



China's optimal stockpiling policies in the context of new oil price trend

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ABSTRACT

Optimizing the size of oil stockpiling plays a fundamental role in the process of making national strategic petroleum reserve (SPR) policies. There have been extensive studies on the operating strategies of SPR. However, previous literatures have paid more attention to a booming or stable international oil market, while few studies analyzed the impact of a long-term low oil price on SPR policy. As a supplement, this paper extends a static model to study China's optimal stockpiling policy under different oil price trends, and in response to different current oil prices. A new variable “FC”, which demonstrates the appreciation and depreciation of the reserved oil economic value, has been taken into account to assess the optimal size of SPR. In this paper, a more multi-perspective of view is provided to consider the policies of China's SPR, especially under the different trend of international oil price fluctuations.

1. Introduction

1.1. Oil supply security of China

With rapid economic development, crude oil consumption in China keeps climbing from 227.9 to 559.7 million tons between 2001 and 2015 (BP, 2016a). However, the same period has only witnessed a slight rise of domestic oil production to 214.6 from 164.8 million tons (BP, 2016b). As a result, thirst for oil and high dependence on imports prompted China to concern more about energy supply security, which is epitomized by China's gradual establishment of its own strategic petroleum reserve (SPR) since 2003, during the process of which a size equivalent to 90 days of net oil import amount is planned to be reached by 2020. Therefore, three-phase construction process of China's SPR was proposed. Specifically speaking, phase 1 was completed in 2009, with a total storage capacity of 102 million barrels (equivalent to approximately 13.8 million tons) being built. Phase 2 began in 2010 and was completed in 2015, during which the total storage capacity of China's SPR had risen to 271 million barrels (equivalent to about 36.9 million tons). Next, Phase 3 started in 2016 (Bai et al., 2012a). Recently, the data released by the National Bureau of Statistics (NBS) of China indicates that China boasts a total of 31.97 million tons of SPR, slightly falling short of the original plan, but the

construction process is generally within control. Since SPR is one of the most effective measures to ensure national oil supply security (Wu et al., 2008), the relevant work is supposed to be implemented in increased speed and scale.

1.2. New economic trends and oil price fluctuation

International crude oil price had a booming decade until 2014. Therefore, most literatures and energy policies focused on thorny issues involving high oil price instead of the downward trend. However, the subdued world economic development has reversed the trend of oil price movements abruptly and substantially, with little sign of a sound recovery. Specifically speaking, the international oil price, which remained steady at \$110/bbl from 2011 to 2013, started to slump in 2014 and plunged to \$52.39/bbl in 2015 (BP, 2016c). In the first quarter of 2016, under the double blow of excessive global supply and sluggish demand (IEA, 2016), the price of Brent crude oil even hit a decade low of \$30/bbl. Although major oil producers finally reached an agreement on reduction to stimulate the oil price at the end of the year, average price of 2016 still stood at less than \$50. In early 2017, an effective rebound is hardly likely to be obtained in oil price, which fluctuated within the range of \$50 to \$55. Such a long-term weak oil price is almost unprecedented in history.

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There are two causes behind the current fluctuations in the international crude oil market. First, the market demand for the crude oil has been weakened sharply by the sluggish global economy. The second is that the global crude oil market has become relatively oversupplied due to the shale oil revolution coupled with the impracticability of more production slash in major oil producers. Among the two factors mentioned above, the latter might exert a more serious and longer-term impact on the oil price. According to rule of thumb in oil industry, the reduction of costs would eventually incur the cyclical fall in prices. The increasing production of shale oil caused concern since 2012 for the exploiting technology advances in horizontal drilling and the hydraulic fracturing while the producers have become increasingly cost-efficient (Kilian, 2016). Nonetheless, there still remains uncertainties about the stable oil production constrained by the scope of the shale oil boom (Kilian, 2016). At the same time, many conventional exploration and development projects had already been postponed to wait for the oil price to bounce back. Apparently, all factors were mixed complicating the whole situation to an unprecedented extent. To keep pace with the changes in the international socio-economic environment, an SPR scale decision that can be optimized on divergent oil price trends deserves more research.

1.3. Studies relevant to SPR strategies

There have been extensive studies on SPR strategies. The research directions closely related to this paper include operating strategies of SPR, oil price impacts on SPR, SPR policies of China, and auxiliary policy tools.

The studies focused on operating strategies of SPR usually address on the issues of optimal stockpiling size and subsequent operational policies of acquisition, release, test sale, drawdown and replenishment. Right after the oil crisis in 1973, Nordhaus (1974) employed a two-period static model to identify SPR and tariff policy as two effective policy tools to deal with oil supply disruption. Following his study, a wealth of researches explored the SPR issue from different perspectives: Wright and Williams (1982) gave an in-depth analysis of the relationship between government and private stockpiling; Zweifel and Bonomo (1995) studied the relevant alternative energies; Samouilidis and Berahas (1982) applied a decision tree model to determine the optimal stockpiling size; Oren and Wan (1986) introduced a new model for analyzing oil stockpiling policies (which is characterized by its computational simplicity) with the simple two-period models to capture the important features of the stochastic dynamic programming formulation. Different from the static models mentioned above, Teisberg (1981) firstly developed a dynamic programming model to calculate the optimal stockpiling size and acquisition/release policy. Murphy and Weiss (1987) extended the model by taking into account a Nash dynamic game among several oil-importing countries. Furthermore, Murphy and Oliveira, (2010, 2013) developed a Markov game to examine the pricing option contracts on SPR to maximize consumer welfare and the profit of private inventory. Maddah et al. (2014) developed optimal stockpiling policies by incorporating a replenishment policy, with periodic restocking, to offset the additional SPR costs caused by exponential deterioration.

As an essential factor for the total cost and operating strategies of SPR, the impact of international oil price on SPR has also aroused strong academic interest. A variety of methods in existed literature have been applied to analyze both the oil prices and the trends of its fluctuation. Chao and Manne (1983) adopted dynamic programming to study the mutual interactions between OECD's oil demand, international oil price and the U.S. SPR policy. Murphy et al. (1989) employed a Nash dynamic game model to investigate public and private sector oil inventory policies in a volatile globe oil market. Demirer and Kutan (2010) applied ARCH model and Fama-French three-factor model to study the impact of 63 OPEC meetings and 15 THE U.S. SPR statements on global oil spot/future price from March 1983 to June

2008. The result shows that neither OPEC meetings nor the U.S. SPR employment statements have significant impact on international oil price. Gallo et al. (2010) applied the method of unit-root test to simulate endogenous oil supply disruption, and analyzed the correlation between global oil market demand (consumption), supply (production) and price. They draw the conclusions that the change of consumption is the result rather than the cause for international oil price fluctuation, which stems mainly from the change of oil production. Scheitrum et al. (2015) estimated the private storage responses to SPR release announcements to test substitution between private and public storage in the U.S. market. Agnihotri (2015) predicted that rising US crude inventory and weak global demand would bring forth cheap oil, benefiting the two largest global importers of oil, India and China. Meanwhile, Agnihotri indicated that a smart strategy for China is to cash in on and store cheap oil as SPR.

In recent years, operating strategies for China's SPR have also been explored in various perspectives. Wu et al. (2008) quantified the impact of uncertain international oil price on optimal stockpile acquisition strategies of China's SPR for the period 2007–2010 and 2011–2020 with an uncertain dynamic programming model. Zhang et al. (2009) developed a stochastic dynamic programming model based on a total potential cost function of establishing SPRs to evaluate China's optimal SPR policy, which consisted of the optimal size and the best acquisition and drawdown strategies. Fan and Zhang (2010) developed a stochastic dynamic Nash game model, in which the players, such as China and India, competed with each other and made individual decisions to minimize their expected total SPR cost. Besides, Lin and Du (2010) designed a static model with lower computational cost to study the optimal stockpiling size of China's SPR. They explained that although static model only predicted optimal results for one particular period, the decision-making authorities could adjust operational measures at the end of each period. For the sake of simplicity, they assumed the decision-making period as 1 year. Zhu et al. (2012) developed a Markovian dynamic programming model to minimize the SPR policy costs over a finite decision period. Bai et al. (2012b) also applied a dynamic programming model to determine the optimal stockpiling path for China's SPR, assuming a specific stockpiling size by 2020. Wu et al. (2012) improved their existed dynamic programming model by using exogenous oil price given on a monthly instead of annual basis to view the more realistic simulation of optimal strategies each year. Zhang (2013) studied the influence of speculators' positions on WTI crude oil futures returns with the historical data from 2007 to 2010. To cope with uncertain global oil market, Chen and Mu (2013) built a dynamic programming model to study the optimal stockpiling path. Bai et al. (2014) used a dynamic programming framework to explore an optimal stockpile and drawdown strategy, taking into account stockpile cost, oil price and supply disruptions. In their study, the influence of the stockpile on price is examined with an embedded supply-demand equilibrium model. Li et al. (2015) built a system dynamics model to access the effects of China's SPR releasing on domestic oil market in various scenarios in 2020, with different international oil prices and different SPR scales. Bai et al. (2015) proposed a Markov Decision Process to study how the SPR operating actions, which include acquisition, release, and replenishment, would affect market factors, such as oil demand or price and so on. Bai et al. (2016) examined the desirable sizes and optimal SPR operating strategies for oil consumption countries by using a Markov decision process model.

In addition, to study auxiliary policy tools other than SPR, Bai et al. (2012a) developed a two-period model to analyze China's optimal tariff rate and stockpiling size and aimed to minimize potential social welfare loss and macroeconomic loss associated with oil supply disruptions; Chen et al. (2014) developed a multi-dimension stochastic dynamic programming model to describe the benefits from using stockpile delegation as an auxiliary of SPR policies for China.

Although there have been a host of literatures regarding the optimal operating strategies of China, most of them are done under an implicit

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