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Stockpile strategy for China's emergency oil reserve: A dynamic programming approach

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HIGHLIGHTS

- China's SPR policies are examined by dynamic programming.
- The optimal stockpile acquisition rate varies from 9 to 19 million barrels per month.
- The optimal stockpiling drives up world oil price by 3–7%.

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ABSTRACT

China is currently accelerating construction of its strategic petroleum reserves. How should China fill the SPR in a cost-effective manner in the short-run? How might this affect world oil prices? Using a dynamic programming model to answer these questions, the objective of this paper is to minimize the stockpiling costs, including consumer surplus as well as crude acquisition and holding costs. The crude oil acquisition price in the model is determined by global equilibrium between supply and demand. Demand, in turn, depends on world market conditions including China's stockpile filling rate. Our empirical study under different market conditions shows that China's optimal stockpile acquisition rate varies from 9 to 19 million barrels per month, and the optimal stockpiling drives up the world oil price by 3–7%. The endogenous price increase accounts for 52% of total stockpiling costs in the base case. When the market is tighter or the demand function is more inelastic, the stockpiling affects the market more significantly and pushes prices even higher. Alternatively, in a disruption, drawdown from the stockpile can effectively dampen soaring prices, though the shortage is likely to leave the price higher than before the disruption.

1. Introduction

China's oil dilemma stems from the expanding supply–demand gap along with rapid economic growth. As the second largest energy consumer in the world, China consumed 483.7 million tonnes of oil in 2012 which accounted for 11.7% of global consumption. However, domestic oil supply was only 207.5 million tonnes. China's reliance on international oil supplies reached over 40% (British Petroleum, 2013) and has been steadily increasing since China became a net importer in 1993. China's sense of energy vulnerability is related to external threats as well as internal challenges. Now China imports more than 70% of its oil, mainly from the Middle East and Africa. Rising tensions in these regions strengthen concerns over China's future oil supply security (Bai et al., 2012a).

The rapidly increasing imports of oil have catalysed the Chinese government into establishing strategic petroleum reserves (SPRs). It has been reported that the government aims to comply with the IEA standard on stock requirements for its member countries, i.e. holding crude oil stockpiles equivalent to 90 days of net petroleum imports. Construction of China's SPRs began in 2004 and they are expected to be fully completed in three phases over 15 years. Phase I (2004–2009) is completed, with 102 million barrels of storage capacity in four separate sites (e.g. Zhenhai, Zhoushan, Dalian and Huangdao). Between the second half of 2008 and the

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first half of 2009, it is estimated that 102 million barrels of strategic reserves were filled into Phase I SPR facilities, implying an average stockpiling cost of $58/bbl and a total crude acquisition cost of RMB 6 billion (Goldman Sachs, 2010). The construction of Phase II, with a total of 169 million barrels, began in late 2008. Phase III of the programme is still in the planning stage. Fig. 1 shows the locations of China's SPRs at different phases. At the same time, China has been establishing an SPR management system. The National Oil Reserve Centre (NORC), established in 2007, manages the SPR construction and filling. It, in turn, is overseen by the National Energy Administration (NEA).

2. Literature review

To date, the relevant studies have considered several issues, including desirable SPR size, along with long-term fill and drawdown strategies. Such issues have been examined using many methods. Popular models include two-stage optimization models, game theory models and dynamic programming models.

Samouilidis and Berahas (1982) and Wei et al. (2008) used decision tree models to quantify the optimal SPR size for the U.S. and China, respectively. Nordhaus (1974) and Tolley and Wilman (1977) employed two-period models to identify a desirable stockpile size. Nordhaus (1974) examined the optimal stockpile size in the U.S. in a numerical example. Most recently, Bai et al. (2012a) developed a two-period optimization model in which the marginal costs and benefits of SPRs are defined and employed to examine the optimal SPR size for China.

Such policy instruments can be also examined in a dynamic programming model. Teisberg (1981) developed a long-term stochastic dynamic programming model that explores the SPR size, as well as the fill and drawdown policy for the U.S. Several later studies extended Teisberg's model from various aspects such as objective function and market structure, and applied the model to other countries like China (Chao and Mane, 1983; Oren and Wan, 1986; Wu et al., 2008; Zhang et al., 2009). Most recently, Wu et al. (2012) examined China's SPR optimal stockpiling and drawdown strategies. Different from earlier studies, the authors consider the oil price as exogenous variable and examine the results for three interesting scenarios.

Previous studies have also focused on finding the desirable SPR size. However, in some cases, the SPR size was already stipulated, i.e. the government had announced that China planned to build up its SPRs in 15 years and they would hold 440 million barrels.

Here, we limit ourselves to exploring the optimal fill and drawdown strategy for the chosen capacity and timeframe. We build a dynamic programming model for the Chinese reserves and focus on the immediate problem of minimizing the stockpile compliance cost. Other studies have also examined the value and use of strategic oil stockpiling by a risk-neutral government and private actors in reducing the expected cost of oil supply disruptions (Toman and Macauley, 1986). But none of these consider the other major factor, namely, the feedback from stockpiling to the world oil price together with sensitivities of these results to variations in the parameter assumptions.

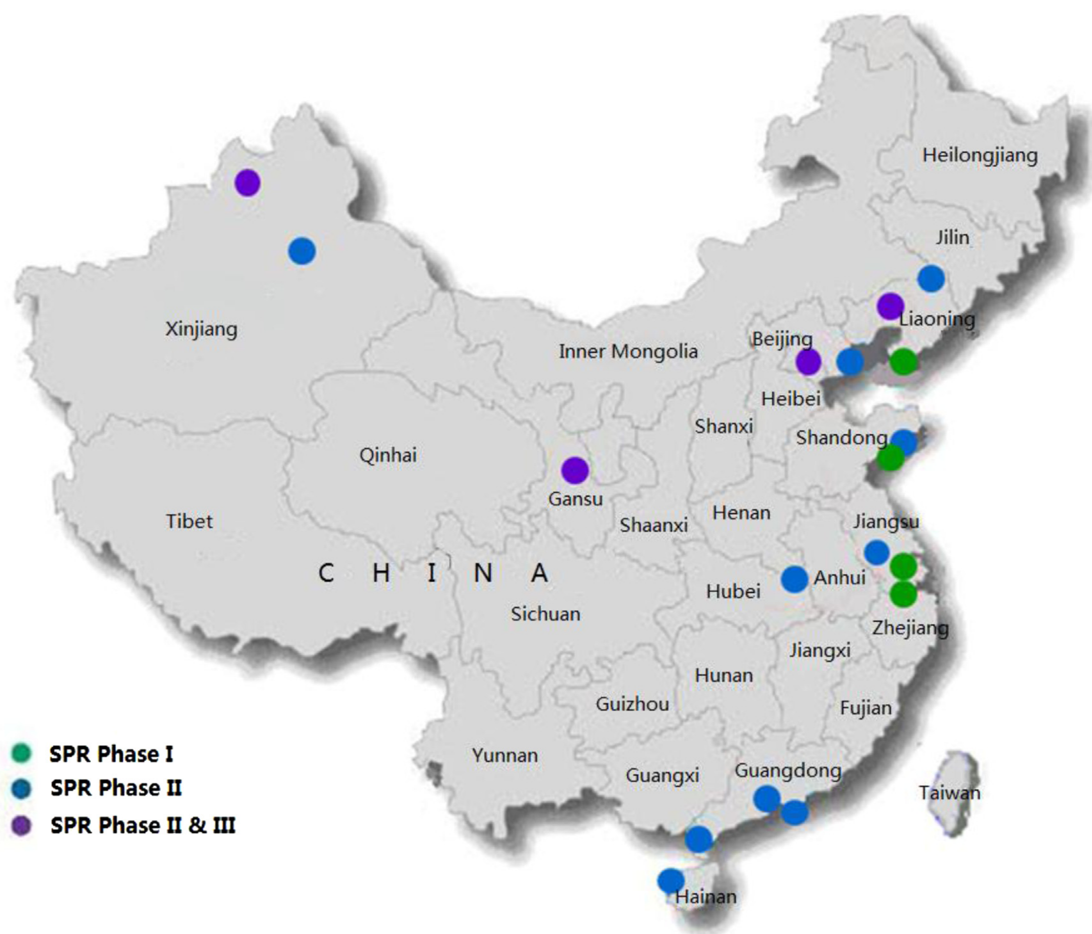

Fig. 1. Layout of China's SPR sites for three phases.

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