A Study on Impacts of Mineral Right Regime on China’s Shale Gas Market Structure Based on A Multi-stage Common Value Auction Model

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Abstract

China is faced up with challenges to foster a competitive shale gas drilling market in recent years. The type of market structure has a closely relationship with the mineral right regime, since mineral ownership decides reasonable returns for entrepreneurial gas firms from their early investments in technology innovations. This paper examines the mineral right regime in China and its impact on the market structure of shale gas development. It conducts a statistical review on the current market structure and progress of China’s shale gas drilling, and builds up a multi-stage common value auction model with imperfect information to illustrate the optimal strategies of government agencies, oil and gas companies and small and median-sized new entrants. Both the modelling and the results gained from the two rounds of shale bidding have confirmed that a release of successful signal is the key to motivate others to participate and further form a competitive landscape. Given no positive signals and high-competence incumbents, hundreds of potential entrants can hardly participate in the game. This article also suggests ways to optimize China’s mineral rights transaction mechanism to escalate the circulation of mineral right transfer, which eliminates the underlying risks and lowers the threshold for late comers.

1 Introduction

Shale gas reserves before the Cenozoic Era and even Cambrian age are widely distributed from the north liquid-rich basins to the Southern China. The ministry of land and resources (MLR), 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). In 2012, to encourage the exploration of shale gas, the Chinese government established a four-year, $1.80 per million British thermal unit subsidies program for any Chinese company reaching commercial production of shale gas. In mid-2015, these subsidies were extended to 2020, but at a lower rate. Several national demonstration plots have been established, of which the Changning-Weiyuan block and Fuling field in the Sichuan Basin are the most geologically favorable areas, where all of the current reserve verification took place and commercialized development firstly start from.

Shale gas development in China is still in its infancy, but has promising prospects. There have been an accumulated 10-year investment of more than 20 billion RMB from central finance, local government and industry since 2005. More than 400 shale gas wells have been drilled, reaching cumulative production levels of 1.3 billion cubic meters and the average single well production up to 0.1 million cubic meters per day. By the end of September 2015, 227 wells had been completed and 146 wells been under production in the Fuling field. Accumulated shale gas output from those wells reached 3 billion
cubic meters, building up an annual capacity of 4.235 billion cubic meters. This field, operated by Sinopec, has been verified as nation’s first large shale find. The horizontal well drilling cycle has been shortened to 46-70 days, and the single well cost has dropped to 40-70 million RMB, cutting the total life cycle cost to 1.6-1.8 RMB per cubic meter. But these substantial breakthroughs are mostly achieved in the favorable Sichuan basin by Sinopec and the CNPC.

Figure 1: Natural gas development in the Sichuan Basin, China


Before the global surplus of crude oil and the crash down of oil price, several international companies and local enterprises are actively working to exploring shale gas in China. However, shale gas development in these most favorable areas are still led by Sinopec and the CNPC, two of China's national oil companies. China's shale gas industry have long been dominated by these two majors, controlling about 70% of China's total gas assets, both conventional and unconventional, and accounting for nearly all shale gas initiatives. This oligopolistic market structure can’t guarantee a quick increase in natural gas production or the nation’s objective to optimize its energy utilization structure. An open oil-gas market with thousands of large-, median-and small-sized firms are widely believed as the key reason for shale gas revolution in the United States. China has learned about that and urges to form an open market with fierce competition, which requires the deep involvement of private enterprises, foreign-funded enterprises and new SOEs.

In order to pave a fast track for energy development, Chinese central government promoted a revolution in energy governance in the year 2013. Measures include firmly progressing reform to give energy back its commodity nature, building a competitive market, forming a mechanism where the market determines energy prices, changing the way the government regulates the energy industry and building a system of rules by the law. Shale gas provide a breakthrough point for mining right reform by introducing a competitive transaction mechanism of tender and bidding. After shale gas verified as an independent mineral pilot, Chinese government arranged two rounds of shale gas prospecting right bidding in 2011 and 2012 respectively, motivating more companies to participate and further diversifying investment bodies.
In economics of regulation, bidding and auction is a kind of trading mechanism to ensure fair competition, and is commonly used to allocate public resources by the government. According to whether the subject matter holds a common value, auction is classified into two types, the private value auction model and the common value auction model. In the first model, each bidder knows exactly the value of the subject matter for them, but doesn't know the value of the target item for the others; while in the second model, the value of the subject matter is the same for everyone, but different bidder holds different valuation for the target item. More specifically, the posterior value is the same for all bidders, but each bidder can only observe the value-related signals as the bidding proceeding. The auction of the mining rights is a typical common value auction, and government can adopt sealed auction or English (public) auction to sell the mining right. It is very controversial whether auction is an efficient mechanism to guarantee bidder the maximized profit. Empirical study has shown that winner’s curse exists in the common value auction. Capen, Capp and Campbell (1971) first observed the surprisingly low yields for oil companies in the OCS lease sales during the 1960s and 1970s. They owned it to that only when the bidder offers the highest price can he win, which means a higher probability of overestimation. So despite winning, but obtain lower yield than normal profits or even suffer negative profit. Similarly, Lorenz and Dougherty (1983) also found winner’s curse in their study of auction for oil prospecting rights. Hendricks, Porter and Boudreau (1987) found that when there’re more than seven bidders in an OCS lease sales auction, the average profit of the deal is negative. The more bidders to participate, the more serious adverse selection will be. Experimental studies suggests a bidder with less experience is more vulnerable to winner’s curse. (Bazerman and Samuelson, 1983; Kagel and Levin, 1986; Kagel, Levin, Battalio and Meyer, 1989). 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. It can be inferred that in an oligopoly market, where all technology, experience and capital has long been in the hands of a few companies, a sudden opening of mining market can hardly form an effective competitive market structure in the short time. In this paper, the discussion will be on the basis of establishment of a three-phase common value auction model for shale gas prospecting right. For each stage the bidding strategy of potential bidders will be analyzed, then it will focus on the essential problem that whether the government can successfully attract investors through bidding reform, and how to adjust the policy to promote a highly competitive market structure for shale gas industry in China.

2 A Three-stage Common Value Auction Model

2.1 Assumptions

In China, the structure of land and mineral rights is characterized by a system of state-owned property right. Assume the government adopt first-price sealed auction to sell the prospecting right, and set a low restriction on the qualifications (experience, financial capacity and corporation size) of bidding participants. It implies that a poorly qualified company can still win the game by offering a high bid. Suppose there are \( K \) firms in this auction and each of them can carry on the task to look for shale gas, but the probability of successful finding is positively correlated with their qualification. Let \( i \) indicate the qualification of bidder \( i, i \in \{1,2,3,...,K\} \) (we don’t consider the laziness of winners, that means the degree of hardworking equals their capacity). \( S_i \) is the number of firms that with a qualification
degree of at least \( i \). \( S = (S_1, S_2, \ldots, S_K) \). Therefore, \((i, S)\) describes the space of the market state and the position of each participant. Based on the assumption of low threshold to take part in the auction, the payment to enter equals 0. \((i, b)\) describes bidder \( i \)'s strategy. As for the tenderer, his utility is decided by two factors, the qualification of winner that might deliver a faster finding of shale gas resources, and the bid price that might fuel the State’s revenue base. So tenderee’s utility function can be written as followed:

\[
U = w(i, \theta) + b
\]  

(1)

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. The winner will be the tenderer who offers the maximum utility for the government, and should complete the exploration task according to the commitment in the auction. According to the provisions of China on the mining royalty and the price of mineral prospecting right, the purpose of the fees charged is to recover the cost of the national funded geological survey program, therefore, it can be referred that the government concerns more about the sustainable development of natural resources than a lump-sum payment, which means in the process of the exploration of shale gas, the high capacity of bidders brings more satisfaction than the bid price.

\[
\frac{\partial U}{\partial w} > \frac{\partial U}{\partial b} = 1
\]

(2)

2.2 The 1st Stage

Before the auction starts, tenderer \( i \) has an estimate for the prior probability of state \( \theta \), namely \( p(\theta_i) \). The corresponding enterprise value in the state of \( \theta_i \) is determined by a \( n \)-dimensional vector, where \( n \) means the number of possible states. Tenderee knows specific state, but bidding firms do not know the specific state. Tenderer only has a prior probability estimates according to his experience and prediction of the reserve state. As the exploration investment goes on, the testing results turns out. Bidding company \( i \) will adjustment its estimation on posteriori probability, \( p(\theta_i|d(\theta_i)) \), where \( d(\theta_i) \) indicates the incremental signal. To simplify the model, we assume that:

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

(3)

Indication of oil and gas finding has contingency. It depends on factors such as geological condition and technical level.

The probability of finding under the given geological conditions is a function of the exploration investment, \( f_i = \frac{ax_i}{1 + ax_i} \), where \( a \) is constant, and \( x \) measures the input of exploration investment. Exploration cost \( c(x) = mx \), of which \( m \) is the unit exploration cost. Set a restriction
on $P(d|\theta) = 0|x = 0) = 1$, which guarantees the possibility of shale gas finding equals to 0 if no investment are made.

Prior to the auction, the tenderer $i$ determines a bidding strategy $b_i$ according to his estimation on the value of the block. Let $\beta(\cdot)$ represent the bid price mapped from the estimate of the value, so the condition $b_i \leq \beta(V(\hat{\theta}_i))$ must be satisfied because the bidder's offer will not exceed the estimated value of the mining right, $V(\hat{\theta}_i)$.

$$V(\hat{\theta}_i) = \sum_{j=1}^{n} p(\theta_j) \times v(\theta_j)$$  \hspace{1cm} (4)

Where: $p(\theta) = \sum_{j=1}^{n} p(\theta_j) = 1$

The expected profit of bidder $i$ as follows:

$$\pi_{\tilde{i}} = \begin{cases} V(\hat{\theta}_i) - c(x_i) - b_i & \text{if} \quad b_i > \text{max} \ b_{j \neq i} \\ 0 & \text{if} \quad b_i < \text{max} \ b_{j \neq i} \end{cases}$$ \hspace{1cm} (5)

Bidders should determine $(b^*, x^*)$, that is how much to offer and the number of inputs to maximize their profits: $(b^*, x^*) \in \arg \max \pi_{\tilde{i}}$.

2.3 The 2nd Stage

In this stage, bidder $i$ will adjust their valuation based on his inputs and finding results in stage one.

At this point, if the government list adjacent blocks for bidding, bidders’ estimate on prior probability of adjacent blocks will equal to the posteriori probability of the existing asset.
So the value of the adjacent blocks is:

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

The expected profit of bidder $i$ is as follows:

$$\pi_{i2} = \begin{cases} 
V(\hat{\theta}_i) - c(x_i) - b_i & \text{if } b_i > \max_{j, j \neq i} b_j \\
0 & \text{if } b_i < \max_{j, j \neq i} b_j 
\end{cases}$$

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: $(b^*, x^*) \in \arg \max \pi_{i2}$.

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.

$$d(\theta_i) = \begin{cases} 
0 & \text{Bidder } i \\
1 & \text{Bidder } i 
\end{cases}$$

<table>
<thead>
<tr>
<th>Bidder $j$</th>
<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>
<td></td>
</tr>
</tbody>
</table>

1. 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 $U_i < U_j$.

2. 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 $U_i > U_j$, otherwise, nobody will ask.

3. 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 $i$. Obviously, the winner in this round will be bidder $j$ because $U_i < U_j$.

(4) 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 will be the more experienced 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. However, since the probability of finding is positively connected with input, the possibility that the aggressive winner $j$ to suffer winner’s curse is extremely high. So this success won’t last long.

Based on the analysis of the possible four situations, two factors will affect the prior probability density: the comparative advantage of the incumbent company, and the exploitation result by the incumbent company. If findings occur, it will increase the incentives for new entrants. Firms with more competence can win with a higher possibility, but this won’t shut down the door to speculators by taking an aggressive bidding strategy. If no finding occurs, bidders’ enthusiasm will calm down than in the first round. Especially, no finding in the hand of an experienced incumbent company will be a strong bearish signal, which will gradually expel those inexperienced participants and lead to a shrinking market.

2.4 The 3rd Stage

After two round of bid and auction, the potential new comers (such as bidder $k$) can observe the entry and exit of the incumbent companies. Assume the tenderee has listed two adjacent blocks in last two auctions. The possible combinations of the incumbent firm $i$ and firm $j$ can be described in the following table:

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

Where 1 indicates winning and holding the block, while 0 indicates losing or giving up the bid for that block.

If $i \succ j$, then

(1) $i (1, 1), j (0, 0)$, the consistence of the behavior of experienced company $i$ will be a strong signal of economic benefits, but it also exhibits a relatively high barriers to entry. This will inspire potential bidders to share the opportunity.
(2) \( i(1,0), \ j(0,1) \), the reversed action of experienced early bird \( i \) matters, which send insights that the breakthrough is not as satisfying as a support for continuing investment. However, this also gives new comers \( (k \succ j) \) options to take a seat in this race, the possibility for bidders \( (i \succ k \succ j) \) to suffer winner’s curse would still be high;

(3) \( i(1,0), \ j(0,0) \), 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 enthusiasm will enter into a downward channel with negative expectations.

If \( i \prec j \), then

(1) \( i(1,1), \ j(0,0) \), the reinforcement strategy of inexperienced company \( i \) may be considered as blowing his own horn because the experienced late comer \( j \) take no action. Experienced firm is not involved proving their judgment on the economic feasibility low. So the optimum strategy of inexperienced winners might be “enclosure without exploration”, that is to wait until breakthroughs. If no hard regulation and punishment rules are made for their laziness, then this signal will attract more inexperience speculators to enclose blocks, leading to a speculator-dominated market structure;

(2) \( i(1,0), \ j(0,1) \), in the second round auction, 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;

(3) \( i(1,0), \ j(0,0) \), the same conclusion with the situation when \( i \succ j \).

Based on the analysis above, 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. Discovery in the first phase of exploration will greatly stimulate the enthusiasm of the late entrants, but the capacity of the early entrants will determine the height of barrier to entry for successors: high-competence incumbent determines high barriers to entry, easy to form a centralized market structure; low-competence incumbent determines low barriers to entry, easy to form the relatively decentralized market structure with fierce competition and frequent replacement of the dominator. However, even in the second situation, with increasing expansion and awakening of market participants, bidding results will form a Markov optimization solution, and 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: given loose restriction and supervision, the blocks will
be occupied by speculators for enclosure without exploration, or low-ability bidders gradually withdraw, leaving a few high-competence enterprises to continue mining investment, spontaneously forming a concentrated market structure again.

3 Experience From the Two Auction Rounds for Shale Gas Prospecting Right

Upstream oil-gas industry is currently implementing a tenement-level management, while shale gas has procured in two rounds of bidding as an independent mineral pilot. Chinese government has arranged two rounds of shale gas prospecting right bidding in 2011 and 2012 respectively, motivating more companies to participate and further diversifying investment bodies.

3.1 The 1st round of shale gas prospecting right bidding, 2011

The ministry of land and resources adopted the form of invitation to tender in the first round of shale gas bidding in June 2011. The MLR listed four shale gas blocks for prospecting right bidding and chose six firms to participate. Among them, in addition to the three national state-owned enterprises (SOEs): Petra China, Sinopec and CNOOC, the three local SOEs, there are Shanxi Yancheng, CUCBM and CBM Henan. Neither foreign investment nor private enterprises are invited.

The bidding results is far from satisfying because only two blocks are taken by a branch of Sinopec and CBM Henan. Furthermore, within the 3 years of the validity of the exploration permit, neither company had fulfilled the projected investment or committed drilling workload. In November 2014, the Ministry of Land Resources of China proposed tough punishments for both of them, including paying a fine and subtracting their block area. See the table below.

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

3.2 The 2nd round of shale gas prospecting right bidding, 2012

The MLR took a more open attitude in the second round of auction. 19 blocks were released for tender in September 2012, with bidding open to private enterprises and foreign joint ventures as well as state-owned enterprises. To be eligible for bidding, all companies must have registered capital of at least
300 million RMB, but this is a very low access requirement for shale gas exploration.

14 SOEs got 17 blocks and two private firms got the remaining two blocks. The results broke the old pattern in which the three biggest SOEs carve up the cake. However, 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.

Figure 3: Types and Industry of Winners in the 2nd Bidding Round

Figure 4: Follow-up Movement of Winners after a Half Year

The ultimate conclusion is that all winners are having very slow progress. Since no satisfying achievements after the past two auctions, the projected third auction round has been delayed again. Both BLM and Chinese shale gas investors are haunted by the risks and challenges, including matching between technology and the formation, related land, tax, mining right and financing policies.
<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>China Coal Geological Engineering Corp.</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>China Coal Geological Engineering Corp.</td>
<td>Henan Wenxian</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>China Coal Geological Engineering Corp.</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>Huadian Hubei Power</td>
<td>Hubei Laiyang 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>
4 Evaluation of the Behavior of Bidding Enterprise

Since the MLR adopted the form of invitation to tender in the first round of bidding, the players are limited to experienced major state-owned energy companies, therefore it’s not open tender without barriers to entry. The first round of tender even didn’t disclose the geographic coordinates of the bidding blocks. Some participants complained that the tender documents given by MLR didn’t provide sufficient information of the target blocks, making it difficult for them to judge their economic value. In the case of serious asymmetric information, coupled with inadequate technology and experience in the exploration and development of shale gas, these invited domestic enterprises have to lower their estimate on the rate of successful discovery \( f_i \), thereby reducing valuation for the underlying asset. The lower the valuation, the lower the enthusiasm and the offer will be. In addition, due to a serious asymmetry of information, experienced oil companies can only estimate the value of exploitation of shale gas in accordance with conventional projects, for example, CNPC’s prediction is based on their cost of conventional natural gas, and less the opportunity cost of giving up the current low risk conventional projects to engage in the R&D of shale gas. So even though the objective success rate of experienced enterprise is higher than the inexperienced, experienced firms suffer higher opportunity cost, making their estimated value \( v(\theta^j) \) 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. The practical results of the first round of the tender conform to the conclusion above: the CNPC, the most experienced gas producer in China, didn’t win any block, instead, it is an enterprise engaged in oil and gas downstream business and new market entrants won the bid. Their subsequent underinvestment and punishment is in line with the phenomenon of winner’s curse.

In the second round of shale gas bidding, the MLR relaxed the qualification restrictions trying to lower the threshold to break the dominance of state-owned enterprises in the first round of bidding. With oil and gas or gas mineral survey qualifications 142 enterprises and institutions can participate in the tender. The MLR also provided relatively rich geological data, reduced the information asymmetry problem. However, after the first round of the tender there isn’t any successful discovery \( d(\theta) \neq 1 \), we can’t say \( d(\theta) = 0 \) due to the short interval between the two auction rounds). There is no essential difference in the uncertainties faced by bidders in these two stages. 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. The results of this round turned out to be the same: serious adverse selection making the inexperienced the winner and experienced the loser due to higher opportunity cost and conservative bidding strategy.

If the interval between the two rounds of bidding is long enough, for example the second round arranged at the end of three-year validity the prospecting right of first round’s winner, then the results of forerunners have been revealed, and shale gas industry turns out to be naturally monopolistic because of the characteristics of high-cost, high-risk and slow return on investment. Then the attitude of bidder \( j (j > i) \) to the tender is not affected by the results of the first round, and he will select the bidding
strategy (Normal, Conservative), Inexperienced bidder \( j (j < i) \) will select the bidding strategy (Conservative, Conservative). Therefore, the bidding result is a bleak from the perspective of tenderee (government).

5 Another Example Demonstrating the Importance of Initial Signal

It can be seen from the analysis of three-stage bidding strategy that a successful signal release is the key to motivate others to participate in and form a competitive landscape. It is also revealed by the two rounds of shale gas bidding held by the MLR that the adverse selection problem is very serious after bid opening in the absence of any successful precedent, and the risk to encounter winner's curse will increase. To the contrary, in a major signal under the premise of successful discovery, strong, large and diversified enterprises will constitute the main body of the market.

Another example to demonstrate the importance of initial signal is the experience from the United States. The shale gas boom didn’t take off until the firm Mitchell Energy firstly announced its breakthroughs to commercialize the exploration and development of shale gas in the Barnett play of East Texas, which happens around the year 2000. Statistical analysis shows that before the year 2000, it’s Mitchell Energy who drilled the overwhelming majority of the shale gas wells in the Barnett play until the late 1990s. By 1999, Mitchell Energy had drilled a total of 482 Barnett wells, and its 15 competitors together drilled only 102. The disparity is even more pronounced from 1981 through 1995, when Mitchell Energy drilled 264 Barnett wells, and its 8 competitors drilled merely 20. After Mitchell Energy achieved a major breakthrough in hydraulic fracking, it was acquires by Devon Energy, one of the largest natural gas producers in the United States, then the industry realized the great economic potential of shale gas investment (Wang and Krupnick, 2013). The number of wells drilled per year increased from 193 in 2000 to a peak of 6962 in 2011, and then decreased to 5365 in 2012. The number of active firms increased from 15 in 2000 to a peak of 248 in 2008, and then decreased to 162 in 2012. Of the 677 firms that drilled wells in the major six modern shale gas plays, nearly 34 percent drilled a single well, and 27 percent drilled only 2 to 5 wells. These infrequent drillers drilled 799 wells in total, about 2 percent of the 39589 wells drilled in the six modern plays. In contrast, the four most active firms (Chesapeake Energy, Devon Energy, XTO Energy, and Southwestern Energy) together drilled 15,589 wells, or 39 percent of the total. The top 30 firms drilled 30,311 wells, or 77 percent of the total. Of these 30 top drillers, 27 are independent oil and gas exploration and production companies and only 2 (SWEPI LP, a subsidiary of Shell, and Chevron) are integrated oil and gas companies.

Based on the retrospect of how shale gas industry was born in America, it can be conclude that few firms participated in the game before the first great positive signal despite it’s a complete and fully competitive market. After 2000, news spread like wildfire, attracting companies, small and large, to take an active part in, and finally forming a competitive but centralized market structure.

6 Conclusions and Suggestions

This paper conducts a statistical analysis on the current market structure of China’s shale gas drilling and the results of two rounds of shale gas bidding for prospecting right. It develops a three-stage common value auction model to explain the results of past two rounds of mineral right auctions and the stagnancy of the yet-to-come third auction projected by MLR. Conclusions are draw from the statistical analysis and modelling results:
First, it shows that the current shale gas development in the most geologically favorable areas is led by Sinopec and the CNPC, two of China's large national oil companies. China's shale gas industry is dominated by these two majors, controlling about 70% of China's total gas assets, both conventional and unconventional, and accounting for nearly all shale gas initiatives. This oligopolistic market structure can’t guarantee a quick increase in natural gas production or the nation’s objective to optimize its energy utilization structure.

Second, it is confirmed by the results of two rounds of shale gas bidding that serious adverse selection problem exists after bid opening in the absence of any successful precedent. To the contrary, the quick expansion of shale gas drilling in the United States can be an evidence to support that a release of successful signal is the key to motivate others to participate and form a competitive landscape.

Third, the market structure has a close relationship with mining right management. The number of market players and the types of participants depend on the findings in previous stages and the type and behavior of the incumbents. In the first scenario, discovery in the first phase of exploration will greatly stimulate the enthusiasm of the new entrants. High-competence incumbent determines high barriers to entry, easy to form a centralized market structure, while low-competence incumbent determines low barriers to entry, easy to form a relatively decentralized market structure with fierce competition and frequent replacement of the dominator. To the contrary, in the second scenario, it will make the late comers more cautious and more conservative if no findings happen in the initial stage and competent bidders take no action, leading to a market structure with speculators for enclosure without exploration, low-ability bidders gradually withdrawing, and few high-competence enterprises continuing investment.

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. The importance of initial positive signals for shale gas industry has been clearly demonstrated by both the current stagnancy in China and breakthroughs in the United States. Shale gas drilling in China encounters more complex geological problems and requires higher development cost, which set the entry level several times higher than that in the United States. Since last year, the objective to commercialize shale gas development has come to a bottleneck as oil price crashing down. Demonstration plots are set up as pioneers’ business incubator for technological innovations, which should contribute to lowing cost and undermines the uncertainties. Thus, government should reinforce their support in these plots. Measures include continuous subsidy, tax reduction and fund for R&D programs, geological information sharing and compensable transfer of know-how and critical techniques.

2. Accelerate the transfer of mineral rights to promote the quality of bidding asset. In our auction model, the quality of underlying block is a key factor for accurate valuation. The reasons for which these new participants have little progress are manifold. Besides from a lack of expertise or funding, the poor condition of the blocks sold by MLR is major obstacle. Current shale gas exploration and development largely overlapes with areas where CNPC and Sinopec hold conventional oil and gas rights, making it very difficult for new comers to enter the race (Chou, 2013). According to an energy consulting firm in China, before the issue of overlapping rights being settled down, only 23% of the non-overlapping blocks are available for state-run and affiliated with big utilities and coal miners and even private firms to conduct shale gas exploration and development.1 Therefore, although Chinese regulators have taken some steps to allow more companies into the field, opening bidding for prospecting rights to small

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private companies, the new policy only attracts groups of speculators, who sit on the land rights in hopes of technology innovation breakthrough and another buyer would come along. With the conflict between stable land and mineral right regime and increasing demand for breakthrough in shale gas development, government should push the state-owned oil companies to exploit shale gas resources or compulsory withdrawal the vacant blocks.

(3) Disclose detailed information on bidding asset to reduce winner’s curse. Tenders will estimate how much to offer on the basis of obtained information. Information asymmetry is the main reason for winner’s curse especially of those inexperienced firms. Under the effort of enterprises and scientific institutions, in the past year, China has continuously gained breakthroughs in shale gas geophysics, well drilling, well completion and fracturing reformation in these areas, but most of these innovations are confidential. If the government is urgent to form a market with large number of entities, a premise for this is to build up a dataset directly matched with the management of mining right. Establish a mechanism for the collection, processing and storage of shale gas dataset, and accelerate the digitization of the shale gas data to form a fair platform to publish and share, thus effectively implement the opening policy of auction on shale gas mining right.

(4) Bundle cooperation agreement on prospecting between the government and the bid winners. This measure aims to provide inexperienced entrants with valuable expertise that can be applied to its own exploration and production, helping to lower well exploration costs. Due to shale gas investment involved with large volume of capital investment and long period of cost recovery, the risk is unbearable for the inexperienced pioneers. Since QE and VC are not well developed in China, the government shall play the role of risk taker in this game. Like the jointly launched Eastern shale gas projects in 1970s and 1980s by the Department of Energy of the United States and Natural gas Research Institute, the government took part in geological data analysis, evaluation and disclosure the proved reserve of shale gas blocks, and provided technical support for the research and development of shale gas exploration, reducing the risk of subsequent entrants through providing sufficient information.

(5) Firmly implement supervision while lowering barriers to entry. Although the MLR proposed punishments for winners in the first round of shale gas auction, the fine is less than 1/20 of the unfinished investment that was committed in the contract. Absence of strict regulation and tough punishment leaves room for speculation. The government needs to change the way they regulate both during and after the bidding, and build a system of rules by the law.

REFERENCE