[*PAPER/POSTER TITLE*]
POlICY MODELLING AND SIMULATION OF THE DEVELOPMENT OF CHINA'S SHALE GAS

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Overview

China's shale gas industry is constantly growing under the stimulation of market demand and the demand of national energy security. Government's support and guidance can achieve its healthy growth. This paper constructed a dynamic model of production-transportation-consumption system of shale gas in China. Combining with the three policies, namely, direct subsidy from the central government， technical subsidy and tax reduction, we adopted the output as scenario objectives in 2020 and 2030 from Shale Gas Development Plan（2016-2020）(SGDP) issued by National Energy Administration , and then simulated the development of shale gas industry in China under single fiscal or taxable policy scenario and multi-policy scenario. The results show that: ①under single fiscal or taxable policy scenario, the performance of single-policies is different in the policy costs, industry profits, production space and implementation flexibility. The single direct subsidy policy has the highest flexibility and can adjust the subsidy level flexibly according to the development of shale gas industry. However, the profit margin of shale gas industry is low with high subsidy cost, and the space for increasing production is limited. The cost of technology subsidy policy alone is the lowest, and the output growth is sustained, but the flexibility is poor. So it is necessary to ensure that the subsidy amount is paid in full year by year. The industry profit is the highest under single tax scenario, but subsidy costs are the largest and the contribution to the sustained growth of output is small. Compared with the technology subsidy, the tax scenario can adjust the amount of tax reduction flexibly, but its flexibility is lower than the direct subsidy scenario.②Under multi-policy scenario, the planning target of large-scale development of shale gas in China can be successfully realized. After-tax incomes of mining enterprises and sales enterprises increases continuously, and the prospects of the industry are good. At the same time, subsidy costs increase with the increase of shale gas production, but the increase of costs is smaller than that of tax reduction alone. The dual objectives of reducing the policy cost and increasing industry profits can be achieved in this scenario. Based on above conclusions, the following suggestions are put forward: ①properly raise the standard of central direct subsidy and encourage local governments to subsidize early shale gas exploitation； ②rationally distribute the proportion of tax reduction to ensure the profits of shale gas production and marketing enterprises；and ③ properly increase technical subsidies.

Methods

1. Model assumption

When modelling system dynamics model（SD）, we need to consider all the factors involved in shale gas large-scale development in China. Therefore, the SD model constructed in this paper reflects the production, transportation, consumption and other links of China's shale gas industry and its main related factors. Considering the simplicity of the model and the availability of data, the following assumptions are proposed here:

（1）The behavior of variables in the model shows time consistency, that is, the value of variables will change according to the change of time step. The time for commercial shale gas production in China can be traced back to 2012. The year We set the research time of this model is from 2012 to 2030 which is the peak time of carbon emissions set by China's National Independent Contribution Program, , and the time step is 1 to observe the development of shale gas industry every year.

（2）To simplify the model, the model only considers the influence of the main variables affecting conventional gas consumption on shale gas demand, and does not consider the role of other majeure. Shale gas, as a practical supplementary energy source for conventional natural gas, has a similar role in the demand market as conventional natural gas. For example, gas production is affected by GDP and utilization efficiency. Domestic gas consumption is affected by population and natural gas consumption per capita. In order to simplify the model, when constructing the demand subsystem, only the influence of factors such as the above variables on shale gas consumption is considered, and the influence of occasional majeure is not considered. In addition, considering that the retail price of natural gas in China has not yet formed a market pricing mechanism, the shale gas pricing mode in the model is set as the average gate station price, without considering the competition of alternative energy.

（3）Shale gas production and proven reserves are not considered in the model. The technologically recoverable reserves of China's shale gas disclosed in the SGDP are 21.8×10 12m3, which is much higher than the expected production target in the plan. It can be inferred that the existing geological reserves will not become the bottleneck factor restricting shale gas large-scale production in the future.

2. Model Structure

Stakeholders, such as the upstream exploration and development enterprises, selling enterprises in the middle stream, downstream industrial and residential users, and central and local governments at all levels. It is necessary to consider the different participants of shale gas industry when we construct the SD model of shale gas development in China and analyse the supporting role and effectiveness of fiscal and taxation policies for shale gas development. Considering the demands of exploration and development enterprises, pipeline transportation enterprises, end users and government stakeholders, the SD model of shale gas industry in China is further divided into production subsystem in the upper reaches, transportation subsystem in the middle reaches and consumption subsystem in the lower reaches, and the subsystem of finance and taxation policies.

Through reasonable coupling of subsystems and considering the interaction of variables in the system, this paper constructs a SD model covering the whole process of shale gas production, transportation and consumption, seeing in Figure 1. Based on this model, the development status of shale gas industry in China under different fiscal and taxation support policy scenarios can be investigated and the effectiveness of the policy can be evaluated.

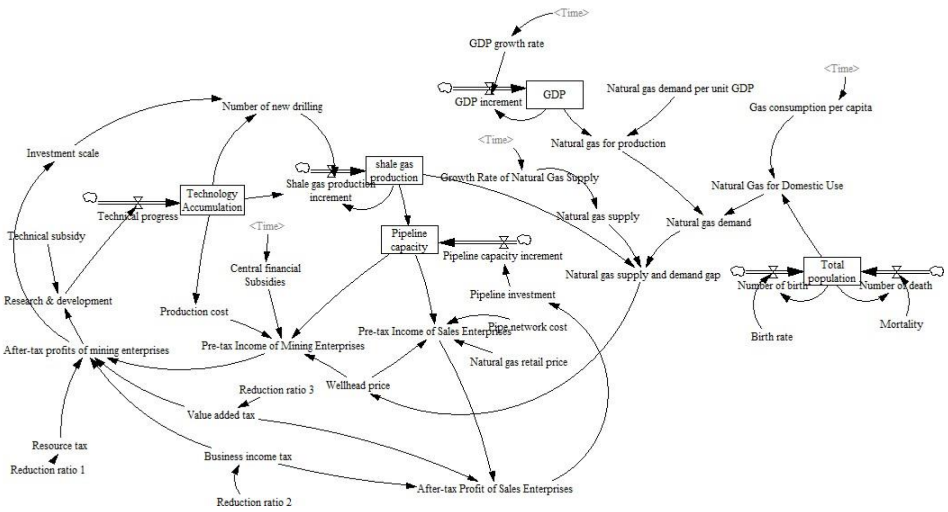

Figure 1 SD Model of Production-Transportation-Consumption System of Shale Gas Industry in China

Results

1. Model operation test

After completing the construction of the SD model and setting the model parameters, the adaptability of the system structure and system behavior needs to be tested to ensure that the SD model can effectively simulate the reality. The operation results of the shale gas production-transportation-consumption model in China are shown in tables 1 and Figure 2. As can be seen from Table 1, except in 2014, the simulated and actual shale gas production values obtained by the model have little difference, and the average absolute error of all years is less than 15%. It can be concluded that the model is reliable and can be used to simulate and predict the policy scenarios of large-scale shale gas development in China in the future.

Table 1 Comparison of simulated and actual of shale gas production in China (Unit: $10^8 m^3$)

	Actual value	Stimulated value	Absolute error（%）
2012	0.34	0.34	0.0
2013	2	2.16	8.0
2014	13	18.61	43.1
2015	45	51.91	15.4
2016	78.82	72.53	
2017	91	92.43	7.9
2018		112.65	1.6
2019		135.64	
2020		158.82	
2025		324.84	
2030		720.26	

Figure 2 shows that under the current policy scenario, China's shale gas production will continue to increase, exceeding to 720×10 ^{8}m^{3} by 2030, slightly lower than the target of SDGP of 800~1000×10 ^{8}m^{3} by 2030. Under the current policy, the inflection point of shale gas production in China will appear in 2024. Before 2024, shale gas production increased slowly, and after that shale gas production increased rapidly. This indicates that the existing single direct subsidy policy cannot promote the development of shale gas until 2024 because of the lagging effect of policy implementation. Relying solely on the current direct subsidy policy, China's shale gas production by 2020 will be significantly lower than the planned level of 300×10^{8}m^{3}, only 158×10^{8}m^{3}.

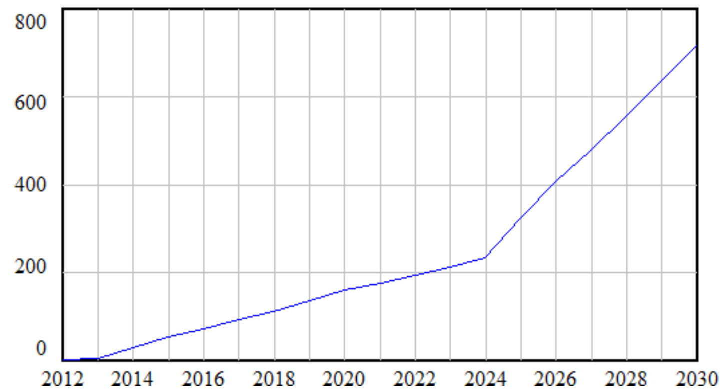

Figure 2 Scenario simulation of shale gas production in China under current policy scenario (10^{8}m^{3})

2. Single fiscal or taxation policy scenarios

Figure 3 forecasts the shale gas production under single fiscal or taxation policy scenarios. S1 only exists the situation of central direct subsidy. Due to the lagging effect of the policy, the growth rate of shale gas production is relatively slow before 2024 in S1. In order to achieve the target production of 300×10 8m3 by 2020 and 800~1000×10 8m3by 2030, the central government's subsidy for each production of 1m3 shale gas from 2018 to 2021 is set at 0.6yuan, and 0.2yuan after 2022 in order to achieve the planning target. Under the improved S1 scenario, shale gas production in 2020 will reach to 349×10 8m3, and 1171×10 8m3 in 2030.

S2 is the only tax reduction scenario. In order to achieve the planned output level, the resource tax, value-added tax and enterprise income tax of shale gas industry need to be reduced completely, that is, the values of setting variables R1, R2 and R3 are all 1. Under this scenario, the growth of shale gas production is relatively slow. By 2020, the output will be 187×10 8m3, which is lower than the target output level. It will not break through 300×10 8m3 production until about 2023, which is three years later than the targeted year. However, shale gas production will be increased to 1144×10 8m3 by 2030 to ensure the realization of the long-term target. This indicates that in the long run, tax reduction policy can stimulate shale gas enterprises to carry out production and operation activities, but due to the correlation between tax reduction policy and production level, the incentive effect on shale gas industry is not obvious in the short term.

Only technology subsidy scenario is set as S3. In order to reach the target production level, the technical subsidy for shale gas is set at 3 billion yuan, and the annual production is shown in figure 3. Under this scenario, the output of shale gas will be 302×10 8m3 by 2020 and 1181×10 8m3 by 2030, which achieves the planning target.

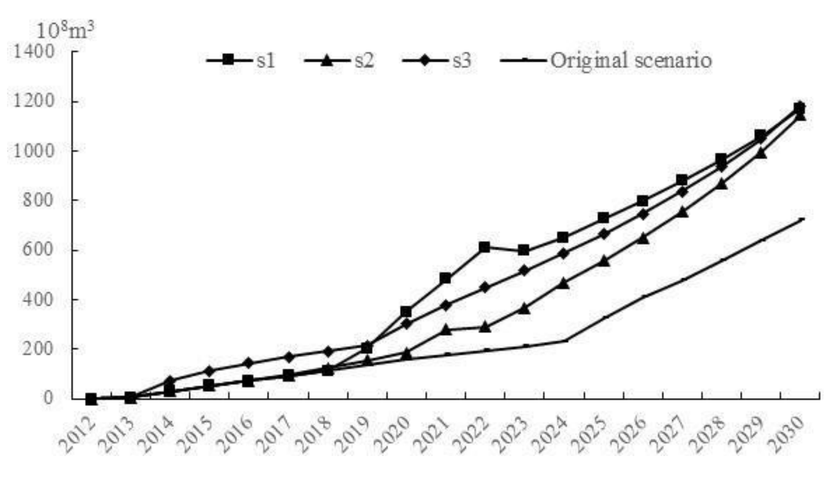

Figure 3 Simulated Shale Gas Production under Single Fiscal or Taxation Policy Scenarios in China

Note: S1 is only central subsidy scenario, S2 exists the only tax reduction scenario, and S3 stands for only technical subsidy scenario.

The profits and subsidy costs of China's shale gas industry under single fiscal or taxation policy scenarios are shown on Table 2. The profits of shale gas industry increase obviously with the increase of production. Compared with the original scenario, the profits of shale gas industry increase the most under S2, which is higher than that under S3. profits in S1 is the smallest.

Table 2. The Development of Shale Gas Industry and the subsidy Costs under single fiscal or taxation policies (unit: 100 million yuan)

	S_1			S_2			S_3		
	C	A_u	A_m	C	A_u	A_m	C	A_u	A_m
2018	80.5	56.1	134.2	144.6	44.6	255.1	30	48.3	214.8
2019	126.4	77.5	210.6	198.9	33.3	381.4	30	51.3	326.7
2020	209.4	116.0	350.3	289.4	50.5	542.0	30	57.4	476.3
2021	96.8	5.1	584.9	402.4	25.3	784.1	30	79.9	674.2
2022	96.2	95.0	806.6	607.8	106.4	1023.6	30	134.1	898.0
2023	104.5	111.9	1122.7	830.0	105.7	1375.6	30	198.4	1170.3
2024	120.8	132.9	1472.0	1136.2	140.7	1790.0	30	281.5	1484.9
2025	134.9	203.3	1833.1	1557.4	238.8	2277.1	30	375.4	1853.4
2026	149.0	306.8	2221.9	2049.7	380.8	2849.0	30	515.8	2242.5
2027	164.7	402.0	2689.2	2612.6	510.8	3568.2	30	651.6	2714.8
2028	181.7	544.2	3178.4	3277.8	736.7	4350.7	30	839.5	3218.3
2029	200.3	708.3	3724.7	4049.1	979.3	5287.1	30	1049.4	3796.5
2030	221.2	894.3	4337.3	4950.3	1273.6	6372.8	30	1291.6	4453.8

Note: C represents costs of government subsidies. Au and Am is the after-tax income of upstream mining enterprises midstream sales enterprises, respectively.

Under S2, the added profits in shale gas industry is the amount of tax deduction by the government, that is, the cost of tax deduction. Therefore, subsidy costs of S2 is the highest.. In the case of S1, subsidy costs are directly related to the amount of subsidy to per unit shale gas production and shale gas production. Therefore, subsidy costs increase with the increase of production in general. Under this scenario, in order to achieve the target of shale production of 300×10 8m3 in 2020, the standard of central financial subsidy is relatively high; shale gas production began to grow steadily in 2021, but the increase is less than the decrease of the amount of central subsidy. So subsidy costs of shale gas decreased slightly in this scenario from 2020 to 2021. In the case of S3, subsidy costs are the lowest, but the elasticity of costs is small.

The development of China's shale gas industry is different under the above three single scenarios. Table 3 compares the performance of these scenarios in terms of subsidy costs, industry profits, space for increasing production and implemented flexibility. Under the same goal, the implementation flexibility is the highest under S1, which can adjust the subsidy level flexibly according to the development of shale gas industry, but the profit margin of the industry is low, and subsidy costs are high, and the space for increasing production is limited. In the case of S3, subsidy costs are the lowest and the output growth is sustained, but the flexibility of policy implementation is poor. So it is necessary to ensure that the subsidy amount is paid in full year by year. Under S2, the industrial profit is the highest, but the subsidy cost is the largest, and the contribution to the sustained growth of production is small. Compared with S3, the case of S2 has higher flexibility, but its flexibility is lower than that of S1.

Table 3 Comparison of Single Fiscal and Tax Policies

	S1	S2	S3
subsidy costs	★★	★	★★★
industrial profits	★	★★★	★★
space for increasing production	★★	★	★★★
implemented flexibility	★★★	★★	★

3. Multi-policies nested scenario

The results of single fiscal or taxation policy scenarios indicates that costs of S3 is the lowest and the stimulating effect on production is obvious. Considering that appropriate tax reduction policy can guarantee the profits of shale gas industry and can attract oil and gas enterprises to enter the field of shale gas exploration, development and sales, and that the flexibility of supporting policies should be taken into account, the nested simulation of multiple fiscal and taxation policies should be carried out. The technical subsidy is set at 3 billion yuan, the central financial subsidy is set at 0.1yuan/m^3 from 2021 to 2030, and the reduction ratios of resource tax, enterprise income tax and value-added tax are 50%, 20% and 30%, respectively. The simulation results are shown in Figure 4.

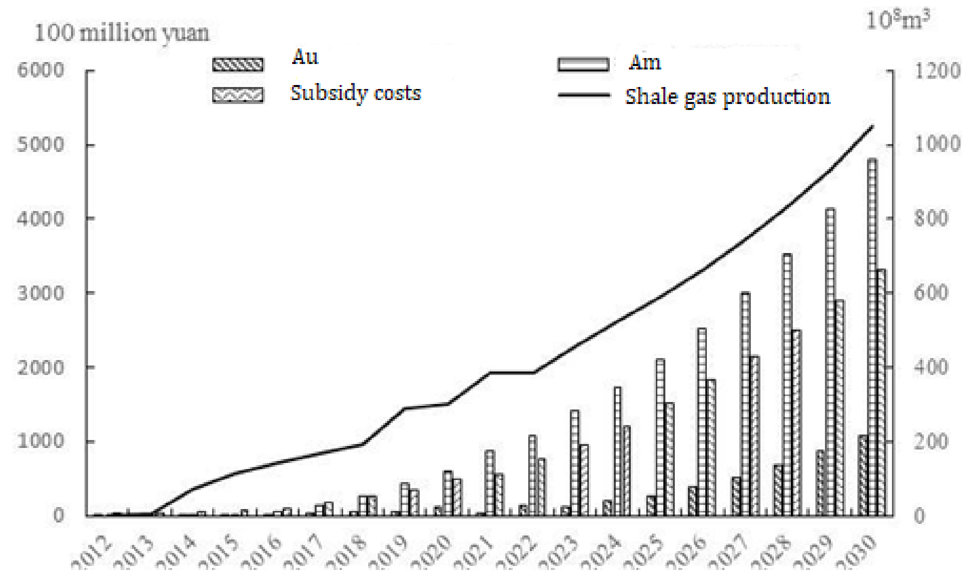

Figure 4 Shale Gas Industry and Policy Costs of in China under Multi-policies Nested Scenario

Under multi- Under multi-policies nested scenario, shale gas production reaches to $302\times10^{8}m^{3}$ in 2020, more than $1049\times10^{8}m^{3}$ in 2030 , indicating that shale gas planning objectives can be achieved. After-tax income of mining enterprises and sales enterprises are increasing continuously, which means the industry has good prospects. Subsidy costs increase with the increase of shale gas production, but the increase of costs is less than that of S2. This shows that under the multi-policies nested scenario, we can achieve the dual goals of reducing the burden of government finance and taxation and increasing industry profits.

Conclusions

This paper divided China's shale gas policies into two categories: fiscal subsidy policy and tax preferential policy and found the problems of existing policy system, such as insufficient fiscal policy subsidy and low tax preferential policy. In order to improve the fiscal and taxation policy support system of China's shale gas industry, this paper simulated three single policy subsidy scenarios and multi- policy nested scenarios, that is direct subsidy, tax reduction and technology subsidy, from the perspective of shale gas production, industrial profits, policy costs and flexibility by constructing a SD model of shale gas production-transportation-consumption system in China. The results implied that:

(1) The performance of single fiscal or taxation policy scenarios is different in the costs of policies,industry profits, space for increasing production and implemented flexibility. Individual direct subsidy policy has the highest flexibility and can adjust the subsidy level flexibly according to the development of shale gas industry. However, the profit margin of the industry is low, with higher subsidy costs and limited space for increasing production. In the case of technology subsidy alone, subsidy costs are the lowest and the output growth is sustained, but the flexibility of implementation is poor. So it is necessary to ensure that the subsidy is paid in full year by year. Industry profits are the highest under the separate tax scenario, but the subsidy cost is the largest, and the contribution to the sustained growth of output is small. Compared with the separate technical subsidy, the flexibility of the separate tax reduction policy is higher, but its flexibility is lower than that of the separate direct subsidy scenario.

(2) Under the multi-policies nested scenario, the planning shale gas objectives can be achieved. After-tax revenue of mining enterprises and sales enterprises continues to increase, meaning industry development prospects are good. Subsidy costs increase with the increase of shale gas production, but the increase in cost is smaller than that of tax reduction alone, which shows that under the multi-policy nested scenario, government fiscal burden and tax burden can be reduced and industry profit growth can be achieved.

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