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## THE ROLE OF NUCLEAR POWER IN ENHANCING JAPAN'S ENERGY SECURITY

Energy security is a major public policy concern in Japan. Japanese energy consumption is among the highest in the world, but the country lacks significant domestic energy resources, with imports supplying more than 81 percent of primary energy requirements and 99 percent of fossil fuel requirements. This dependence leaves Japan's economy highly exposed to disruptions in international energy markets.

Prompted by energy security concerns, Japan has promoted measures to increase energy efficiency. Japan also has diversified its primary fuel requirement away from oil. Oil consumption declined from 77 percent of Japan's total primary energy use in 1973 to about 52 percent in 2002. Moreover, oil consumption has been relatively stable in recent years, rising only 0.5 million barrels per day to 5.3 million barrels a day in 2002 from 4.8 million barrels a day in 1988. This is a stark contrast to trends in neighboring China and South Korea, where oil consumption has more than doubled over the same period.

The existence of a negative relationship between oil prices and macroeconomic performance in industrialized oil-importing nations has been well-documented, and the oil shocks of the 1970s brought this relationship to the forefront of Japanese energy policy. Following the malaise of the 1970s, Japan acted to reduce the extent to which unexpected increases in oil prices would negatively impact macroeconomic performance of Japan's economy. Government policy, along with economic and technological factors, have resulted in increased use of natural gas, nuclear power, and coal to generate electricity, thus facilitating Japan's declining oil dependence.

Oil continues to play a prominent role in the Japanese economy, however. Indeed, an investigation into historical trends reveals that, after accounting for the changing share of oil in total energy use, rising oil prices have a significant negative impact on Japanese macroeconomic activity as growth measured by gross domestic product (GDP). Conversely, oil price increases are less detrimental as the share of oil in total primary energy use declines.

Expansion of nuclear power has been a cornerstone of Japanese energy policy over the past two decades. Nuclear power has been favored as an alternative source of energy, not only because it enhances energy security but also because it allows electric utilities to meet stated environmental objectives. Japan has plans to increase nuclear generation capacity by up to 30 percent (roughly 10 to 12 power plants) through 2010.

If the additional nuclear power plants are not built, Japan faces an eventual shortfall of as much as 28 gigawatts, which will require turning to other energy sources to meet the deficit. This could translate into additional imports of up to 1.2 million barrels per day of oil, or 186.7 billion cubic meters per day of liquefied natural gas, thus increasing Japan's exposure to potential supply disruptions.

Proponents of nuclear power point to its low operating costs and the historically stable costs for uranium fuel, especially when compared to oil or natural gas. They assert that the stable costs, in particular, demonstrate that nuclear power contributes to Japan's energy security as uranium does not face the same commodity price risk of other fuels for power generation. In addition, Japan has been able to source uranium imports

from different, and arguably more reliable, foreign suppliers than its oil and gas providers.

Nuclear accidents, however, such as the major incident in 1999 at Tokaimura, have undermined public confidence in atomic power. That accident—a radiation leak caused by human error at a fuel reprocessing plant—killed two workers exposed to high levels of radiation and forced the evacuation of thousands of nearby residents. A later scandal, involving falsified data and other reports of accidents and mishaps, forced an eight-month closure of 17 plants for inspection in 2003. The nuclear crisis, which led to electricity shortages in Japan, contributed to tightening of world oil markets as Japanese utilities were forced to burn imported crude oil to make up for lost nuclear-generated electricity supplies. Japan's oil use was roughly 300,000 barrels a day higher in 2003 than a year earlier due to the disruption in nuclear power generation.

Japan's series of nuclear problems have raised questions about the role of nuclear power in the country. Among the issues being debated is the importance of nuclear power in Japanese energy security.

To quantify the energy security value of nuclear power to Japan, the James A. Baker III Institute for Public Policy conducted an economic modeling study. The study considered only the benefits derived from nuclear power's role in reducing the economic impact of an oil price shock. Specifically, the study was primarily concerned with the savings, in terms of macroeconomic output, associated with the development of nuclear capacity. Although the research did not take into account other operational issues about nuclear power, such as waste-disposal and the potential costs of nuclear accidents, these questions would be interesting to explore in the future.

The modeling exercise quantified the energy security value of nuclear power generation in Japan, giving consideration to a number of issues, including:

1. The magnitude and probability of sudden cost increases or supply shortages of imported oil and gas;
2. The damage to the Japanese economy from such oil and gas price increases or supply disruptions, including loss of GDP;

3. The economic and security risks that would follow from a partial or total elimination of nuclear power from Japan's energy mix;
4. The dollar value and security benefits provided to Japanese society by the existence of nuclear power; and
5. The relative value and costs of expanding nuclear power's share of Japan's electricity system against other fuel sources.

The modeling exercise took into account: available fuels; possible price scenarios; electricity demand trends varying according to differing assumptions about future GDP growth, population growth, and weather; and requirements for pumped storage as a means to meet fluctuations in demand. Fuels were chosen on the basis of technologies believed to be commercially viable in Japan over the next 30 years. The impact of environmental policies also was taken into account. Among the fuel/technologies used in the study were nuclear, coal integrated gas combined-cycle, coal super-critical, combined-cycle fuel oil, steam (simple-cycle) fuel oil, combined-cycle natural gas, and combustion turbine natural gas.

The simulation added new capacity only if the discounted present value of the margin between the anticipated wholesale electricity price and the marginal operating costs of production of the new capacity was greater than or equal to the capital cost of construction. If there are enough choices for the size, operating costs, and commissioning date for new capacity, the model can ensure that the marginal unit of new capacity will just recover its capital costs.

Historical fuel price data were used to approximate the relationships between prices of different fuels in Japan, while random fluctuations in oil prices observed in the past were used to simulate future shocks to the oil market. For the purposes of the modeling exercise, hydro and geothermal capacity were programmed to remain fixed. Wind and solar were set to grow according to government targets.

The model examined how Japan's economic performance might have fared in an energy crisis had the country never constructed nuclear facilities and compared those outcomes to the economic impact of a

future energy crisis under a business-as-usual scenario and other scenarios with fewer or more nuclear facilities in the energy mix.

The study found that there is a clear energy security value for nuclear power in Japan. Nuclear power can provide stable fuel costs on a day-to-day basis and protect overall national economic performance during times of disruption. A broad mix of fuels, including nuclear power, has helped Japanese consumers enjoy lower overall electricity costs. In addition, nuclear power has helped protect the Japanese economy from the negative impact of oil price fluctuations. For example, Japan's nuclear power capacity saves cumulatively about 2.0 trillion yen in GDP—or 42 million yen per megawatt (MW)—in the presence of a single 25 percent oil price shock when prices are otherwise stable over the study period. In this case, the simulation found the value of nuclear power to be about 42.0 million yen (U.S. \$382,132) per MW, or about 15.7 percent of the capital cost of constructing a nuclear power plant in Japan. Larger, more frequent oil shocks provide a higher value for nuclear power. For example, under a different scenario that included a large up-front shock followed by prolonged volatility in oil prices, the value of nuclear power rises to as much as 154.6 million yen (U.S. \$1.4 million) per MW of installed capacity, or the equivalent of 57.8 percent of the capital cost of constructing a Japanese nuclear power plant. This means that, under these extreme scenarios and ignoring potential externalities such as waste disposal and other environmental issues, a government subsidy to nuclear facilities may be justified.

It is possible, however, to stimulate too much investment in nuclear power. Specifically, the simulations demonstrate that fuel diversity is integral to maintaining system stability and keeping Japanese electricity prices low. Modeling results demonstrate that if all new electricity generating capacity in Japan were to be limited to nuclear power, electricity prices would increase substantially above their current levels.

Thus, while playing a key role in protecting Japan's economy from the potential cost of volatile oil prices, too heavy a reliance on nuclear power would actually raise the country's electricity costs to the point of

diminishing returns. On the other hand, if nonnuclear generating capacity had not been available during the recent staged shutdown of nuclear reactors in Japan, the costs would have been exceedingly high.

More generally, each type of generation capacity is best suited to meet particular loads. For example, while lower capital cost facilities are preferred when generating for peak demand periods, nuclear and coal-fired generation facilities are preferred baseload providers because their comparatively low variable costs and continuous baseload operation enable a steady opportunity to capture a margin between prices and operating costs that can be used to defray the large up-front capital costs. The analysis determines that there is a level of nuclear capacity for Japan that is cost-minimizing, indicating that movement toward a level of nuclear capacity that is either above that level or below it will raise the overall costs of electricity generation in Japan.

Since it is possible to push the use of one particular type of fuel beyond its efficient level, a government should be careful in employing subsidies to encourage artificially the use of particular fuels. The impact on overall electricity costs must be weighed against the value of promoting energy security for the society as a whole.

The model suggests that the most cost-effective fuel to replace nuclear power in Japan from an energy security point-of-view, disregarding environmental considerations, is coal. Coal prices are the lowest on a British thermal unit (BTU) equivalent basis and the least variable of the remaining fuels. Like uranium, coal also is sourced from different suppliers than is oil or natural gas and this, too, helps it contribute to energy security. On the other hand, while new clean coal technology avoids problems of SO<sub>X</sub> and NO<sub>X</sub> pollution, a potential issue is that the clean coal process does not eliminate CO<sub>2</sub> emissions. Natural gas, in particular, when used to fuel high-efficiency combined-cycle generation plants, would be next as a potential alternative in terms of cost. Natural gas has clear environmental benefits compared to coal. Still, the results of this study suggest that the Japanese government is correct in its pursuit of clean coal research and development.

## CONCLUSION

The study demonstrates that there is a clear benefit from the use of multiple fuels to generate electricity. This benefit comes not only from lowering overall electricity costs to Japanese consumers but also from protecting the national economy from the negative economic effects of a major international energy disruption, such as the oil crises of the 1970s. The implication is that government subsidies to promote fuel diversity may be justified. Without such subsidies, individual firms may not take these broader national energy security effects of fuel choices into account when selecting new generation capacity.

The findings also indicate limitations of government intervention in electricity fuel markets are necessary. In the case of promoting nuclear power, the overall energy security contribution and benefit to the national economy must be judged against other consequences outside the scope of this study. Moreover, the study results also indicate that a certain level of nuclear capacity is cost-minimizing and that movement toward either too much nuclear capacity or too little will raise

the overall costs of electricity generation in Japan.

More generally, diversity of fuel sources increases flexibility to keep overall costs low during sudden or prolonged disruptions. Having alternative choices also helps keep costs low in the face of more normal day-to-day fluctuations in fuel prices. Our simulation demonstrates that electricity prices will be, on average, lowest when there are no constraints on construction of new capacity. After examining various oil price shock scenarios inside the bounds of historical experience, the security value of nuclear power was estimated to range from 12 percent to 58 percent of the capital cost of constructing a nuclear power plant in Japan.

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