</tr>
<tr>
<td><strong>Committed Investment</strong></td>
<td>591.1 million RMB; drilling 11 wells</td>
<td>247.56 million RMB; drilling 10 wells</td>
</tr>
<tr>
<td><strong>Actual Investment</strong></td>
<td>433.89 million RMB; drilling 4 wells</td>
<td>126.84 million RMB; drilling 7 wells</td>
</tr>
<tr>
<td><strong>Punishment</strong></td>
<td>7.9798 million RMB; cut block acreage to 593.44 km²</td>
<td>6.0355 million RMB; cut block acreage to 994.15 km²</td>
</tr>
</tbody>
</table>
The Behavior of Bidding Enterprise

- The 1st Round

- Barriers to entry
  - invitation to tender -- experienced major SOEs----tender with barriers

- Information asymmetry
  - no disclosure of the geographic coordinates----information asymmetry---uncertainties for valuation----lower estimate on the rate of successful discovery--- reducing valuation---- lower bid price.

- Opportunity cost
  - Even though the objective success rate of experienced enterprise is higher than the inexperienced, experienced firms suffer higher opportunity cost, making their estimated value much lower.

- Therefore, the results of the first round of the game can only be inexperienced enterprises to win, experienced companies are not active to the contrary.
Experience From the Two Auction Rounds

The 2nd Round

- The MLR took a more open attitude in the second round of auction. 19 blocks were released for tender in Sept 2012, with bidding open to private enterprises and foreign JVs as well as SOEs. To be eligible for bidding, all companies must have registered capital of at least 300 million RMB.

- 14 SOEs got 17 blocks and two private firms got the remaining two blocks.
### Experience From the Two Auction Rounds

#### The 2nd Round

Winners in the second bidding round and their follow-up actions

<table>
<thead>
<tr>
<th>Company</th>
<th>Block</th>
<th>Time</th>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anhui Energy Group</td>
<td>Zhejiang Linan</td>
<td>Jun-13</td>
<td>Joint venture with Anhui Geology and Mining Investment Group</td>
</tr>
<tr>
<td>Beijing Taitan Gas Technology</td>
<td>Guizhou Fenggang 3</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Guizhou Fenggang</td>
<td>Jul-13</td>
<td>Sign a cooperation agreement with Guizhou Chengcheng Energy Investment LTD</td>
</tr>
<tr>
<td>Chongqing City Energy Investment</td>
<td>Chongqing Qianjiang</td>
<td>Nov-13</td>
<td>spud 2 exploration wells</td>
</tr>
<tr>
<td>Chongqing Mineral Resources Development</td>
<td>Chongqing East Youyang</td>
<td>Nov-13</td>
<td>complete 2D seismic</td>
</tr>
<tr>
<td>Henan Geological Exploration and Mine Investment</td>
<td>Henan Wenxian</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Henan Zhongmu</td>
<td>Oct-13</td>
<td>start 2D seismic</td>
</tr>
<tr>
<td>Huadian Coal Industry Group</td>
<td>Guizhou Suiyang</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Huadian Engineering Group</td>
<td>Hunan Huayuan</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Huadian Hubei Power</td>
<td>Hubei Hefeng</td>
<td>Jul-13</td>
<td>start geological survey</td>
</tr>
<tr>
<td></td>
<td>Hubei Laifeng Xianfeng</td>
<td>Jul-13</td>
<td>start geological survey</td>
</tr>
<tr>
<td>Huaying Shanxi Energy Investment</td>
<td>Guizhou Fenggang 2</td>
<td>May-13</td>
<td>joint venture with Jiangsu Changjiang Geological Survey Institute</td>
</tr>
<tr>
<td>Hunan Huasheng Energy Investment and Development</td>
<td>Hunan Longshan</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Hunan Shale Gas Development</td>
<td>Hunan Yongshun</td>
<td>Sep-13</td>
<td>start 2D seismic</td>
</tr>
<tr>
<td>Jiangxi Natural Gas Holdings</td>
<td>Jiangxi Xiuwu Basin</td>
<td>May-13</td>
<td>start geological survey</td>
</tr>
<tr>
<td>Shenhua Geological Exploration</td>
<td>Hunan Baojing</td>
<td>Jun-13</td>
<td>start 2D seismic</td>
</tr>
<tr>
<td>State Development Investment Corp.</td>
<td>Chongqing Chengkou</td>
<td>Sep-13</td>
<td>spud an investigation well</td>
</tr>
<tr>
<td>Tongren City Energy Investment</td>
<td>Guizhou Cengong</td>
<td>Nov-13</td>
<td>spud an exploration well</td>
</tr>
</tbody>
</table>
Experience From the Two Auction Rounds

- **The 2nd Round**
  - The follow-up movement of the winners delayed repeatedly due to technical and capital barriers.
  - Until now, no substantial breakthroughs have been achieved by these winners. The phenomenon that just occupied but not explored seems not avoidable.

![Pie chart showing the distribution of 2D seismic, Spud exploration wells, JV or cooperation, and Unknown.]
- 2D seismic: 7
- Spud exploration wells: 3
- JV or cooperation: 4
- Unknown: 5
The Behavior of Bidding Enterprise

- The 2nd Round
  - lower the threshold
    - relaxed the qualification restrictions----142 entities can participate ---- relatively rich geological data---- reduced the information asymmetry
  - Poor quality of the blocks
    - The exploration risk and technological backwardness has no improvement, plus a number of high-quality blocks been divided by the national oil companies as demonstration areas, so the experienced companies more clearly understood a lower quality of the tender in the second round.
  - Adverse selection
    - making the inexperienced the winner and experienced the loser due to higher opportunity cost and conservative bidding strategy.
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Example of the U.S. shale gas boom

- Rapid increase of US Shale Gas Production
  - 1.6% of total US natural gas production in 2000, 40.4% by 2012
Example of the U.S. shale gas boom

Early Devonian Stage
- Shallow, Natural Fractures Vertical Drilling
- 1st shale gas well
- 1st Barnett Horizontal Well
- Discover Barnett

Modern Shale Gas Development
- Deep, Tight, Artificial fracturing
- Experimental Stage
- Refracturing Technology
- Commercialize Horizontal Drilling
- Scaling-up Stage
- Haynesville
- Woodford
- Marcellus
- Fayetteville
- Eagle Ford
- 2008
- 2009
- 2010
- 2011
- 2012

Modern Shale Gas Development
- Early Devonian Stage
- Modern Shale Gas Development
- Experimental Stage
- Scaling-up Stage
- Commercialize Horizontal Drilling
- Shale gas well project启动
- Barnett
- 1st Barnett Horizontal Well
- 1st Barnett Horizontal Well
- Discover Barnett
- Shallow, Natural Fractures Vertical Drilling
- 1821
- 1982
- 1999
- 2009
- 2012

Example of the U.S. shale gas boom

Modern Shale Gas Development
- Early Devonian Stage
- Modern Shale Gas Development
- Experimental Stage
- Scaling-up Stage
- Commercialize Horizontal Drilling
- Shale gas well project启动
- Barnett
- 1st Barnett Horizontal Well
- 1821
- 1982
- 1999
- 2009
- 2012
Market structure before the breakthrough

During 1982–1999

- Highly concentrated, dominated by one independent operator

<table>
<thead>
<tr>
<th>rank</th>
<th>operator</th>
<th>Drilled wells</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mitchell Energy</td>
<td>482</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>Enre</td>
<td>36</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Lakota Energy Ltd</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Republic Energy Inc</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>subtotal</td>
<td></td>
<td>552</td>
<td>80%</td>
</tr>
<tr>
<td>others</td>
<td></td>
<td>102</td>
<td>15%</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>686</td>
<td>100</td>
</tr>
</tbody>
</table>

Market structure before the breakthrough
Market structure after the breakthrough

During 2000–2012

- “a successful signal release is the key to motivate others to participate in and form a competitive landscape


Market structure after the breakthrough

During 2000–2012

- “more larger companies, a long tail of small– and median–sized firms”

Top 30: 30,874 wells, contribute 77%
Top 4: 15,589 wells, contribute 39%
Market structure after the breakthrough

During 2000–2012

“more larger companies, a long tail of small– and median–sized firms”

Top 4:
• Chesapeake Energy
• Devon Energy
• XTO Energy
• Southwestern Energy

Top 30:
• 27 independent oil and gas development companies

Top 4: 15,589 wells, contribute 39%
Top 30: 30,874 wells, contribute 77%
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Conclusions

1. The current shale gas development in the most geologically favorable areas is led by Sinopec and the CNPC, controlling about 70% of China's total gas assets, both conventional and unconventional.

2. Two rounds of shale gas bidding exist serious adverse selection problem in the absence of any successful precedent.

3. Market structure depends on the previous findings and the type and behavior of the incumbents.
Suggestions

In order to improve incentives of participants and form a competitive market structure, the government needs several adjustments in its current management of mining right:

1. Reinforce the incentive effect of the key demonstration plots.

2. Accelerate the transfer of mineral rights to promote the quality of bidding asset.

3. Disclose detailed information on bidding asset to reduce winner’s curse.

4. Bundle cooperation agreement on prospecting between the government and the bid winners.

5. Firmly implement supervision while lowering barriers to entry.
Thank you