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Original Article

Bargaining strategy of oil companies in international oil and gas development Projects—Based on a bilateral bargaining model

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ABSTRACT

Bargaining between the host country and oil companies is very common to international oil and gas development projects. The existence of information asymmetry gives the host country an endogenous bargaining advantage. Foreign oil companies might change their unfavorable negotiating position by changing the order of bidding and adjusting bidding strategies. This paper introduces both factors into a bilateral bargaining model to study the impact of information asymmetry and bidding order on the strategy and equilibrium returns of oil companies. According to the ownership of the right to bid first, two scenarios are designed for the model to compare the equilibrium returns of the host country and oil companies. The results show that: 1) There is a first-mover advantage in the process of bilateral bidding, so oil companies better bid first; 2) The information asymmetry will lead to a higher nominal income ratio of oil companies and a lower nominal income ratio of the host country, but it doesn't affect the total income ratio at all.

1. Introduction

Accounting for over 57% of global primary energy consumption, oil and gas are widely used as fuel or feedstock in human society (BP, 2019). However, countries with large oil and gas reserves often cannot finish the development of reserves independently, which allows foreign oil companies to take part (Hu, 2014). Because of a variety of uncertainties such as geopolitical turbulence, policy change, and price fluctuation, international cooperation on upstream oil and gas projects may face multiple risks (Wang et al., 2006; Cheng et al., 2017, 2019). As a result, it is difficult to deal with the local government of resource countries as a foreign company, and the results of original strategies are hard to predict.

The bilateral bargaining mechanism is widely used in international oil and gas development projects, especially when the host country has to seek external capital and technology to develop domestic oil and gas resources. The mechanism also allows both the host country and oil companies to accept or reject each other's proposals during the negotiation because both buyer and seller have certain bargaining power. To maximize the income of a project, the oil companies must strive for a favorable contract through negotiation. Simultaneously, the host country has a motivation to give some concessions at the initial stage of the talks to disperse the potential underground risk and above-ground risk.

Before the bilateral negotiation gets started, the oil companies focus on three fundamental questions. First, what kind of strategy should be taken to reach an agreement with a minimum negotiation cost? Second, what's the impact of the host country's information advantage on their income since the host country is the player and the resource owner? Third, what's the effect of a bidding order on their income within a bilateral bargaining mechanism? This paper tries to answer the above three questions and builds a bilateral bargaining model considering information superiority to study the impact of bidding order and information asymmetry on the equilibrium income of the oil companies in an international oil and gas development project.

Current research often measures players' bargaining power based on bargaining theory when studying stakeholders' behaviors in international oil and gas cooperation. Nagayama and Horita (2014) introduced bargaining power into a network game to analyze the influences of Russia, Ukraine, Belarus, and Western Europe on pipeline gas trade between Russia and Western Europe. Cobanli (2014) introduced bargaining power into a cooperative game model to analyze the relationship between Europe and China

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in the natural gas trade in Central Asia and concluded that there is no conflict of interest between the two players. Osmundsen et al. (2015) used bargaining power to describe the relationship among drilling cost, oil price, rig utilization, contract duration, and many other indicators related to drilling activities of the jack-up platform in the Gulf of Mexico. Vivoda (2009) found that many factors will affect the bargaining power of oil companies and governments in international oil and gas cooperation, such as the resource endowment of the host country and financial strength of the oil company. Stulberg (2012) discussed how oil-producing countries, consumer countries and transit countries bargained to reach the agreement on the Eurasian pipeline through political games. Malin and DeMaster (2016) analyzed the game between Pennsylvania farmers and shale gas producers. They found that the Pennsylvania farmers who have long relied on the shale gas industry are losing their bargaining power in the game, and are getting much more challenging to protect their land use rights as well as the environment. Motomura (2014) studied the positive impact of importing oil and gas from Russia on Japan. He said that importing oil and gas from Russia will help improve Japan's bargaining power in oil and gas trade with suppliers from the Middle East. Vatansever (2017) analyzed the bargaining strategy of Russia when the oil and gas export surplus weaken its bargaining power.

Bargaining theory is also used in the game analysis to investigate the interaction among players. Menegaki (2011) used Muthoo's bargaining model to analyze the game among Bulgaria, Greece, and Turkey over the construction of the Burgas-Alexandroupolis pipeline. Okullo and Reynès (2016) used the bargaining model to find the optimal production strategy of each OPEC member under the scenarios of monopoly, imperfect cartel, or perfect cartel. They also found that OPEC members' strategies were more in line with an imperfect cartel. Nordal (2002) used a bargaining model to find that the intertemporal government default may not hinder foreign direct investment since both investors and the government can profit from short-term agreements. Omonbude (2007) used the bargaining theory to analyze the operation of cross-border pipelines and proved that the motivation of pipeline construction is essential to prevent the risk of pipeline interruption. Due to the uncertainties in the oil and gas industry, Castillo and Dorao (2013) designed a game model for oil companies to make better investment decisions of oil and gas projects. Vivoda (2011) established a game model to study the dynamic bargaining between the host country and foreign oil companies. Anandalingam (1987) studied how to better allocate the profit between the host country and foreign companies under the framework of the product-sharing contract system. Hosman (2009) applied Moran's dynamic bargaining theory to explore the bargaining process between international oil companies and host countries. Wilson (2015) added political variables into the bargaining models when analyzing the formation of resource nationalism. Based on the theory of power reliance, Müllner and Puck (2018) established a bargaining framework to analyze the interaction between international oil companies and the host country, while Orazgaliyev (2018) discussed the same topic based on Obsolescing Bargain Model proposed by Raymond Vernon.

As shown above, bargaining power is a fundamental parameter in the bargaining model, but few works of literature embed it in the bargaining process and quantitatively analyze it in depth. The application of bargaining theory in literature is mainly qualitative, thus makes limited contributions to the study of international oil and gas development cooperation. Indeed, a vast information advantage attaches to the host government because of its dual identities of the game player and resource owner, making it easier for the host country to occupy excess return over foreign oil companies. It's worth examining how the information asymmetry affects both parties' bargaining power and calculating the specific equilibrium income-sharing results in the game.

This paper uses the bargaining theory to study the negotiation problem between the host country and oil companies in an oil and gas development project. It contributes to introducing two indicators, the transfer rate of return and the probability of oil company agreeing to transfer its return, to measure the degree of bargaining power of the host country in the bargaining game model. Both the transfer rate and the consenting probability vary along with the evolution of exploration and development. To make it simpler, we focus our attention on the initial oil and gas negotiation stage. During this stage, the oil company has just completed the target project's feasibility study and considers whether to take the project. It should be pointed out that, when the bidding order of the bargaining is changed, the results of the negotiation might be different. Therefore, this paper also discusses the influence of the bidding order on the share of the equilibrium return of each player through scenario analysis.

2. Methodology

2.1. Bilateral bargaining game model

Bilateral bargaining, which refers to the negotiation about the allocation of future income between the resource owners and the potential investors, is widespread in international oil and gas development cooperation. The most typical bilateral bidding model is the cake-cutting game model: A and B claim the proportion of cake they want to get, θ_A and θ_B, at the same time. When $\theta_A+\theta_B = 1$, both A and B can get their parts of the cake as they expected. While if $\theta_A+\theta_B > 1$, neither A nor B could get any piece of the cake. In a single-round game, a series of Nash equilibrium solutions are available by fulfilling $\theta_A+\theta_B = 1$. However, repeated cake-cutting games will cause the clustering phenomenon (that is, the previous game's results will affect the current game), and the clustering solution will become the only Nash equilibrium solution. When considering the bidding order, the cake-cutting game transforms into the ultimatum game where the first-mover advantage exists. In an ultimatum game, assuming that A acts first, A will hope to get the whole cake, and the equilibrium solution can only be (1, 0). However, this is a weak equilibrium because if B decides to retaliate against A by demanding a share (θ_B) greater than zero, none of them will get any piece of the cake. To achieve general equilibrium, A should suggest a lower proportion θ_A to ensure that the utility of B equals the utility A loses.

Based on the ultimatum game model, a finite alternating-offer bargaining game model for oil and gas cooperation can be built with a discount rate to measure the decay of bargaining power over time. Since the host country is both a player and a supervisor, it has more information than oil companies. The information superiority gives the host country advantages against the oil companies in the negotiation process, and will also have a certain impact on the negotiation results. Therefore, special attention should be paid to the influences of information asymmetry, especially when the oil companies have an option to decide the bidding order of the bilateral bargaining game.

2.2. Scenario settings and behavior analysis

To analyze the influence of bidding order on the balanced income ratio of oil and gas cooperation, we design two scenarios. In scenario 1, the host country is allowed to bid first, while in scenario 2, oil companies are allowed to bid first. In each scenario, this paper analyzes the influences of relative information advantage on the game and finds the optimal strategy of oil companies under

information asymmetry.

Under the bilateral bargaining mechanism, two parties in the oil and gas cooperation game hold different objectives: the host country expects oil and gas resources to be fully developed to maximize their government take while oil companies aim to maximize their net interests. The allocation of incomes principally depends on the power of the two sides. The government of the host country is generally more dominant than the oil companies and tends to get as much profit as possible. However, an allocation beneficial to the host country might be inefficient since the enthusiasm of oil companies will be severely cracked down. In that case, the development cost may be higher and moral hazard can be triggered. Therefore, it is necessary to optimize the allocation of project benefits to avoid the hindrance of oil companies. A reasonable allocation typically has two key features: 1) the possibility of conflict between the two sides can be minimized. 2) it can ensure that the players are prudent in behavior, and it is more likely for the projects to go well with the support of every stakeholder.

A reasonable and fair allocation fully reflecting the relative superiority of the players could raise the attractiveness of the project. According to the principles of incomplete information games, however, neither participant is willing to take the lead in reducing the proportion of the gain. In this paper, the bilateral bidding theory is used to build a benchmark model and find the equilibrium solution of the profit allocation.

3. The bilateral bargaining model

3.1. Model assumptions

(1) Assumption 1: Rational Person

The hypothesis of rational person assumes that the players' behaviors are rational when conducting the bilateral bargaining process, that is, the participants have sufficient knowledge about their interests and can design optimal strategies for their objective of interests' maximization. Under such an assumption, the participants' behaviors and decisions aim to maximize their own interests rather than maximize the gain of the project. Based on this assumption, participants may seek the best strategy to achieve their goals. This hypothesis also implies that both parties expect to reach an agreement within a reasonable time.

As for the model in this section, it is assumed that in the process of bilateral bidding, the host country and oil companies all aim at maximizing their profits, and the government of the host country always tries to improve the project's efficiency and reduce total cost in the negotiation. Ultimately, the two sides can reach an agreement in an equilibrium state.

(2) Assumption 2: Asymmetric Information

In the process of a bidding game, information is an important factor influencing the players' income. Players in the bidding game are impossible to fully aware of the information and strategies of each other, but they can use subjective probability distribution to forecast the possible strategies used by their counterparties. This assumption allows the players to formulate their strategies and make adjustments by observing the reactions of their opponents. In the bidding game, players with information advantage will hold a favorable position.

For an oil and gas cooperation project, the government of the host country has the power to set fiscal policies, contract terms, and other related regulations. In the process of bargaining, the host country has the motivation to hide information and protect its interest, which leads to information asymmetry. Compared with oil companies, the host country has more information advantages in the negotiation process and can force the oil companies to lower their profit expectations.

Many factors, such as the underground risk and above-ground risk, will change the degree of information advantage, which means the information advantage parameter shall not be a constant. Therefore, assume that the government of the host country forces oil companies to cede a certain share of interests because of information superiority, the share is represented by α, $\alpha \in [0,1]$, it means that the host country is unable to force the oil companies to cede any share, and if $\alpha = 1$, it means that the host country can completely dominate the game and obtain 100% interest in the projects.

(3) Assumption 3: Income Allocation

In each round of a bilateral bargaining game, one player puts forward a favored allocation first, and then the other one decides to accept or reject it. When the two sides agree on the income allocation, the bargaining then comes to an end followed by an equilibrium solution. If k is the income ratio that the host country claims, then the ratio that oil companies can share is $1- k$. The negotiation between the two parties centers around the determination of the k.

(4) Assumption 4: Discount Rate

Negotiations often take a long time, thus the time value should be considered. The longer the negotiation lasts, the higher the cost will be. The intention of the players to cooperate will also be weakened as time goes by. Even an agreement is reached, the negotiating costs can be much higher than expected at last. All the players will share the costs, and the net income will also be reduced. Therefore, most players expect to reach an agreement as soon as possible.

Fishburn and Rubinstein (1982) proposed to use discount rates to describe the players' eagerness to reach an agreement. In this paper, the discount rates of the host countries and companies are represented as r_n and r_o respectively, and the income ratios of the host country and oil companies in the first round of negotiation can be described as N_1 and O_1. In the second round, the expected income ratios of the two sides are r_nN_1 and r_oO_1 respectively.

3.2. Model designation

According to Rubinstein (1982), the player who moves first has a relative advantage in a typical bargaining model. However, Whalen (1966) holds that both the first mover and the second mover can have certain advantages, namely the first-mover advantage and second-mover advantage. When the players are extremely patient ($r_n = r_o = 1$), the second-mover advantage is predominant because the second mover could reject any proposal from the other side until all the benefits are obtained. Although researchers hold different opinions about this, it can be seen that the move sequence does have impacts on players' benefits. Therefore, this paper sets two scenarios in which the host country and the oil companies bid first respectively.

(1) Scenario 1

The bilateral bargaining process of scenario 1 is shown in Fig. 1.

In the first bidding round of Scenario 1, the host country takes the lead in proposing its expected income ratio k_1. Accordingly, the expected income ratio of oil companies is $1-k_1$. Meanwhile, due to the information superiority of the host country, oil companies are

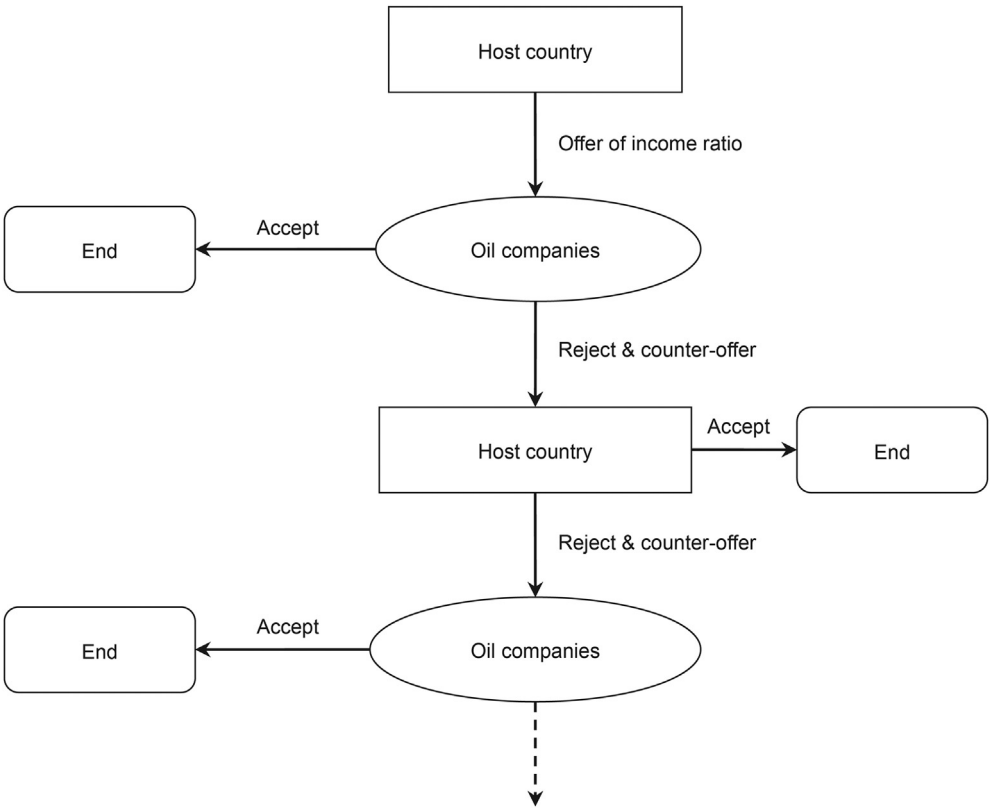

Fig. 1. The bargaining process of scenario 1.

forced to transfer α_1 of income to the host government additionally. Assume that p represents the probability that oil companies agree to transfer. After the host country makes an offer, the companies could accept it and end the bargaining process; but once they reject the offer and suggest a counter-bid, the negotiation will come to the second round, and both parties will suffer additional negotiating costs.

In the second round of bargaining, oil companies offer a counter-bid and their expected income ratio is $1-k_2$, then the host country has to decide whether to accept the offer or not. Similar to the condition of the first round, the host country expects to gain an extra income proportion of α_2 and the probability of getting extra income is p. If the host country accepts the counter-bid, the game will be finished. Otherwise, the host country will make a counter-bid again and come to the third round. The third round of bid and the subsequent bidding rounds are similar. Only when the two parties reach an agreement in terms of income allocation will the bilateral bargaining process end. The expected income of the host country and oil companies in the ith round of bidding can be described as N_i and O_i, the income ratio of each round is shown in Table 1.

The equilibrium solutions can be found by maximizing the expected income of both sides of the game. Following Shaked and Sutton's (1984) methodology in the research of the finite-round bilateral bargaining game, the counterpoint is set in the third round. In the second round, if the offer from oil companies makes $N_2 < N_3$, then the host country will reject it and start the third round, thus the negotiation cost will be raised. To avoid this, the offer of oil companies should meet two conditions: 1) O_2 is higher than O_1, i.e. $O_1 \leq O_2$; 2) the host country's income won't be lower, i.e. $N_2 \geq N_3$. Therefore, the optimal strategy in the second round only exists when $N_2 = N_3$.. In this case,

$$r_n p(k_2+\alpha_2) + r_n(1-p)k_2 = r_n^2 p(k_3+\alpha_3) + r_n^2(1-p)k_3 \quad (1)$$

Thus,

$$k_2 = r_n k_3 - p\alpha_2 + r_n p\alpha_3 \quad (2)$$

The expected income of oil companies in the second and third round are shown as follows respectively:

$$O_2 = r_0(1 - r_n k_3 - r_n p\alpha_3) \quad (3)$$

$$O_3 = r_0^2(1-k_3) - r_0^2 p\alpha_3 \quad (4)$$

Where $0 < r_n < r_0 < 1$, $0 \leq \alpha_3 \leq k_3 \leq 1$, $0 \leq p \leq 1$.

Table 1
The expected incomes of the host country and oil companies in scenario 1.

rounds	Host country	Oil companies
1	$N_1 = p(k_1+\alpha_1) + (1-p)k_1$	$O_1 = p(1-k_1-\alpha_1) + (1-p)(1-k_1)$
2	$N_2 = r_n p(k_2+\alpha_2) + r_n(1-p)k_2$	$O_2 = r_0 p(1-k_2-\alpha_2) + r_0(1-p)(1-k_2)$
3	$N_3 = r_n^2 p(k_3+\alpha_3) + r_n^2(1-p)k_3$	$O_3 = r_0^2 p(1-k_3-\alpha_3) + r_0^2(1-p)(1-k_3)$

It can be seen that $O_2 > O_3$, which means that oil companies' expected income in the second round is higher than that of the third round. As a result, the bargaining game will be halted in the second round.

If the offer of the host country in the first round makes $O_1 < O_2$, then the oil companies will reject it and make a counter-offer. Therefore, when the host country bids, it should not only maximize its own profits but also consider conditions acceptable to oil companies. That is to say, it needs to make $O_1 = O_2$.

$$p(1-k_1-\alpha_1)+(1-p)(1-k_1)=r_0p(1-k_2-\alpha_2)+r_0(1-p)(1-k_2) \quad (5)$$

Thus,

$$k_1=1-p\alpha_1-r_0(1-r_nk_3-r_np\alpha_3) \quad (6)$$

In a finite-round bidding game, no matter the counterpoint is set in the first round or the third round, the consequences of the game are the same, which is

$$k_1=k_3 \quad (7)$$

By combining formula (6) and (7) the model can be solved as follows:

$$k=(1-r_0)/(1-r_0r_n)-p\alpha \quad (8)$$

$$1-k=(r_0-r_0r_n)/(1-r_0r_n)+p\alpha \quad (9)$$

Where k and $1-k$ are the income ratios of the host country and oil companies respectively. The consequences above are the nominal income proportions which contain no additionally transferred income. Since the host country has more advantages, the oil companies have to transfer the income additionally equals to $p\alpha$ to the host country. Therefore, the real income proportions of host country and oil companies are $(1-r_0)/(1-r_0r_n)$ and $(r_0-r_0r_n)/(1-r_0r_n)$ respectively.

(2) Scenario 2

In the first round of Scenario 2 (see Fig. 2), the oil companies take the lead in proposing the expected income ratio k_1, thus the income ratio of the host country is $1-k_1$. Due to the host countries' advantages, the oil companies are forced to transfer a proportion α_1 of its income additionally, and p represents the possibility that the oil companies agree to transfer. After the oil companies make a bid, the host country can accept it and end the bargain, or bring the negotiation to the second round by rejecting it with a counter-offer.

In the second round, the host country offers a counter-bid of $1-k_2$. Then the oil companies have to decide whether to accept the bid or not. Similar to the first round, the oil companies may additionally transfer an income of α_2 with the probability of p. If the oil companies accept the counter-offer, then the negotiation will come to an end. Otherwise, it rolls to the third round. The bargaining process in the third round is also similar to the former rounds. Only when the two sides reach an agreement on income allocation will the bilateral bargaining process ends. If we assume that N_i and O_i are the expected income of the host country and oil companies in the ith round, then the income allocation of the first three rounds can be shown in Table 2 below.

According to the equilibrium results, it can be seen that O_2 always equals O_3 wherever the counterpoint is set in the first or the third round.

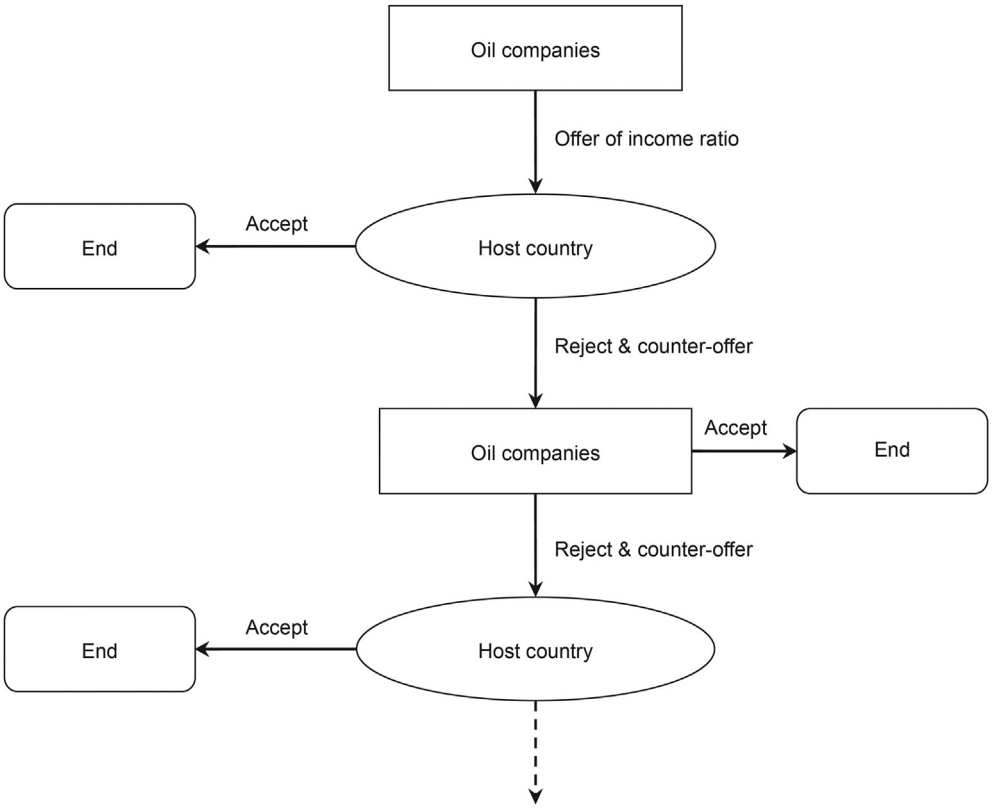

Fig. 2. The bargaining process of scenario 2.

Table 2
The expected incomes of the host country and oil companies in scenario 2.

rounds	Host country	Oil companies
1	$N_1 = p(1-k_1+\alpha_1)+(1-p)(1-k_1)$	$O_1 = p(k_1-\alpha_1)+(1-p)k_1$
2	$N_2 = r_n p(1-k_2+\alpha_2)+r_n(1-p)(1-k_2)$	$O_2 = r_0 p(k_2-\alpha_2)+r_0(1-p)k_2$
3	$N_3 = r_n^2 p(1-k_3+\alpha_3)+r_n^2(1-p)(1-k_3)$	$O_3 = r_0^2 p(k_3-\alpha_3)+r_0^2(1-p)(1-k_3)k_3$

$$r_0 p(k_2-\alpha_2)+r_0(1-p)k_2 = r_0^2 p(k_3-\alpha_3)+r_0^2(1-p)k_3 \quad (10)$$

Thus,

$$k_2 = r_0 k_3 + p\alpha_2 - r_0 p\alpha_3 \quad (11)$$

N_2 and N_3 are as follows:

$$N_2 = r_n(1-r_0 k_3 + r_0 p\alpha_3) \quad (12)$$

$$N_3 = r_n^2(1-k_3+p\alpha_3) \quad (13)$$

Since $0 < r_n < r_0 < 1$, $0 = \alpha_3 \le k_3 \le 1$, and $0 \le p \le 1$, it can be derived that $N_2 > N_3$, which means the negotiation won't go to the third round.

When bidding in the first round, the oil companies will aim to increase their income and try to take the interests of the host country into account as well, which means N_1 needs to equal N_2. That is,

$$p(1-k_1+\alpha_1)+(1-p)(1-k_1) = r_n p(1-k_2+\alpha_2) + r_n(1-p)(1-k_2) \quad (14)$$

Thus,

$$k_1 = 1 + p\alpha_1 - r_n(1-r_0 k_3 + r_0 p\alpha_3) \quad (15)$$

In the finite-round game, the results are the same regardless that the counterpoint is in the first or third round. Thus,

$$k_1 = k_3 \quad (16)$$

The game model can be solved as follows by combining the equation of (15) and (16):

$$k = (1-r_n)/(1-r_0 r_n) + p\alpha \quad (17)$$

$$1-k = (r_n - r_0 r_n)/(1-r_0 r_n) - p\alpha \quad (18)$$

In the above two equations, k and $1-k$ are the income ratios of the oil companies and the host country respectively.

The solutions above are nominal income ratios, and the advantages of the host country could make the oil companies additionally transfer income $p\alpha$ to the host country. Therefore, the real income ratios of the host country and oil companies are $(r_n - r_0 r_n)/(1-r_0 r_n)$ and $(1-r_n)/(1-r_0 r_n)$ respectively.

The equilibrium income ratios of the bilateral bargaining game model in scenario 1 and scenario 2 are shown in Table 3. The factors related to the income ratios of the two players include the discount rate, the probability that the oil companies agree to transfer additionally, and the additional share to transfer. Among the three factors, the latter two are influenced by the degree of information asymmetry. Therefore, the final income ratios are affected by the degree of information asymmetry and discount rate.

4. Results and analysis

In the bilateral bidding game, the income ratios of the host country and oil companies are affected by the discount rate r_o *and* r_n, the income transfer ratio (α), and the probability to agree to the transfer (p). The above four parameters need to be estimated before calculating the income ratios of both sides. To illustrate, we assume that $r_n = 0.82$, $r_0 = 0.86$, $\alpha = 11\%$, $p = 70\%$, the results of the two scenarios are shown below.

(1) Scenario 1

The nominal income ratio of the host country is k=(1–0.86)/(1–0.86 × 0.82)–0.7 × 0.11 = 39.79% and that of oil companies is $1-k = 60.21\%$. By adding the transferred proportion, their real total income ratios change to k+0.7 × 0.11 = 47.49% and $1-k$–0.7 × 0.11 = 52.51% respectively. The real income transfer ratio is 7.7%.

(2) Scenario 2

In this scenario, the nominal income ratios of the host country and oil companies are k=(0.82–0.86 × 0.82)/(1–0.86 × 0.82)–0.7 × 0.11 = 31.24% and $1-k = 68.76\%$, while the real income ratios of host country and oil companies are $k + 0.7 \times 0.11 = 38.94\%$ and $1-k$–0.7 × 0.11 = 61.06%, respectively. The real income transfer ratio is 7.7%, the same as that of Scenario 1.

It can be seen that both the income transfer ratio and the possibility of agreeing on the transfer are affected by information asymmetry, which can be used to measure the degree of information asymmetry. The discount rates mainly depend on their desire to make a deal and are not directly influenced by the degree of information asymmetry. Therefore, we can classify the factors affecting income ratios into two categories according to whether they are related to information asymmetry. In the next part, we will further discuss the relations between the income ratio and its determinants.

Table 3
The expected incomes of the host country and oil companies.

scenario	Host country		Oil companies	
	Nominal proportion	Real proportion	Nominal proportion	Real proportion
1	$(1-r_0)/(1-r_0 r_n) - p\alpha$	$(1-r_0)/(1-r_0 r_n)$	$(r_0 - r_0 r_n)/(1-r_0 r_n) + p\alpha$	$(r_0 - r_0 r_n)/(1-r_0 r_n)$
2	$(r_n - r_0 r_n)/(1-r_0 r_n) - p\alpha$	$(r_n - r_0 r_n)/(1-r_0 r_n)$	$(1-r_n)/(1-r_0 r_n) + p\alpha$	$(1-r_n)/(1-r_0 r_n)$

Note: In this paper, the nominal proportion refers to the direct quotation in the process of bilateral bidding. After the bidding, oil companies will additionally transfer a total income of pα to the host country, so the real proportion of the host country in the whole oil and gas cooperation process equals the nominal income plus extra transfer income.

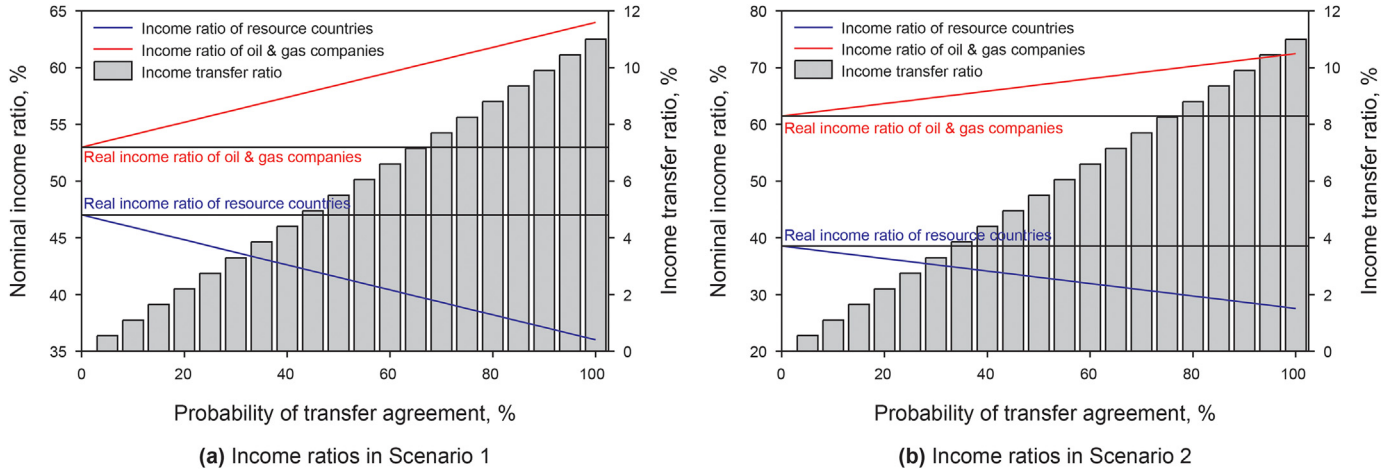

Fig. 3. The relation between income ratio and the probability of agreeing to transfer.

4.1. The impact of information asymmetry on income ratios

As shown in Table 3, α and p significantly impact the nominal income ratio but do not affect the real income ratio. Numerical analysis is adopted to study the influence of α and p on income ratio in a more intuitive way, and two conclusions can be drawn as follows:

(1) As the degree of information asymmetry increases, the host country's nominal income ratio decreases while that of the oil companies increases. However, the asymmetric information does not affect the real total income ratios of both parties.

The probability of agreeing on the transfer is used to illuminate the impact of information asymmetry on income ratios. As information asymmetry increases, the relative information advantage of the host country is growing, which increases the probability for oil companies to agree to transfer. As shown in Fig. 3a–b, in both scenarios, the increase of transfer probability leads to the decrease of the host country's nominal income proportion and the rise in oil companies' nominal income proportion as well. However, the total income proportions of the host country and oil companies are not affected by the probability at all.

A similar conclusion can be drawn by analyzing the income transfer ratio. As discussed above, there is a remarkable negative correlation between the information asymmetry degree and the nominal income ratio of the host country. When it comes to the oil companies, however, the correlation is positive.

Unlike the nominal income ratios of the two parties, the real total income ratios are irrelevant to the degree of information asymmetry. Before the bilateral bargaining, the host country and oil companies have to determine the bottom line of their income proportions. Once any of them receives a bid lower than the bottom line, the offer will be rejected, and the negotiation either moves on with the proposal of a new bid or is terminated with no deals. Therefore, it is the lowest income proportion of each side, not the degree of information asymmetry, that determines the real income ratios. However, as the degree of information asymmetry increases, the oil companies will realize that they might be compelled to transfer more incomes to the host country. As a result, the oil companies will raise their claims on the nominal income proportion. Meanwhile, being sure of their ability to force oil companies to transfer more incomes, the host country will not ask for an increase in its nominal income proportion. Instead, it reduces the expectation of its nominal income proportion to secure the deal.

(2) The income transfer ratio and the probability of agreeing to the transfer have similar influences on the nominal income ratio.

As discussed above, both the income transfer ratio and the probability of agreeing on the transfer significantly influence the nominal income ratio. To compare their influences, we take the nominal income ratio of oil companies in Scenario 1 as an example. The results of sensitivity analysis are shown in Fig. 4. It can be seen from Fig. 4 that the curved surface is a diagonally symmetric figure relative to the cuboid, indicating that the income transfer ratio and the probability to agree on the transfer has an equivalent impact on the nominal income ratio. As shown in Table 3, the income transfer ratio and the probability of agreeing on the transfer are in the same linear relation with nominal income, so they have a symmetrical influence on the nominal income ratio. Besides, their value ranges are both [0,1], which can explain why the nominal income surface is a diagonally symmetric figure relative to the cuboid.

4.2. The factors affecting oil companies' real income

(1) The real income proportion of oil companies positively correlates with the discount rate of oil companies and negatively correlates with that of the host country.

It can be seen in Table 3 that the real income proportion of oil companies is decided by discount rates of both the host country (r_n) and oil companies (r_0). As shown in Fig. 5, the real income proportion of oil companies changes as r_n and r_0 fluctuate. The sensitivity analysis indicates that the real income proportion of oil companies is negatively related to r_n but positively related to r_0. Indeed, r_n and r_0 are relevant to the patience of the host country and oil companies, suggesting that the higher value of r, the more patient the participants are. With a higher r_0, the oil companies are more patient, while the host country will become impatient and wish to reach an agreement as soon as possible. In this case, the oil companies can obtain more real incomes. On the contrary, the host country is more patient with a higher r_n, and it is time for oil companies to become impatient and lose part of their real incomes. Apart from this, if the fluctuation ranges of r_0 and r_n are the same, the influence of r_0 on the real income proportion of oil companies is greater than that of r_n on the host country. This is because any change of r_0 can directly affect the expected income of oil companies while it usually needs a game for r_n to have effects on oil companies, while the game process could weaken its effects.

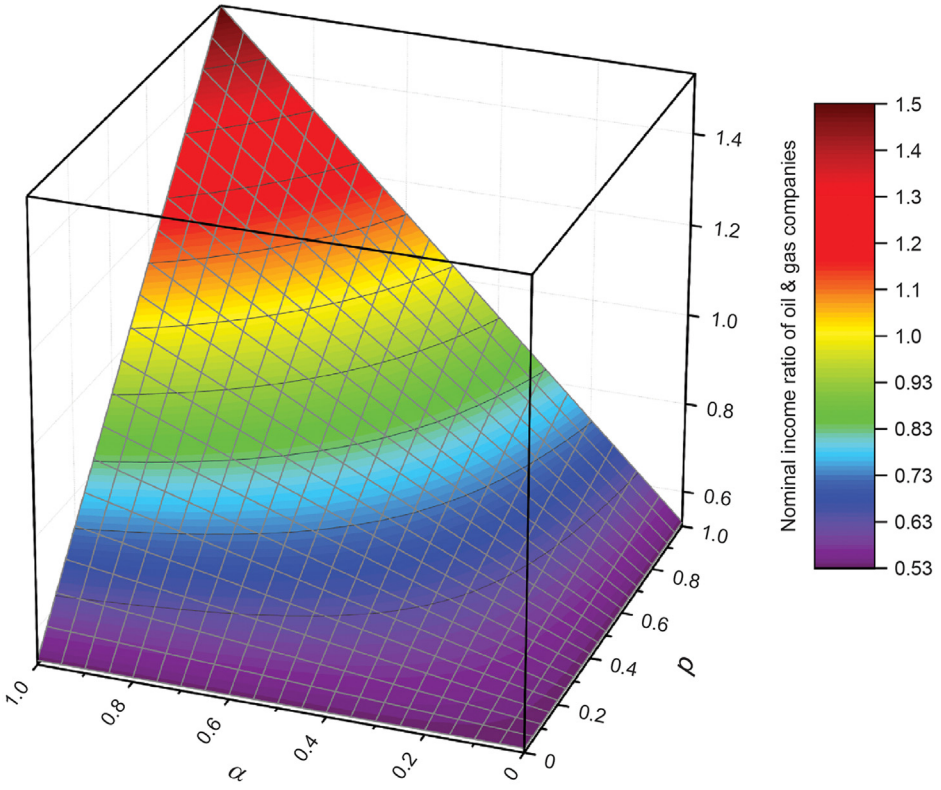

Fig. 4. Sensitivity analysis of α and p on the nominal income ratio of oil companies in Scenario 1.

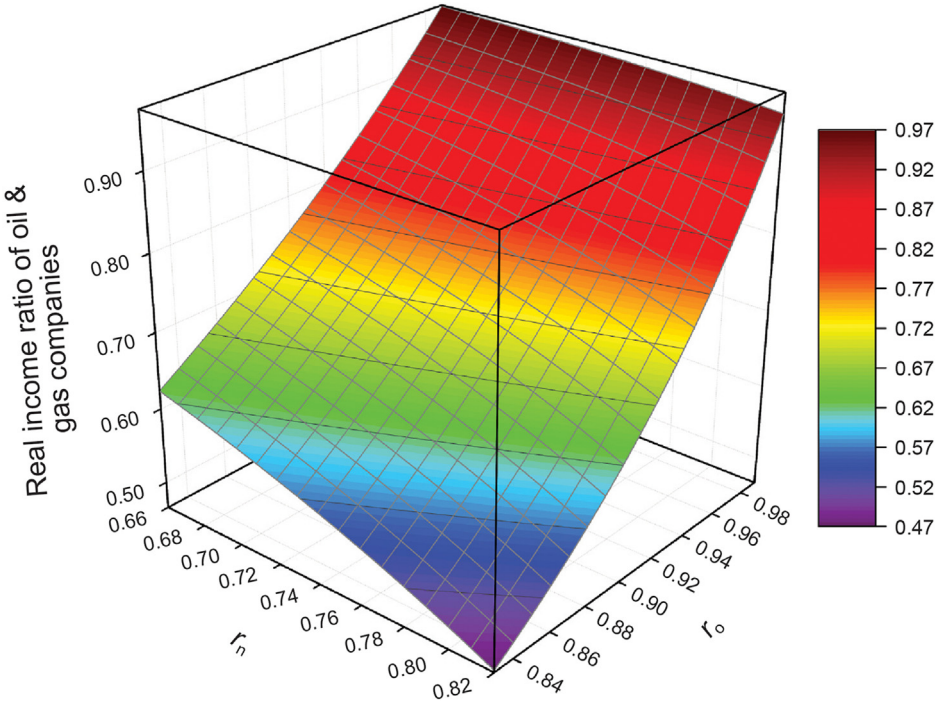

Fig. 5. Influence of r_0 and r_n on companies' real income proportion in Scenario 1.

(2) The first-mover advantage in negotiating oil and gas cooperation enables oil companies' expected income ratio to be higher when they initiate the bidding.

By comparing the real income proportion of companies in Scenario 1 and Scenario 2, it is easy to find a first-mover advantage in the oil and gas negotiation process, i.e., when oil companies initial

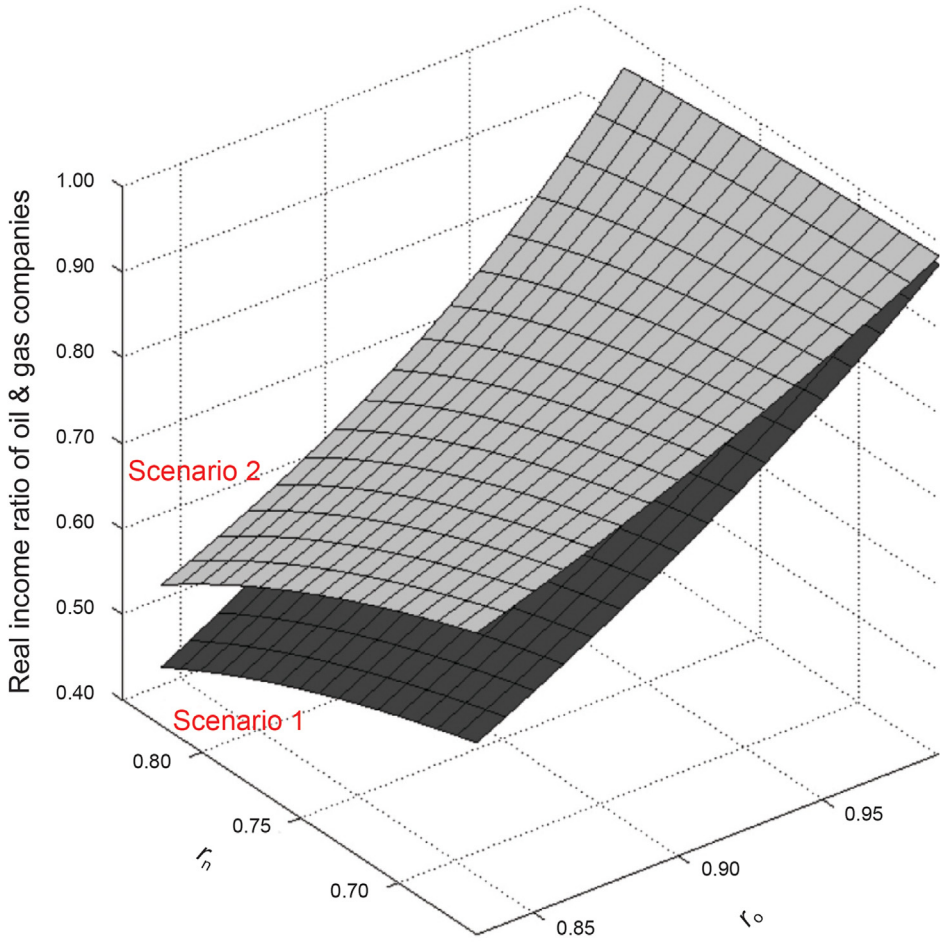

Fig. 6. Comparison of real incomes of companies in Scenario 1 and Scenario 2.

the bid, they can obtain a higher expected income ratio (see Fig. 6). Assumes that there are N rounds of bargaining instead of three rounds in the game. When oil companies initiate the bid, assume the two sides reach an agreement in theT^{th} round, then the real income proportion of companies is $(1-r_n)/(1-r_0r_n)$. This result is the same as that when they reach the agreement in the $(T+1)^{th}$ round in bargaining initiated by host countries, but the real income of oil companies changes to $r_0(1-r_n)/(1-r_0r_n)=(r_0-r_0r_n)/(1-r_0r_n)$. It means, the equilibrium real income of oil companies has been discounted for an extra round according to its discount rate r_0 when countries initiate the bidding comparing with that initiated by companies. Therefore, oil companies can get more real incomes if they move first. As a result, given the first-mover advantage in bargaining, oil companies must initiate the bidding when they bargain with the host country in cooperation.

5. Conclusions and suggestions

This paper aims to find the best bargaining strategy for oil companies participating in international oil and gas development projects. It builds a bilateral bargaining model and analyzes the influencing factors of the equilibrium income ratios. Information superiority and bidding order are proved to be the two influential factors. The host country is assumed to have an information advantage over oil companies, thus increasing the income transferred by oil companies. To quantify the information advantage, the proportion and probability for the oil companies to agree on the transfer of income are used in the bilateral bargaining model as specific measurements of information superiority. Two scenarios are set to analyze the influence of the bidding order in the game. In Scenario 1, the bid is initiated by the host country, while in Scenario 2, the bid is initiated by oil companies. Conclusions are drawn as follows:

(1) In a partnership of oil and gas development, the first-mover advantage in bilateral bargaining makes it necessary for oil companies to bid first in negotiation with the host country.
(2) The increase of information asymmetry degree could decrease the nominal income proportion of resource country while increasing that of oil companies. But the real income proportions of the two parties are not affected by information asymmetry.
(3) The influences of income transfer ratio and the probability of consenting transfer on nominal income ratio are similar.
(4) The real income proportion of oil and gas companies is negatively related to the discount rate of the host country. In contrast, it is positively related to the discount rate of oil companies.

Our conclusions shed some light on the bidding strategy of oil companies that have just completed their feasibility study and are ready to take projects. To cope with the host country's information superiority, oil companies should take the lead in the auction or negotiation. In the negotiation process, the more determined and patient the negotiation team is, the higher the possibility of earning the most actual income. Therefore, the negotiators of oil companies

should improve their negotiation skills and psychological character. This paper also proves that information advantage will cut oil companies' nominal income down, but it doesn't affect their actual income. The distinctive influences are in line with the international oil fiscal and taxation system's characteristics in reality. For example, in the negotiation of risk-taking exploration projects, the information asymmetry between resource countries and oil companies is significant. In this case, the host government may ask for a lower prospecting fee and signature bonus (which can be regarded as the "nominal income" mentioned in this paper) but require higher government take in the later profit oil. In the negotiation of some low-risk exploration projects, the degree of information asymmetry between resource countries and oil companies is relatively low, and the government may claim a lower prospecting fee and signature bonus, but higher offered profit oil. If you add up each stage's income, the oil company's actual income level remains unchanged as a whole. Therefore, information asymmetry will affect nominal income, but not actual income. According to the host government's prospecting fee and signature bonus, oil companies can weigh the offered profit oil. For oil companies eager to obtain projects, they can give a concession to the resource countries at the initial stage at the expense of paying more prospecting fee and signature bonus. Still, they can recover losses by requiring an increase in their share of profit oil.

This paper considers the uncertainty in information superiority but does not thoroughly analyze its influence factors, such as project type, underground and above-ground risk, cooperation willingness. In fact, oil and gas companies will have more resource information after enrolling in the exploration or development stage, which endows companies certain advantages to conceal their profitability and then re-negotiate with resource countries to reallocate profits. So the uncertainties in information superior itself worth profound future research. In our follow-up research, we can make an in-depth analysis of these factors' influencing mechanism and enrich the practical connotation of information superiority.

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