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ECONOMIC IMPACT ANALYSIS OF NATIONAL NATURAL GAS STORAGE

Natural gas storage is meaningful for governments undertaking national energy risk management at the potential stage. The analytical solution used in this study is based on the DIS-Risk simulation model developed by P.N.Leiby & D.Jones (1993) in order to analyze strategic petroleum reserves. Annual natural gas supply disruption is simulated herein via the beta probability distribution, and then it affects annual natural gas import prices, supply and demand. Finally natural gas supply disruption causes gross domestic product (GDP) losses and higher natural gas import costs. As the result of the Monte Carlo simulation for 5,000 times results in the domestic natural gas supply disruption, the national natural gas storage capacity is estimated as the range from 1.30 to 2.25 million tons. The economic effect of avoiding losses ranges from US$ 10,9 billion to US$ 17,7 billion and the total cost US$ 3,4 billion to US$ 5,6 billion over a thirty-year period from 2006 to 2035.

Природные хранилища газа имеют значение для правительств, управляющих энергетическими рисками на национальном уровне. Аналитическое решение, предлагаемое в данной работе, основывается на математической модели DIS-Risk, разработанной P.N.Leiby & D.Jones (1993) для оценки стратегических запасов нефтепродуктов. Ежегодные сбои поставок газа моделируются посредством бета-распределения вероятностей, влияют на стоимость импортируемого природного газа, на спрос и предложение. Сбои поставок газа приводят к снижению валового внутреннего продукта и увеличению затрат на импортируемый природный газ. В результате моделирования по методу Монте-Карло для сбоев поставок природного газа емкость национальных хранилищ природного газа оценивается в 1,3-2,25 млн т. Экономический эффект от предотвращения таких потерь составляет от 10,9 до 17,7 млрд дол.США, общие расходы в пределах от 3,4 до 5,6 млрд дол. США с 2006 по 2035 гг.

INTRODUCTION

Michael Regester & Judy Larkin (2005) suggest the issue and risk lifecycle analysis method in risk management is made up of the potential, emerging, current, crisis, and dormant stages. Natural gas storage is meaningful in effective risk management for diminishing or reducing the shock of a quantitative energy crisis at the potential stage.

METHODOLOGY

The analytical solution used in this study is based on the DIS-Risk simulation model (P.N.Leiby & D.Jones, 1993; P.N.Leiby & D.C.Bowman, 1997; P.N.Leiby & D.C.Bowman, 2000; P.N.Leiby, 2003). In this model, several stockpile sizes are compared side by side. They are subjected to the same random disruptions as simulated in Eq.1. Natural gas supply disruption size depends upon the beta probability distribution, same as in the case of petroleum. Annual reserves are specified in terms of cost and target size. Natural gas supply disruptions are simulated against reference paths for natural gas prices, supply and demand, as seen in Eq.2:

$$\left[\frac{\Delta_g(t)}{D_{kr}(t)}\right]\times 100 \sim beta(\alpha,\beta), \quad (1)$$
$$\Delta_{st}(t) = \max\{\Delta_g - S_S,\ 0\};$$

$$P(\Delta_{st}) = P_{kr}\left(\frac{D_{kr}-\Delta_{st}}{D_{kr}(t)}\right)^{1/\varepsilon(\Delta_{st})}, \quad (2)$$
$$\varepsilon(\Delta_{st}) = a(t) + b(t)\Delta_{st},$$

where $\Delta_g(t)$ is the domestic natural gas supply disruption, $D_{kr}(t)$ is the base natural gas demand, $P_{kr}(t)$ is the base natural gas import price, S_s is the natural gas supply through national storage in the function of offsets, $\Delta_{st}(t)$ is the effective domestic natural gas supply disruption after offsets, $P(\Delta_{st})$ is the effected natural gas price after disruption, and $\varepsilon(\Delta_{st})$ is the elasticity of demand effected on the natural gas supply disruption.

After offsets, if $\Delta_{st}(t)$ is not zero, then natural gas supply disruption affects natural gas import prices, supply and demand. Finally natural gas supply disruption causes gross domestic product (GDP) losses and higher natural gas import costs, as in Eq.3 where σ is the elasticity of the GDP brought about by natural gas price levels.

$$C_{import}(P(\Delta_{st})) = (P(\Delta_{st}) - P_{kr})(D_{kr}(P(\Delta_{st})) - S_{kr}), \quad (3)$$
$$C_{GDPloss}(P(\Delta_{st})) = GDP_{kr}[1-(P(\Delta_{st})/P_r)^{\sigma}].$$

The economic impact of non-covered natural gas supply disruption is quantitated as an expected net benefit in the present value of year 2005. The expected net benefit is dependent upon avoiding GDP losses and higher natural gas imports, offsetting the costs of natural gas storage construction costs and operation costs including overseas natural gas purchase and domestic provision costs.

DATA AND ASSUMPTIONS

In this analysis model, first to be distributed is $\Delta_{st}(t)$, the domestic natural gas supply disruption size and probability. Through the historical analysis of oil market disruption, Park & Lee (2002) determined natural gas supply disruption distribution as $beta(0.15,\ 3.7991)$, the distribution with a 1,3 % probability in disruption size from 10 % to plus infinite. In this analysis, the distribution of Park & Lee (2002) is accepted but the disruption is limited to 15 % in size. The duration of the natural gas supply disruption is assumed to be *uniform* (1, 6), the uniform probability distribution from one to six months considering the seasonal fluctuation of natural gas and the findings of Park & Lee (2002).

Secondly, the base economic factors for the natural gas are determined as follows: $P_{kr}(t)$, the base natural gas import price, is set by the Energy Information Administration (EIA), 2005, Annual Energy Outlook; $D_{kr}(t)$ and GDP_{kr}, the demand and GDP, are set by the EIA, 2005, International Energy Outlook.

When the domestic natural gas supply disruption after offsets is effective, thirdly, the elasticity factors are determined as follows: the elasticity of the natural gas import price affected by natural gas supply disruption is determined as 4 under the original DIS-Risk assumption and considering the findings of Park & Lee (2002); the elasticity of demand affected by the natural gas supply disruption is determined as -0,09483 through an analysis of Gang (2004) short-term demand elasticity of natural gas products such as town gas and electricity; the elasticity of the GDP affected by the natural gas price level is determined through an annual weighting analysis under the DIS-Risk assumption and taking into consideration the findings of Park & Lee (2002). For example, in 2006 it is 0,081 %.

RESULTS AND DISCUSSION

Using this model and data, the economic impact over the next thirty years (2006 to 2035) is determined as follows. All values are calculated in year 2004 values and the discount rate is 7 %.

First, the Monte Carlo simulation for 5,000 times results in the domestic natural gas supply disruption as shown in Fig.1. The probability of the natural gas supply disruption is smaller as the size of the natural gas supply disruption is larger.

Second, as a result of the disruption and base supply and demand, the national natural gas storage capacity is estimated as shown in

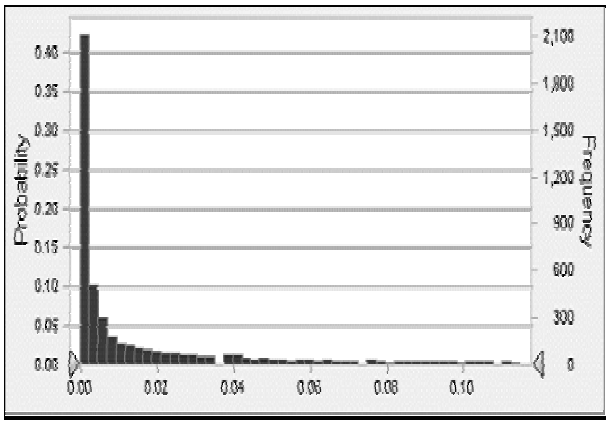


Fig.1. Supply disruption distribution

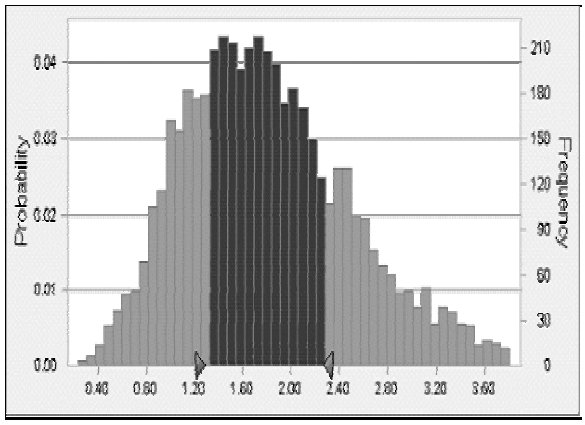


Fig.2. Expected national storage capacity (in million tons)

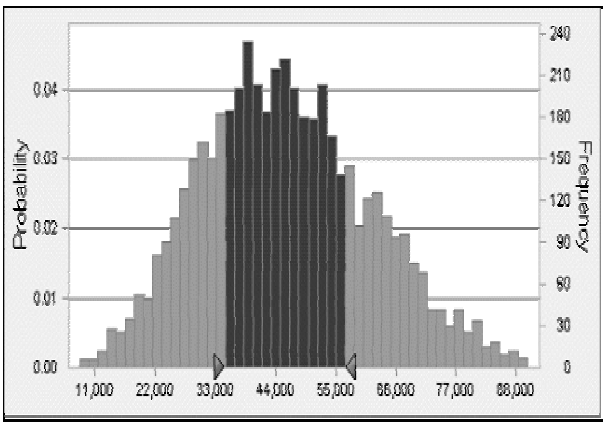


Fig.3. Expected benefits (in US$ 0,1 million)

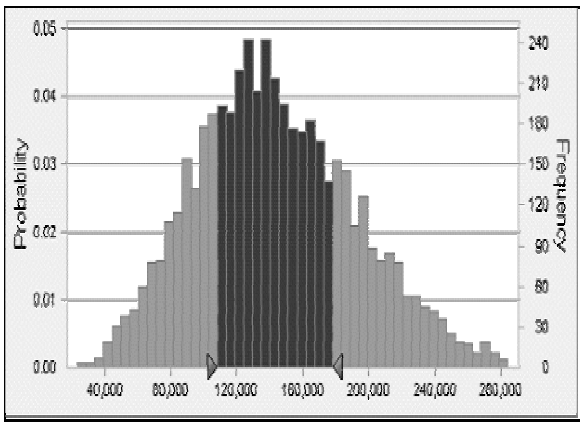


Fig.4. Expected costs (in US$ 0,1 million)

Fig.2: the minimum is 230,000 tons, the maximum is 4,56 million tons, the median is 1,73 million tons, the average is 1,82 million tons; and the 50 % confidence interval excluding extreme cases ranges from 1,30 to 2,25 million tons.

Third, a disruption of the natural gas supply should create economic losses, but releasing national natural gas storage in effect avoids losses. The disruption of the natural gas supply increases natural gas import costs despite decreasing demand for natural gas because of the extreme increase in the natural gas prices.

The effect of avoiding an increase in natural gas import costs is as follows: the minimum is US$ 1 billion, the maximum is US$ 16 billion, the median is US$ 5.9 billion, the average is US$ 6.1 billion, and the 50 % confidence interval excluding extreme cases ranges from US$ 4,6 billion to 7,5.

The effect of avoiding GDP losses is as follows: the minimum is US$ 1,3 billion, the maximum is US$ 21 billion, the median is US$ 8 billion, the average is US$ 8,3 billion, and the 50 % confidence interval excluding extreme cases ranges from US$ 6,3 billion to 10,2.

The total effect of national natural gas storage is as in Fig.3: the median is US$ 14,0 billion, the average is US$ 14,5 billion, and the 50 % confidence interval excluding extreme cases is from US$ 10,9 to US$ 17,7 billion.

Finally, the total costs for national natural gas storage are shown in Fig.4: the minimum is US$ 0,8 billion, the maximum is US$ 11 billion, the median is US$ 4,5 billion, the average is US$ 4,6 billion, and the 50 % confidence interval excluding extreme cases ranges from US$ 3,4 billion to 5,6. These costs are considered the gas losses in a 0,04 %/day boil off rate in the underground storage case.

LITERATURE

Y.Y.Gang, 2004, Long-term Polices and Strategies on the United Nations Framework Convention on Climate Change, Korea Energy Economics Institute.

C.W.Park & *Y.K.Lee*, 2002, the Risk Premium and the Proper Level of Emergency Oil Stockpiling, Korea Energy Economics Institute.

Energy Information Administration (EIA), 2005, Annual Energy Outlook.

Energy Information Administration (EIA), 2005, International Energy Outlook.

Michael Regester & *Judy Larkin*, 2005, Risk Issues and Crisis Management, Third Edition, KOGAN PAGE.

Paul N. Leiby, 2003, Improving Energy Security through an International Cooperative Approach to Strategic Oil Stocks, Presented at the International Energy Agency Seminar on Oil Stocks.

Paul N. Leiby & *David C. Bowman*, 1997, DIS-Risk Model for SPR Analysis: Model Documentation, Oak Ridge National Laboratory.

Paul N. Leiby & *David C. Bowman*, 2000, The Value of Expanding the U.S. Strategic Petroleum Reserve, Oak Ridge National Laboratory.

Paul N. Leiby & *Donald Jones*, 1993, DIS-Risk Model for SPR Analysis: Model Documentation and Benchmarking Results, Oak Ridge National Laboratory.