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Strategic oil stockpiling for energy security: The case of China and India

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ABSTRACT

Compared with the developed countries, the developing countries could be more vulnerable to oil supply disruptions due to their lack of strategic petroleum reserves (SPRs). Several developing countries, including China and India, are establishing their SPRs to ensure energy security. In the common world oil market, one country's SPR decisions can be affected by the decisions of other countries. This paper investigates the SPR policies of China and India, two of the largest developing countries, in a game-theoretic framework, where the interactions between the two countries are taken into account. The results show that players' equilibrium stockpiling strategies and total expected costs could vary significantly with the initial oil market state, stockpile acquisition capacity and the probabilities for disruptions to persist.

1. Introduction

Energy is a vital resource for development in modern society, and this is especially true for developing countries due to their rapid-increasing energy demand in the process of industrialization and urbanization. This makes the security of energy supply become an increasingly important concern in developing countries such as China and India. Moreover, the world oil market is subject to a number of factors, including strikes, political instability or wars, natural disasters, or cartel action, which may lead to disruptions or contingencies in oil supply and consequently result in supply shortage, price increases, and possible decreases in the output and employment of an oil-consuming country. The recent political crisis and instability in Middle East and North African countries have heightened such a concern about energy security and the potential risks of oil market disruptions. Once the world oil supply is interrupted, not only the economic activities but also the social stability in oil-consuming nations could be affected substantially. Therefore, it is of great importance to take effective measures to reduce the vulnerability of an oil-consuming country to oil supply disruptions.

The oil market disruptions during the oil crisis in 1970s gave a heavy strike to the major industrial countries and it triggered a wave of concerns about energy security. The risk of oil disruptions drove many industrial countries to take measures to ensure their energy security, e.g., through the establishment of strategic petroleum reserves (SPRs). For instance, the United States started its SPR in 1977 and reached 590 million barrels in size in 1990, just before the outbreak of the Gulf War. After some further stockpile acquisitions during the early 2000s, the current size of the US SPR is maintained at around 700 million barrels (EIA, 2015a). Besides, the concern on energy security after the oil crisis leads to the establishment of the International Energy Agency (IEA) in 1974, which serves as an international energy policy organizer for the member states to coordinate the stockpile releases in emergency oil supply scenarios.

With the rapid growth of their economy and oil consumption, the developing countries are playing a more and more important role in the world oil market and become an increasingly important concern when modeling the world oil market (see, e.g., Skeer and Wang, 2007; Wu and Zhang, 2014). For instance, the share of China and India's oil imports in the world traded oil in 2014 is about 16% and 10%, respectively, which implies that China and India in total accounts for more than a quarter of the world oil imports (BP, 2015) and that the developing countries would suffer greatly once the oil market is disrupted. However, while many developed countries have already established their SPRs to energy security, most developing countries did not start their preparations until recently. For instance, the Chinese government officially approved the establishment of an SPR in 2001 to ensure its oil security; The Indian cabinet approved a plan for the establishment of an SPR in early 2004 to provide an emergency response mechanism

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against disruptions of oil supplies and the Indian government has declared its intention to adopt IEA standards for strategic oil stock deployment. However, the inherent fungibility of oil in the world oil market implies the essential international character of an energy security policy (Hogan, 1983). This implies that in the common world oil market, one country's SPR decisions can be affected by the decisions of other countries. Therefore, it is reasonable to investigate the SPR policies in a game-theoretic framework, where the interactions among oil-stockpiling countries (such as China and India) can be taken into account.

The SPR policies, aiming at enhancing energy security, have been widely analyzed since the oil crisis in the 1970s. A number of studies have examined those policies from a point view of a single country. Teisberg (1981) developed a dynamic programming model for the SPR of the U.S., which could be used to determine the optimal SPR size, acquisition and drawdown strategies for the U.S. in various scenarios. Samouilidis and Berahas (1982) established a decision-tree model, based on a cost function which included procurement, maintenance, and shortage costs, to evaluate a number of SPR-size scenarios. Samouilidis and Magirou (1985) presented a concise analysis for the optimal selection of oil-stockpile size for a small country, based on the work of Samouilidis and Berahas (1982). Chao and Mane (1983) presented a multi-period dynamic programming model for obtaining optimal stockpile sizes and petroleum usage rates based on an analysis of U.S. oil supply policies. Oren and Wan (1986) presented a dynamic programming approximation model to conduct a steady-state analysis of the optimal size, buildup, and drawdown rates for an SPR under various supply and demand conditions. Zweifel and Bonomo (1995) developed a model which could address multiple energy-supply risks and illustrated not only that one-dimensional rules such as an "oil reserve for 90 days" are suboptimal, but also suggested that certain adjustments could make them even more suboptimal. However, these studies ignored the strategic interactions among oil consuming nations. As we have mentioned above, in a common world oil market, any stockpiling acquisition/release action of one country would affect the other countries. This should be taken into account in the studies of SPR policies.

Another literature employed a game-theoretic framework to take into account the interactions among different agents in SPR policy analysis. Balas (1981) developed a short-run game between importing nations and a politically motivated cartel that takes advantage of disruptions to inflict economic losses on importing nations to determine the desirable SPR size for the U.S. and the drawdown policies in case of an embargo. He examined the "deterrence effect" of a strategic stockpile, which means the value of a strategic reserve when the stockpile not only reduces the economic losses from a disruption, but also reduces the likelihood of a disruption. Hogan (1983) extended Teisberg's model to a Stackelberg model to examine the interactions of stockpiling policies, including optimal stockpile buildups and releases, between two oil-consuming countries where one follows the other's lead, where he found that there are substantial benefits for the player who leads. Hubbard and Weiner (1986) addressed the motivations for private and public stockpiling in an inter-temporal optimizing model for the U.S. and found that the dampening price effects of public releases will serve (although slightly) to discourage the private sector's speculative stock build. Murphy et al. (1987) established a Nash dynamic game model of interactions among the oil-inventory and tariff policies of oil-importing countries to analyze the SPR policies of oil-consuming nations, including U.S., Japan, and Germany. They found that the differences between non-cooperative and coordinated stockpile (build-up and drawdown) polices appear to be minor, due to the inventory limits on the U.S. and foreign Strategic Petroleum Reserves. Murphy et al. (1989) presented a Nash dynamic game model to examine the interactions between the public-sector and private-sector oil-inventory policies in uncertain world oil markets, where they found in general, the total two player build-up and drawdown are the same as the public build-up/drawdown when there is no taking account of private inventories. All these studies on developed countries provide valuable references for the modeling of SPR policies in the developing countries.

In the context of developing countries, studies have increased rapidly in recent years due to greater concerns about the energy security in the developing world. Wei et al. (2008) conducted an empirical analysis of the optimal SPR size for China based on a decision tree model and suggested that China's optimal SPR size should be the equivalent of 30–60 days of net oil import, when the oil price is $50/bbl. Wu et al. (2008) presented an uncertain programming model for analyzing acquisition strategies for China's SPR and showed that the future stockpile acquisition is related to oil prices and their probability. Zhang et al. (2009) analyzed the optimal size of China's SPR and the best acquisition and drawdown strategies for several scenarios based on a stochastic dynamic programming model. Bai et al. (2012a) examined the optimal path for China's SPR acquisition in several scenarios based on a dynamic programming analysis and suggested that China's optimal stockpile acquisition rate should be increased from 19.2 to 52 million barrels from 2008 to 2020 with no oil supply disruption and the acquisition rate should be much lower when an oil supply disruption occurs. Wu et al. (2012) also employed a dynamic programming model to investigate the optimal stockpiling and drawdown strategies for China's SPR under various scenarios of (exogenous) oil prices, where they found that the optimal stockpiling and drawdown strategies of China's SPR are very different in different emergency conditions (natural disaster, armed conflict, and so on). Bai et al. (2012b) developed a two-period non-linear optimization model to explore China's optimal tariff rate and stockpile size, where they recommended higher tariff rate and lower stockpiling size, in contrast with current tariff and stockpiling policy. Zhang (2014) employed a stochastic dynamic programming framework to investigate China's optimal strategic stockpiling polices, taking into account the possible tariff/quota polices. He found that the combination of optimal tariffs and SPR policies could substantially reduce the expected oil insecurity cost for China; the effect is larger when the probability that a disruption will continue is higher. Again, these studies on China's SPR policies fail to take into account the interactions with other oil-stockpiling countries duo to their single-country context.

However, very few studies have investigated the energy security policies of developing countries in a multiple-country context to take into account the strategic interactions among stockpiling countries. Fan and Zhang (2010) established a dynamic Nash game to model the possible mutual influences between the SPR polices of China and India in various cases. Though illustrative results and important implications were obtained, there are a number of shortcomings in their study. For instance, they focus on the comparison of stockpiling strategies rather than the total oil insecurity cost of different countries in equilibrium, thereby ignoring the equilibrium payoffs of players in different situations. Moreover, only the purchase cost and stockpile holding cost were considered in their study for simplification, which implies that they ignore the loss of consumers' surplus due to price increase by stockpile acquisitions or supply disruptions that was highlighted in the literature (see for instance, Teisberg, 1981; Hogan, 1983; and Murphy et al., 1987), which implies that their results can be somehow distorted. This paper tries to fill these gaps and to answer the following questions — what the optimal stockpile build-up/drawdown strategies and total oil insecurity costs for China and India would be in a game-theoretic setting; how the optimal strategies and total costs will be affected by different factors, including the initial SPR sizes, the acquisition capacity limits, and so on; and what policy implications can be obtained from the comparison of strategies and costs across different cases.

The rest of this paper is organized as follows. Section 2 presents the dynamic game of strategic oil stockpiling. The implementation of this model is described in Section 3. Section 4 presents and discusses the