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Interfaces with Other Disciplines

Developing a market-based approach to managing the US strategic petroleum reserve

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ABSTRACT

The Strategic Petroleum Reserve has not been used effectively to manage the consequences of oil shocks in the United States. The main reason is that political decision makers tend to hoard the reserves during crises and bureaucratic processes delay the sale of the reserves. Also, the enabling legislation focused on ameliorating shortages whereas disruptions result price spikes rather than shortages. We develop a Markov game of the buildup and drawdown of the reserve in which a public player aims to maximize consumer welfare at the same time private holders of inventory maximize their profit. The methodological contribution in this paper is the development of financial options to implement the public player's optimal policy. We use the solution of this game to calculate the number and value of options necessary for the private marketplace to trigger the optimal buildup and drawdown of the reserve.

1. Introduction

The recent 2008 run up in oil prices and increased price volatility, along with the US government's continuing additions to the US Strategic Petroleum Reserve (SPR) during a period of high prices have led to new debates on SPR policy. In early 1975 the US Congress authorized the SPR in response to an attempt by Arab OPEC members to impose a directed embargo against the United States. Because this embargo failed to cut off US imports, the research and planning for the SPR focused on using the reserve to dampen price spikes and associated macroeconomic impacts due to losses in supply. The SPR holds 724 million barrels of oil and private crude stocks have ranged between 280 and 375 million barrels in 2008 and 2009. Thus, the SPR constitutes 2/3 of US crude stocks.

The first papers on the optimal level of the SPR drew from early work on storing grain for famine protection, Gustafson (1958). The first storage models by Balas (1979) and Teisberg (1982) optimized the buildup and drawdown of a reserve using dynamic programming. There is a free-rider problem in building the SPR because crude prices move in tandem around the world and others benefit from the US inventory withdrawals without having to pay any of the costs of building and storing inventory. Hogan (1983) looked at the free-rider problem of one country benefiting from another country's expenditure on a strategic reserve. He used a Stackelberg game with the US the leader in making decisions and other countries lumped into a single player that follows the leader.

Murphy et al. (1986, 1987, 1989), as part of a project for the Office of Policy of the Department of Energy, examined international free riding on a US reserve and the interaction of public reserves and private crude oil inventories. They formulated a Nash game and developed an algorithm to find an equilibrium in an infinite-horizon game where the market states were described by a Markov process. See Chao and Manne (1983), Samouilidis and Magirou (1985) and Oren and Wan (1986) for other models of the reserve. All of these models were built before forward markets for crude and petroleum products were developed. Companies now buy and sell in futures and options markets to manage their risks. An oil producer can guarantee revenues by selling in forward markets. A refiner can buy crude oil futures and sell product futures to lock in a significant portion of its margins. Companies that consume large amounts of oil such as airlines can protect themselves from market volatility using forward markets.

The use of financial tools and improved business processes has meant that the ratio of the volume of inventory to the volume of sales has been in long-term decline. A byproduct of the inventory reduction is that there is less of a physical cushion, adding to the increased volatility in spot markets when disruptions in the supply chain occur.

Financial markets have directly affected the valuation of private stocks. One measure that is used to understand the marginal value of inventory in company operations is convenience value, an estimate of the value of the last barrel in inventory in facilitating operations. Convenience value is discussed in Pindyck (2001) and Considine and Larson (2001), where they estimate the value using financial markets, based on the relationship of spot and futures

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prices. Milonas and Henker (2001) also estimate the impact of price spreads on convenience values.

The contributions of this paper are the following. From a policy point of view, we explore an alternative way to manage the strategic reserve based on financial options. We develop a model that computes the number of options to be issued in order to replicate the optimal welfare policy. Next, we construct an example, illustrating the size, drawdown, and buildup policies and the social welfare benefits of the SPR and estimate the size of the options market required to support government policy. Finally, we develop an improved solution methodology for the Markov game that allows us to use standard optimization software, unlike earlier approaches, e.g., Murphy et al. (1986, 1989).

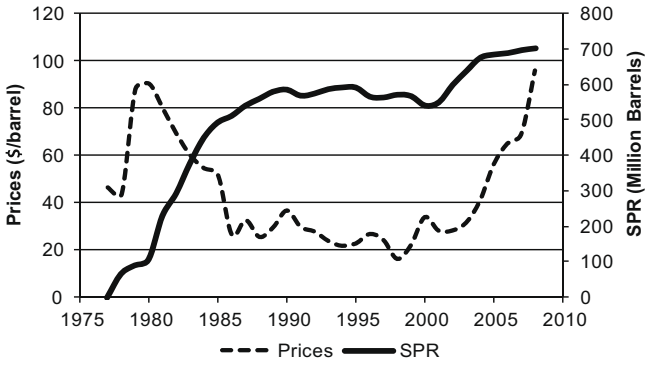

Fig. 1. SPR Levels and Crude Oil Prices over Time (1977–2008).

2. Reconsidering the SPR

A reserve makes sense only if there are losses that can be ameliorated through a government-held stock versus private inventories that are externalities to the internal costs of disruptions to the industry. The chief externality is macroeconomic impacts. Hamilton (2003) finds that oil price increases dampen economic activity, decreases do not have the mirror-image benefit to the macro-economy, and increases that are price recoveries from recent falls do not have as strong a predictive effect on the macroeconomy as an increase from a baseline price. Huntington (2007) shows that real incomes decline immediately, followed by the lagged effects on GDP.

The measured relationship between oil prices and economic activity has weakened since 1985, according to Hooker (1999) due to the activity of governments that have learned how to better manage the impacts of commodity shocks (see Bernanke et al., 1997), and because the recent studies were done during an era of low oil prices, see Jones et al. (2004) for an extensive review of this literature. From simulations done in 1992 at the Energy Information Administration, volatility was more important than price levels (Energy Information Administration, 1992, Appendix F). Since average monthly oil prices increased from $15 to $95 between 1998 and 2008, in real 2006 dollars, the oil share of domestic expenditures has increased several fold and oil-product costs are now crowding out other purchases by consumers.

Gordon (1992) was one of the first to argue that the government should not hold a reserve. Considine and Dowd (2005) show that there have been problems with the timing and amounts of sales from the reserve. Taylor and Van Doren (2005) state that "the government ought to cut its losses by selling the oil and shutting the program down." Considine (2006) develops a model of crude markets with Saudi Arabia acting as a constrained monopolist that undertakes actions to negate the value of a strategic reserve. Williams and Wright (1991, ch. 15) point out that most arguments for storage beyond the macroeconomic argument do not hold up to scrutiny. They note that the reserve can provide a strategic advantage over an intentional embargo by taking away the economic value of the embargo. However, this argument does not apply to the kinds of disruptions that historically have affected oil markets, which have been collateral damage from events such as the Iraqi invasion of Kuwait or the overthrowing of the Shah of Iran.

The main reason for reconsidering the SPR is that the US government has not proved to be adept in managing the reserve. Fig. 1 presents real yearly average crude oil prices (in 2006 Dollars, source British Petroleum, 2009) versus the SPR size in millions (source Energy Information Administration, 2009), from 1977 to 2008. A DoE (2009) website summarizes the draw downs, and highlights the problem. The two main draw downs occurred around Iraq's invasion of Kuwait and Desert Storm in 1990–1991 and to replace domestic production and imports after hurricane Katrina in 1995.

The 1990–1991 events illustrate the weakness of DoE procedures. Iraq invaded August 2, 1990. Crude from the first sale of 4 million barrels flowed on October 19th, a two and one half month delay to replace less than three days of Kuwait's exports. Then 17.3 million barrels were released between February 5 and April 3 1991. Again too little too late to lessen the subsequent recession.

The government responded better to Hurricane Katrina in 2005 with the hurricane hitting in late August and oil beginning to flow in late September. In 2008, after hurricanes Gustav and Ike, the SPR delivered over 5 million barrels of oil to companies that had lost supply in exchange for barrels delivered between January and May of 2009. So, although a portion of the high prices in 2008 was due to disruption threats in countries like Nigeria, the US government made no guarantees that the SPR would cover potential shortfalls, which it could not do because of the cumbersome sales process.

In 1996 and 1997 the SPR sold 28 million barrels at an average price below $20, nominal, to reduce the federal deficit and cover SPR expenses. On the purchase side, the highest fill rates were, understandably, during a period of high oil prices at the beginning of the reserve program. The high fill rate continued into the mid 1980's, a time OPEC's share of the market was falling and Saudi Arabia was losing its capacity to support prices by cutting production, signaling that prices were headed down. Once the price dropped precipitously, the fill rate declined.

Government policy can be described as skipping purchases and selling during periods of low prices because there is no immediate threat, being late on using the reserve in response to world issues, and acting quickly with exchanges of oil to address domestic disruptions because of a standardized contract structure for the exchange.

Several authors suggest using markets to determine the amounts to drawdown. Like much of the literature, these papers are old and focus on the issues of hoarding and panic buying. Devarajan and Hubbard (1984) note that a reserve can forestall hoarding by private inventory holders. Adelman (1982) proposes a preset price at the highest price of the day plus a year's storage cost. This restricts purchases to firms that have higher internal shortage costs than the market price and do not have access to oil.

Historically, hoarding has been more of a problem with governments than with private players: purchases by the French and Japanese governments during the height of the Iranian crisis in 1979 drove prices much higher. Governments are more problematical than the private sector because the public decision makers do not face the financial losses from buying at the peak and score political points by showing that they are doing something to address anxieties with their purchases and hoarding of oil.