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THE OPTIMAL SIZE OF CHINA'S STRATEGIC PETROLEUM RESERVE

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ABSTRACT

Energy security usually considers both the stability of energy supply and security of energy use and it is receiving increasing attention globally. Considering the strategic importance and sensitivity to international change of the crude oil supply, we decided to examine China's energy security. The first research question of this paper is how suppliers' unreliability may impact the Chinese oil market and how this affects Chinese oil market decisions. The second research question of this paper is to what extent China should invest in strategic oil storage capacity to mitigate the effects of possible supply withholding by risky countries. The results of this paper is helpful for government decision-making.

Keywords: Energy security, Oil supply, Oil storage, Game theory.

1. INTRODUCTION

Energy security, as an important factor affecting economic production and human life, is important for sustainable development. It is generally acknowledged that energy security includes two aspects, i.e., the stability of energy supply (meaning that the energy supply is maintained at a stable level that can satisfy the demand of national development) and the security of energy supply (meaning that energy use will not pose any threat to the environment or human survival and development) (Bielecki, 2002; Cai and Zhang, 2005; Wang, 2006; Hughes, 2012).

At present, the security of energy supply is facing a huge challenge because of deregulation of the energy market, high energy prices, increasing energy demand, intensive competition for geographically concentrated resources, and the instability of international politics. China became a net oil importer in 1993 and the gap between oil supply and demand has increased since then because of the corresponding rapid socioeconomic development (Leung, 2011). China's dependency on oil imports will reach 59.6% in 2014 and will increase more than 60% in 2015. Here, we pay much attention to the security of energy supply, which plays an important role in national economic and political security. We focus on crude oil because of its strategic importance and sensitivity to the international situation.

In recent years, numerous studies on the definition and evaluation of indicators of energy security have been reported. The term energy security is polysemous (Chester, 2010), and its definition is usually related to the site, purpose, and period of a given study (Chuang and Ma, 2013). Some studies only focused on resilient energy systems, stable energy supply, acceptable prices, or sustainable economic development (Lefèvre, 2010), while others also considered environmental effects (Hughes, 2012; Selvakkumaran and Limmeechokchai, 2013). Among the various definitions of energy security, the one developed by IEA (International Energy Agency) is widely used, which is defined as "the uninterrupted physical availability at a price which is affordable, while respecting environment concerns". With regard to various indicators of energy security, different classifications can be obtained. Generally, some studies assessed energy security from concrete energy-based factors such as energy availability, price affordability, energy use technologies, and efficiency (Chester, 2010; Chuang and Ma, 2013). Some studies considered macroscopic energy-related factors such as social, economic, environmental, and institutional effects (Martchamadol and Kumar, 2013). Other studies discussed the energy storage.

Energy storage is accomplished by devices or physical media that store energy to perform useful processes at a later time. A device that stores energy is sometimes called an accumulator. High oil external dependency greatly increases the risk of China's oil supply disruptions. So oil supply security has been attached great importance, and strategic petroleum reserve construction has started. In the process of the construction of the strategic petroleum reserve, the reserve scale is a key issue of concern. The greater the oil reserves, the greater the degree of oil supply security, but the corresponding reserve costs are inevitably higher. So the government must choose its optimal petroleum reserve quantity to balance the oil supply security with reserve costs. This paper examines China's energy security strategies with a focus on the petroleum reserve strategy.

2. MODEL

China is modeled as a large number of uncoordinated gas consumers and domestic gas producers, with an overarching government that can decide to invest public funds in gas storage capacity. We assume China is a price-taker with a linear long-run inverse demand curve for oil:

$$p(q) = \alpha + \beta q \quad (1)$$

q_D is the oil supply from Chinese domestic producers, which is assumed to be exogenous and fixed (inelastic). $q - q_D$ denotes the import quantity, which q_U is the supply with a higher disruption risk, for $q_U = \frac{p_U - \alpha}{\beta} - q_D - q_0, q_0$ indicates the import from other country with little disruption risk. As oil demand is very strong rigidity, so demand will not change in short-term disruptions circumstances.

We assume that decisions on long-term oil import contracts and publicly financed strategic storage capacity investments are based on a combination of the interests of importers, end-consumers, domestic producers and taxpayers. We therefore assume that Europe maximizes the expected total 'Chinese surplus' E[S]:

$$\max \mathrm{E[S]} \text{ with } \mathrm{S} = \mathrm{CS} + \Pi_{\mathrm{D}} - \mathrm{G} \quad (2)$$

where CS is the consumer surplus, Π_D represents the profits of domestic producers, and G is the public expenditure on oil storage capacity investments, $G = a + bq$. Note that equation (2) assumes risk-neutrality.

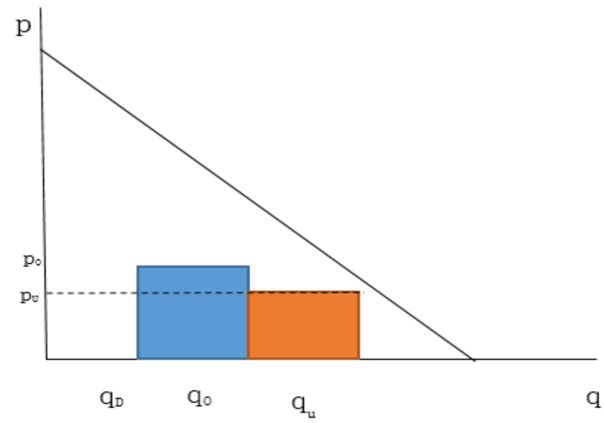

Figure 1. Demand and Supply in Case 1

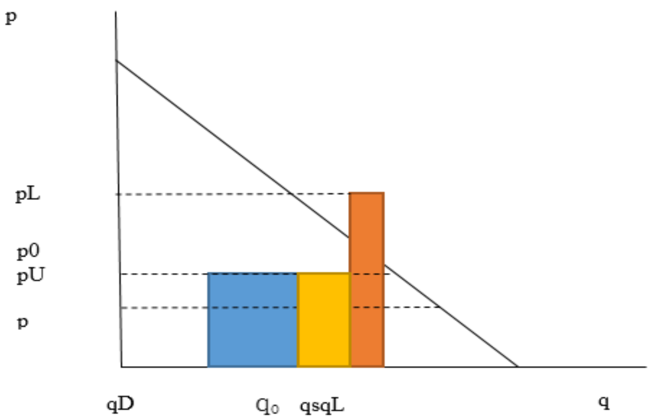

Figure 2. Demand and Supply in Case 2

There is a probability δ that high risk country does not comply with its previous supply commitments. Conversely, there is a probability (1 − δ) that they complies with its long-term contracts during the entire period. In the short term cases, the price of oil we import from other is:

$$p_L = c_0 + d_0 q_L \quad (3)$$

with $b > 0, d_0 > 0, c_0 > c_R, p_L > p_0 > p_U$.

At the same time, for other low risk suppliers, they making decisions is order to meet its own profit maximization, namely:

$$\max \mathrm{E[R]} \text{ with } \mathrm{R} = (p - c_R)\mathrm{q} \quad (4)$$

The producing cost is c_R, and long term supply price is $p_0 = c_1 + d_1 q_0$, with $d_1 < d_0, c_0 > c_1 > c_R$.

Case 1: All suppliers comply with long-term contracts. China obtains surplus S=S$_1$. Other low risk suppliers obtain profits $R = R_1$.

Case 2: High risk suppliers interrupt the supply. China obtains surplus S=S$_2$. Other low risk suppliers obtain profits $R = R_1 + R_2$.

So Chinese expect surplus is

$$E[S] = (1 - \delta)S_1 + \delta\ S_2 \quad (5)$$

Suppose that the interruption duration is τ of one year, the 1 – τ of one year is as regular supply. To ensure the normal supply, the basic oil reserve must be more than τq_S. Because of the strong rigidity demand, we can find $q_s + q_L = q_U$.

Therefore, in case 1 Chinese surplus S$_2$:

$$S_2 = (1 - \tau)S_1 + \tau(S_1 - \Delta S) = S_1 - \tau\Delta S \quad (6)$$

Reserves of oil without storage cost is p_0, then:

$$S_1 = \alpha(q_D + q_0 + q_U) + \frac{1}{2}\beta(q_D + q_0 + q_U)^2 - p_0 q_0 - p_U q_U - (a + b\tau q_s) \quad (7)$$

$$\Delta S = (p_0 - p_U)q_s + (p_L - p_U)q_L \quad (8)$$

And in interruption case, the oil price that China imports from other countries is: $p_L = c_0 + d_0 q_L$, so $q_L = q_U - q_s, p_L = c_0 + d_0(q_U - q_s)$.

For other low risk suppliers, they making decisions is order to meet its own profit maximization, that is:

$$\max E[R] = R_1 + \delta\ R_2 = (p_0 - c_R)q_0 + \delta(p_L - c_R)q_L = (c_1 + d_1 q_0 - c_R)q_0 + \delta[c_0 + d_0(q_U - q_s) - c_R](q_U - q_s) \quad (9)$$

From(6)(8)(9)we can find:

$$E[S] = \alpha(q_D + q_0 + q_U) + \frac{1}{2}\beta(q_D + q_0 + q_U)^2 - p_0 q_0 - p_U q_U - (a + b\tau q_s) - \delta\tau[(p_0 - p_U)q_s + (p_L - p_U)q_L] \quad (10)$$

Taking with $q_L = q_U - q_s, p_L = c_0 + d_0(q_U - q_s), p_0 = c_1 + d_1 q_0, q_U = \frac{p_U - \alpha}{\beta} - q_D - q_0$, then respectively for q_s, q_0 derivation:

$$\frac{\partial E[S]}{\partial q_0} = p_U - c_1 - 2d_1 q_0 = 0 \qquad (11)$$

$$\frac{\partial E[S]}{\partial q_s} = -b\tau - \delta\tau[p_0 - c_0 + 2d_0(q_U - q_s)] = 0 \qquad (12)$$

$$q_0 = \frac{p_U - c_1}{2d_1} \qquad (13)$$

$$q_s = \frac{\delta(p_0 - c_0) + b}{2d_0\delta} + \frac{p_U - \alpha}{\beta} - q_D - \frac{p_U - c_1}{2d_1} \qquad (14)$$

$\frac{\partial q_s}{\partial \delta} = -\frac{b}{2d_0\delta^2} < 0$. That is the storage quantity decreasing, while the interruption risks increase. Because, when the risk of the supply is increasing, China will import from other stable suppliers, then the storage demand will decrease. Also, we can find that $\frac{\partial q_s}{\partial p_U} = \frac{1}{\beta} < 0$.

3. NUMERICAL SIMULATION

For the base scenario, the parameters are $p_0 = 11, p_U = 10, c_0 = 6, c_0 = 5, d_0 = 0.3, d_1 = 0.2, \alpha = 20, \beta = -0.1, q_D = 50, b = 0.2, \delta = 0.1$.

The Figure 3 shows when the interruption probability increases, the oil storage will decrease. The Figure 4 shows that the price of higher risky supplier rises, while the oil storage will also reduce.

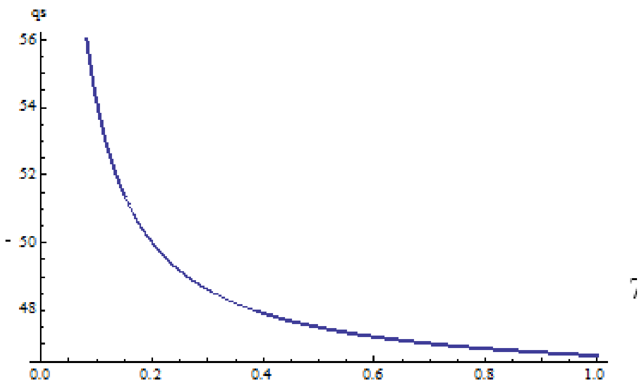

Figure 3. Storage changes with interruption probability

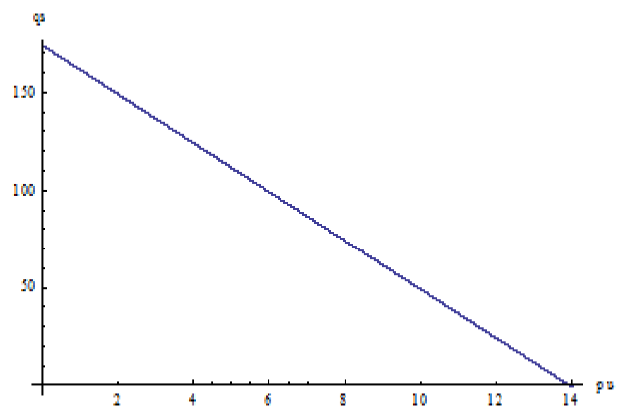

Figure 4. Storage changes with risky supplier price

As Figure 5 shows that all supply price will decrease the oil storage, and the higher risky supplier impacts more significant.

The Figure 6 shows that oil reserve changes with stable supplier price and its price elasticity of supply. The higher elasticity is, the more oil storage will be.

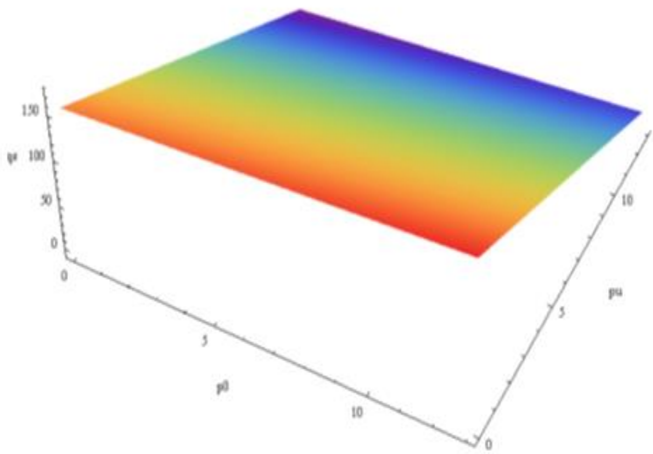

Figure 5. Storage changes with risky supplier price and stable supplier price

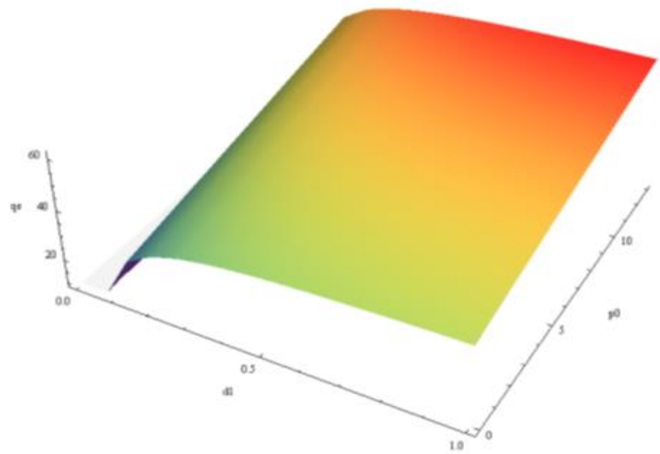

Figure 6. Storage changes with stable supplier price and its supply elasticity

4. CONCLUSIONS

The first research question of this paper is how suppliers' unreliability may impact the Chinese oil market and how this affects Chinese oil market decisions. The second research question of this paper is to what extent China should invest in strategic oil storage capacity to mitigate the effects of possible supply withholding by risky countries. A high interruption risk will decrease the storage quantity, this is not like normal thought. Due to the limit data, I don`t do the simulation analysis. But I will do this in the future research, to find the accurate numerical results, in order to help government to make decisions.

The results of this paper are obtained using a partial equilibrium model of the market for long-term oil import contracts, with differentiated competition between high risk suppliers and other suppliers. Future research could examine the impact of the other suppliers becoming unreliable as well. Another possible extension is to turn our model into a repeated game. In such a game, δ could become endogenous as part of a mixed high risk suppliers` strategy. Finally, the topic of this paper could be placed in a broader comparison of policy measures (import taxes, rationing, interruptible consumer contracts, etc.) that can be used to address oil import challenges.

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