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Analyzing public preference and willingness to pay for spent nuclear fuel facilities in South Korea: A latent class approach

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ABSTRACT

Spent nuclear fuel tends to emit superheat and high levels of radiation, posing a serious threat to human beings and the natural environment, and, thus, warrants special treatments. However, most countries generating nuclear power are yet to achieve a public consensus on the construction and operation of spent nuclear fuel facilities. In this study, we quantitatively analyzed the heterogeneous preferences of the South Korean public regarding spent nuclear fuel facilities and estimated the public's marginal willingness to pay using a choice experiment survey and a latent class model. Then, using the estimation results, we simulated the rate of public acceptance with respect to the construction and operation of such facilities. The results revealed that public preference regarding spent nuclear fuel facilities is divided by two classes on the basis of two heterogeneous preference structures. In addition, we found that the majority of the public was expected to prefer a permanent repository, followed by temporary storages, and an interim storage. Finally, we also confirmed the validity of management options for spent nuclear fuel using a cost-benefit analysis and we concluded that the construction and operation of an interim storage or a permanent repository facility is not economically viable at this time.

1. Introduction

Since the first commercial nuclear power plant began operations in the 1950s, nuclear energy has globally become a major energy source for electricity generation given its advantages of relatively cheap generation costs and low greenhouse gas emission in comparison to other energy sources. As of 2014, 435 nuclear power plants (375,000 MW) have been operating in 31 countries and 10.8% of the total amount of globally consumed electricity is generated from nuclear energy (International Energy Agency, 2014). In addition, 70 new nuclear power plants (75,000 MW), which account for 20% of the total capacity of operational nuclear power plants, are currently under construction (World Nuclear Association, 2015a).

Nuclear power plants generally require uranium fuel to generate electricity. However, nuclear fuel tends to emit superheat and high levels of radiation and, thus, requires special treatment once spent because it can pose a severe threat to human beings and the natural environment (Bassett et al., 1996). Despite these possible dangers, many countries using nuclear power are yet to implement a management policy. This can be attributed to lacking internationally accepted best practices to manage spent nuclear fuel. In addition, existing management policies largely differ across countries (Högselius, 2009). For instance, the United States, Canada, Sweden, and Finland plan to maintain their spent nuclear fuels in a centralized interim storage for about 40 years and, thereafter, permanently dispose of them in a deep geological layer. On the other hand, France and the United Kingdom have proposed to reprocess their spent nuclear fuels, reuse them for electricity generation, and, then, permanently dispose of the final waste in a deep geological layer (European Academies Science Advisory Council, 2014; U.S. Department of Energy, 2013). In addition, most of countries with a spent nuclear fuel management plan have a difficult to achieve a public consensus on the construction and operation of spent nuclear fuel facilities and, thus, they are contemplating how they will manage spent nuclear fuel. The U.S. government, for example, planned to construct a permanent repository in the state of Nevada and a centralized interim storage in the state of Utah, which were then canceled in 2010 and 2013,

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respectively. In fact, only Sweden and Finland have identified a construction site for a spent nuclear fuel facility and Finland is the only country that has begun its construction.

In the case of South Korea, the nation utilizes a high proportion of nuclear energy to generate electricity. In 2014, South Korea generated 30.2% of its total electricity through 23 nuclear power plants (20,716 MW). Unfortunately, it is one of the countries yet to formulate a management policy for nationally spent nuclear fuel (Ministry of Science, ICT and Future Planning, 2014). At present, South Korea temporarily stores their spent nuclear fuel on the site of existing nuclear power plants. However, these temporary storages are already saturated by about 70% and some of them are expected to completely saturate by 2024 (Public Engagement Commission on Spent Nuclear Fuel Management, 2014). Therefore, it is very likely that the South Korean government will have to cease operations of all nuclear power plants, unless it draws up a spent nuclear fuel management plan and follows a plan of action (i.e., construction and operation of a new spent nuclear fuel facility). To tackle this issue, in 2013, the South Korean government set up a Public Engagement Commission on Spent Nuclear Fuel Management to collect public opinions on the issue and attempted to formulate a spent nuclear fuel management plan on the basis of its activities. However, South Korea is yet to achieve an actual public consensus, making it difficult for the government to take a decision.

Consequently, it is crucial for governments to correctly identify public perception, attitude, and preference towards spent nuclear fuel and its related facilities to establish public consensus and design a viable spent nuclear fuel management plan, that is, the construction and operation of new spent nuclear fuel facilities. According to some survey-based studies (Bassett et al., 1996; Jenkins-Smith et al., 2011; Slovic et al., 1991), the public recognizes spent nuclear fuel management as a far more dangerous and important issue than nuclear power generation. Thus, governments should focus more on carefully planning spent nuclear fuel management than expanding nuclear power generation. Flynn et al. (1993) and Sjöberg (2004, 2009) identified a negative relationship between public trust in the government's spent nuclear fuel management policy and perceived risks from spent nuclear fuel. In other words, governments need to build trust relations with the public to lower the perceived risk from spent nuclear fuel and acquire a consensus on spent nuclear fuel management policy. However, to the best of our knowledge, only few studies provide practical implications for governments on public responses to alternatives for spent nuclear fuel management policies and policy design to establish public consensus.

All policy options require continuing payments by taxpayers in some form and the potential for social conflict is always present when people hold very strong and opposed views on a policy issue that they deem to be very important (Carlson et al., 2016; Sjöberg, 2003). Thus, to establish a socially acceptable spent nuclear fuel management policy, governments must understand the public's heterogeneous preferences regarding the specific attributes of facilities, such as storage method, storage depth, spent nuclear fuel reprocessing, procedural democracy, and cost. This is particularly important in the case of South Korea, which needs to formulate a spent nuclear fuel plan to maintain nuclear power generation.

Therefore, in this study, we propose a quantitative method based on a choice experiment survey and a latent class model to analyze the South Korean public's heterogeneous preferences regarding spent nuclear fuel facilities and estimate the public's marginal willingness to pay (MWTP), on the basis of the specific attributes of such facilities. Then, from these results, we simulate the rate of public acceptance with respect to the construction and operation of spent nuclear fuel facilities. Furthermore, we conduct a cost-benefit analysis based on the public's MWTP for different types of spent nuclear fuel facilities and confirm their economic validity.

The remainder of this paper is organized as follows. Section 2 describes the choice experiment design for spent nuclear fuel facilities, as well as the survey data and latent class model. Section 3 presents the quantitative analysis results for customer preference and MWTP for spent nuclear fuel facilities, followed by the simulation results for the hypothetical scenarios of spent nuclear fuel facilities, and verifies the economic validity of spent nuclear fuel facility options using a cost-benefit analysis. Section 4 provides concluding remarks and policy implications for the South Korean government.

2. Methodology and data

In this study, we estimated public preference and MWTP for spent nuclear fuel facilities and simulated the rate of public acceptance for the construction and operation of new spent nuclear fuel facilities. Moreover, we derived the respective benefits of all facilities and compared them with their estimated cost to check the economic validity of the spent nuclear fuel management options. To this end, we collected the public's stated preferences regarding these facilities using a choice experiment survey and then analyzed the data using a latent class model.

2.1. Choice experiment design

To design an appropriate choice experiment for spent nuclear fuel facilities, it is necessary to identify its core attributes and assign their levels accordingly. The choice experiment survey in this study repeatedly presents the respondents with a hypothetical scenario of spent nuclear fuel facilities, constructed from the core attributes specified at certain levels, and asks respondents to choose the most preferred alternative (Louviere et al., 2000).

First, construction and management options for spent nuclear fuel were considered as attributes that describe spent nuclear fuel facilities. As mentioned, South Korea has been increasingly storing spent nuclear fuels at temporary storage sites at nuclear power plants; however, the capacity of some of these storages is expected to be completely saturated within the next decade. To resolve this problem, the South Korean government has considered expanding temporary storages in nuclear power plants or constructing an interim storage[1] or permanent repository. The method of expanding temporary storages, however, simply extends South Korea's current method of managing spent nuclear fuels and its operational lifespan is expected to be about 10 years. Moreover, although such a method involves no purchase cost or social conflict (i.e., external cost), it is clearly a short-term solution. Constructing an interim storage, on the other hand, entails the management of spent nuclear fuels by transporting the fuels from multiple nuclear power plants to the storage. In addition, an interim storage is unlikely to face a capacity saturation problem for the next 100 years, and can be efficiently and safely operated since it has concentrated control over spent nuclear fuels. However, the method is a mid-term solution to wait for final treatment and, thus, can be deemed an unnecessary investment.

A permanent repository, by contrast, is built on a site identified as appropriate and is used to dispose and permanently seal spent nuclear fuels. It is an ultimate and permanent solution that secures sufficient storage capacity for spent nuclear fuels. However, a

[1] The temporary storage facility is a small spent nuclear fuel storage facility located inside an operating nuclear power plant. It is for temporary storage of spent nuclear fuel from the operating nuclear power plant. Meanwhile, the interim storage facility is centralized and stores spent nuclear fuel from several nuclear power plants, though it is also not for final disposal.