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Using stockpile delegation to improve China's strategic oil policy: A multi-dimension stochastic dynamic programming approach

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HIGHLIGHTS

- We provided an auxiliary strategic oil policy rooted in Chinese local conditions.
- The policy strengthen China's capability for preventing oil supply interruption.
- We model to obtain the managing strategies for China's strategic petroleum reserve.
- Both of the public and delegated oil stockpile were taken into consideration.
- The three phase's construction process of China's SPR was taken into account.

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ABSTRACT

There has been much attention paid to oil security in China in recent years. Although China has begun to establish its own strategic petroleum reserve (SPR) to prevent potential losses caused by oil supply interruptions, the system aiming to ensure China's oil security is still incomplete. This paper describes and provides evidence for the benefits of an auxiliary strategic oil policy choice, which aims to strengthen China's oil supply security and offer a solution for strategic oil operations with different holding costs. In this paper, we develop a multi-dimension stochastic dynamic programming model to analyze the oil stockpile delegation policy, which is an intermediate policy between public and private oil stockpiles and is appropriate for the Chinese immature private oil stockpile sector. The model examines the effects of the oil stockpile delegation policy in the context of several distinct situations, including normal world oil market conditions, slight oil supply interruption, and serious oil supply interruption. Operating strategies that respond to different oil supply situations for both the SPR and the delegated oil stockpile were obtained. Different time horizons, interruption times and holding costs of delegated oil stockpiles were examined. The construction process of China's SPR was also taken into account.

1. Introduction

1.1. The strategic petroleum reserve (SPR) policy of China

Issues regarding the security of China's oil supply have been paid much attention recently. On the demand side, this has been largely owing to China's rapid growth in oil demand and high dependence on imported oil. According to Chinese official statistics, the demand for oil in China rose approximately 150% from 1996 to 2011 given China's strong economic growth and the dramatic growth of vehicle numbers in the country (NBS, 2009–2012). From the supply-side perspective, while there was slight growth in China's domestic oil production, there has still been increasing growth in imported oil supply (Fig. 1). In order to meet its rapidly growing oil demand, China has had to accept greater dependence on foreign oil. Furthermore, according to DOE/EIA (2013b), China is becoming the world's largest net oil importer this year. In the short space of 15 years, China has changed from a country that is self-sufficient in terms of its own oil production, into the biggest buyer in the world. As China's economy is steadily becoming more influenced by the world oil market, securing a stable and economical oil supply is becoming a key consideration for Chinese policy-makers in order to ensure China's continued energy supply and economic development.

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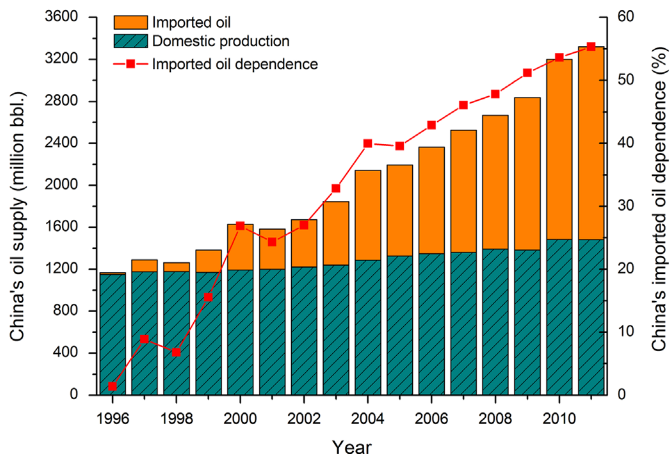

Fig. 1. China's oil supply sources and imported oil dependence: 1996–2011.

Like other oil net import countries, China has begun to establish its own strategic petroleum reserve (SPR). The SPR policy in China was much debated prior to its establishment. The main focus of the discussion was how to build a system that would ensure China's oil supply security. There was a consensus that the security system mitigating China's oil supply should not only consist of several oil stockpile sites but also policies, operating strategies, financial support and so forth. In 2001, the Chinese government finally decided to establish its own SPR sites; that is, oil stockpile sites. The locations of these sites were carefully chosen and spread all over the country, and the functioning of each site was implemented in three phases. Phase 1 began in 2003 and was completed in 2009. Four oil stockpile sites including Zhenhai, Zhoushan, Huangdao and Dalian, with a total storage capacity of 103 million barrels (equivalent to about 21 days of China's net oil import and 3.2% of total oil consumption in 2011), were built. Phase 2, set to completed in 2015, will involve another eight oil stockpile sites including Dushanzi, Zhanjiang, Huizhou, Lanzhou, Jintan, Jinzhou, Tianjin and Shanshan. By 2015, the total storage capacity of China's SPR will rise to 271 million barrels (equivalent to about 54 days of China's net oil import and 8.4% of total oil consumption in 2011) (Bai et al., 2012a). Phase 3 is still at planning stage. Once this is completed, it has been estimated that the storage capacity of China's SPR will rise to 500 million barrels (equivalent to about 100 days of China's net oil import and 15.5% of total oil consumption in 2011) by 2020, which is the ultimate target of China's SPR plan (DOE/EIA, 2013a).

In line with the experiences of Japan and the USA, bringing private oil storage capacity into the oil supply security system could be considered an auxiliary policy. The strategic oil stockpile systems in both Japan and the USA consist of public and private stockpiles. There were 46.81 billion liters (about 294 million barrels, equivalent to 84 days' of Japan's oil net import) of oil stored in public strategic oil stockpile sites in Japan, and 37.29 billion liters (about 235 million barrels, equivalent to 69 days' of Japan's oil net import) of oil held in private sites in August, 2013 (METI, 2013). About 44.3% of strategic oil is not in public stockpiling sites. Private storage capacities therefore play an important role in the Japanese oil supply security system. There were 368 million barrels (34.6% of total oil stored) of crude oil stored in the commercial stockpiles and 696 million barrels (65.4% of total oil stored) of crude oil stored in the SPR in December, 2013 in the USA (DOE/EIA, 2013c). Private stockpiles in the USA play important roles in the oil storage sector, too. Compared with the private stockpile capacity in these countries, there is still no room for private oil stockpiles in Chinese strategic oil policy.

Constructing public SPRs could therefore prevent China from potential economic losses caused by unexpected oil supply interruptions. However, building SPR sites should be just the beginning of building a system aiming to ensure China's oil supply security and economic security. Managing principles and relevant policies should also be proposed and implemented. The roles of private storage capacities also need to be taken into account.

1.2. *Studies relevant to SPR operating strategies and oil prices*

There have been several studies conducted relating to operating strategies for SPRs. Dynamic programming and game theory have been extensively used for this topic. For example, Nichols and Zeckhauser (1977) examined commodity stockpiling as a strategy to suppress future prices by employing a multi-period framework, and game theory. Their model began with a two-period framework under which a consuming nation and producer cartel played as two players. The consuming nation acquired the stockpile in the first period and released in the second period.

Other studies include Teisberg's (1981) multi-period stochastic dynamic programming method for operating the USA's SPR. This model incorporated oil import tariff or quota policy, which may be used in conjunction with stockpile management. Optimal stockpile acquisition and disposal strategies for the SPR were derived. This was considered a classic model for analyzing problems that arose in SPR management. Soon after, Wright and Williams (1982) developed a stylized model to analyze the roles played by public and private storage in the U.S. oil market. The model was based on inter-temporal arbitrage conditions and took oil price and holding cost, into account, among other elements.

William (1983) developed a Stackelberg game model to analyze the interactions between two oil consuming countries where one country acted as leader and the other acted as follower. Chao and Manne (1983) adopted a macroeconomic framework based on the maximization of the expected utility of consumption. They developed a dynamic programming model named STOCKPILE to analyze two U.S. policy choices: stockpiles and disruption 'tariffs'. Later, by assuming fixed fill up and release rates of the SPR, Oren and Wan (1986) built a model with lower computational cost than the dynamic programming models to determine SPR policies. Their model aimed to minimize the expected time-averaged insecurity cost to the U.S. economy due to uncertainty in the imported oil supply.

In contrast to these studies, Murphy et al. (1987) considered a broader view of there being many agents in the world oil markets, each with individual aims. They presented a discrete time Nash dynamic game model of interactions among oil inventory and tariff policies for oil import countries. In the latter study, they discussed interactions between public and private inventories and examined optimal strategies for building and using the SPR in the face of a private inventory response to both disruption risks and SPR policy (Murphy et al., 1989).

Operating strategies for China's SPR have also been discussed. Wei et al. (2008) developed a decision tree model based on cost function and quantified China's optimal SPR from 2005 to 2020. Wu et al. (2008) analyzed the optimal acquisition strategies for China's SPR by developing an uncertain dynamic programming model. Zhang et al. (2009) developed a stochastic dynamic programming model named SOSC model to determine China's optimal SPR size and strategies. This model includes both the acquisition and release strategies for several different situations from 2009 to 2039. Wu et al. (2012) developed a dynamic programming model and simulated optimal strategies for China's SPR in three different emergency scenarios, including a natural disaster scenario, financial crisis scenario and armed conflict scenario. Bai et al. (2012a) developed a tariff-stockpile model to