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Study Plans Concerning Monetary Evaluation of Mitigation Measures for the Fukushima Daiichi Accident

Fumihiro Yamane[a]*, Kyohei Matsushita[b], Hideaki Ohgaki[c], Kota Asano[d]

[a]Graduate School of Economics, Kobe University, 2-1 Rokkodai-cho, Nada-ku, Kobe 657-8501, Japan
[b]Faculty of Economics, Shiga University, 1-1-1 Banba, Hikone, 522-8522, Japan
[c]Institute of Advanced Energy, Kyoto University, Gokasho, Uji 611-0011, Japan
[d]Graduate School of Human and Environmental Studies, Kyoto University, Nihonmatsu-cho, Sakyo-ku, Kyoto 606-8501, Japan

Abstract

The Fukushima Daiichi accident raises various kinds of social unease in Japan. Especially, unease for radioactive contamination around the Fukushima Daiichi plant is serious. Also, around the other nuclear power plants, local residents would feel unease for a similar accident in the future. Although the government and the electric power companies have already implemented or plan to implement several measures to mitigate such unease, it is difficult to progress their policies effectively because the effect of each measure is not quantitatively clarified. The purpose of our research is to evaluate these effects by analyzing fluctuations in local property values and local residents' economic welfare, which are monetary indexes reflecting the social unease, to construct information that is useful to plan an optimal package of mitigation measures in each nuclear power plant site from the viewpoint of cost-benefit analysis. In this paper, we explain the immediate plans of this research and its academic and political contributions.

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Keywords: Fukushima Daiichi accident; mitigation measure; monetary evaluation; property value; residents' economic welfare; risk perception

1. Introduction

The Fukushima Daiichi accident was caused by the Great East Japan Earthquake occurred on March 11, 2011. After that, around the Fukushima Daiichi nuclear power plant (NPP), huge amounts of

* Corresponding author. Tel.: +81-774-38-3423; fax: +81-774-38-3426.
E-mail address: fumihiro.yamane@gmail.com

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radioactive contamination has raised serious social unease about its harmful influence on local residents' health. This contamination has also had negative effects on local economy. For instance, local farmers and fishermen have suffered from the export restrictions imposed on their products whenever the sample tests detected radiation doses exceeding the temporary radioactive standard values in their products. Even if the tests prove those safeties for consumption, they have suffered from stigma.

Moreover, this unprecedented accident has no small effects on other NPP sites. In fact, all NPPs in Japan went shutdown for safety checks, so-called "stress tests." Although the third reactor in the Oi plant was restarted from July 2012, local residents in the surrounding area would be anxious about a similar accident in the future. On the other hand, for the other plants, lengthy shutdowns would have negative influences on relevant business in local areas: e.g., accommodations, eating and drinking services, and retailing for workers engaging in operations and routine maintenances.

Therefore, social unease due to the Fukushima Daiichi accident would cause several economic losses in each NPP site. In more detail, such social unease reduce the attraction of each local society (comfortability of living there, activeness of the economy, expectation of the social and economic developments in the future, and so on), and consequently cause local residents' economic welfare losses and property value losses. Actually, as mentioned in the next section, we had already confirmed significant declines of property values on some NPP sites in Japan before and after the accident.

Although the Japanese government and the electric power companies have already implemented or plan to implement several measures which are expected to mitigate the social unease, it is difficult to progress their policies effectively because the effect of each measure is not quantitatively clarified.

The purpose of our research is to evaluate these effects by analyzing fluctuations in local property values and local residents' economic welfare, which are monetary indexes reflecting the social unease, to construct a useful information to plan an optimal package of mitigation measures in each NPP site from the viewpoint of cost-benefit analysis. In this paper, we explain the immediate plans of this research.

In the next section, we briefly report our analytical results for property value losses in NPP sites in Japan. In section 3, to make our academic contribution clear, we explain the traditional definition of mitigation measure and bring in the improvement of local residents' risk perception as a new category of mitigation measure. The methods we intend to use are explained in section 4 and 5. The last section concludes and summarizes political implications of our research.

2. Nuclear power-related facility siting policy in Japan

In this section, we report the results about property value losses in NPP sites. This work was conducted as a part of "the Mobile Site Research," a research project by Institute of Sustainability Science, Kyoto University. However, we want to omit those details such as concrete values of parameter estimates because a part of these results was summarized as an article and now it is receiving reviews for publication in another academic journal.

The data we used was the *Prefectural Land Price Survey*, a database of land prices assessed by real estate appraisers in every July 1. Using panel data of lands (i.e., lands assessed in both July 2010 and July 2011) in each area described in Fig. 1 (see Table 1 for each sample size), we examined property losses within the framework of hedonic approach. In hedonic approach, "price function" for a certain commodity (e.g., lands) is estimated, which is a function of the commodity's attributes (e.g., land size, distance to the nearest station), to evaluate a market value of each attribute. In this way, we estimated property value losses caused by radioactive contamination and change in marginal values of proximity to NPPs by including the contamination index and distance from NPPs in the land price function of each area.

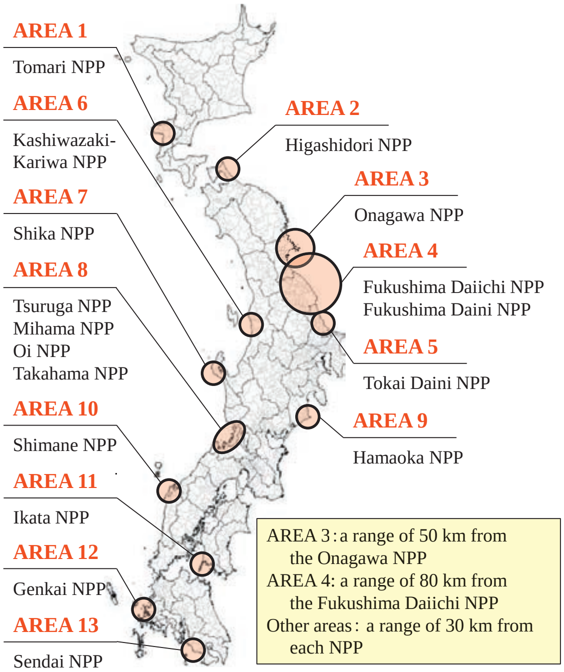

Fig. 1. Objective Areas for Hedonic Analyses

Table 1. Sample Size and Average Land Price

AREA	Sample Size	Average Land Price (yen / m^2) July 2010	July 2011
1	39	12,185	11,723
2	47	13,409	12,653
3	109	27,058	25,653
4	385	30,117	28,043
5	191	45,687	42,780
6	110	39,087	37,785
7	49	20,931	19,761
8	100	54,496	53,287
9	143	35,208	33,511
10	127	40,542	38,821
11	51	45,171	43,455
12	81	21,390	20,361
13	52	19,975	19,296

Each land price function is specified as double-log form. Land prices in 2010 were adjusted to 2011 level prices (yen/m^2) using the *Consumer Price Index*.

Regarding independent variables common to all areas, we included distances from NPPs (m), distance to the nearest station (m), distance to the nearest city with a population of 150,000 or more (m), distance to municipal public office (m), land lot size (m^2), width of front road (m), gas supply (dummy indicating whether gas was supplied in each property), water supply (dummy), sewage service (dummy), designation of city planning areas (dummies), designation of land use restriction (dummies), designation of fire prevention (dummies), fixed effects (unobserved attributes differing across properties but not varying over time), and time fixed effects (unobserved attributes varying time but not differing across properties). For AREA 3, 4, and 5, space radiation dose rate (μSv per an hour) was also adopted. In addition, for these three areas, we added a dummy variable, indicating whether each property was located inside the tsunami inundation areas, to distinguish between the effects of the NPP accident and the tsunami.

The estimation results suggested that land prices in AREA 3, 4, and 5 significantly and monotonically depreciated with space radiation dose rate (see Fig. 2 for a concept illustration of this result) and that the marginal value of proximity to the Hamaoka plant in AREA 9 significantly declined from 2010 to 2011 (see Fig. 3).

The former result would undoubtedly indicate property losses caused by radioactive contamination. To our best knowledge, this is the first case where a statistically significant impact of severe accident in a NPP is detected by hedonic approach. In case of the Three Mile Island accident in 1979, no significant evidence of property value losses was observed ([1] and [2]). On the other hand, there was no investigation on property value losses due to the Chernobyl accident in 1986.

However, we should note that the latter depreciation shown in Fig. 3 does not necessarily reflect only social unease for a similar accident in the Hamaoka plant in the future. Because this plant is located in the predicted hypocentral region of the Great Tokai Earthquake, which is forecasted to occur with an 87% chance within the next three decade, the depreciation has to strongly reflect the unease for the earthquake too. Nevertheless, we should carefully observe the future fluctuation of property values in this area with a mind to the following facts. After the Fukushima Daiichi accident, the previous Prime Minister Kan ordered a prompt shutdown of all reactors in the Hamaoka plant because of the forthcoming earthquake. The Chubu Electric Power Corporation decided to follow the order on May 9, 2011. Such a rapid response

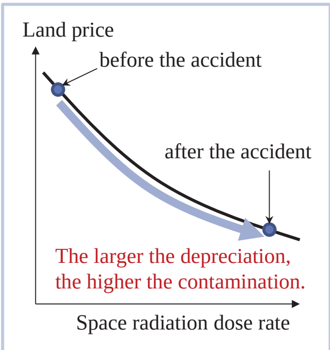

Fig. 2. Estimation Result for Relationship between Land Price and Radioactive Contamination in AREA 3, 4 and 5

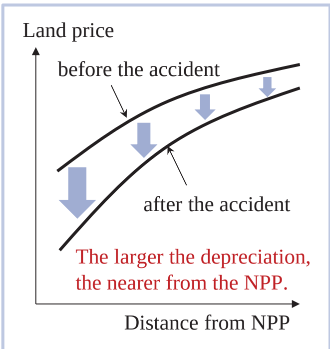

Fig. 3. Estimation Result for Relationship between Land Price and Distance from NPP in AREA 9

reflected a special sense of crisis for this plant, and, of course, may have social unease for a similar accident in the area larger.

3. Traditional definition of mitigation measures and its expansion

The necessity of "mitigation measures" was originally advocated in the discussion on how to compensate host communities of "not-in-my-backyard (NIMBY)" facilities (NPPs, toxic chemical factories, waste disposal facilities, etc.). Traditionally, such communities have been compensated by money (subsidies from the government, donations from the relevant firms or property tax revenues from the facilities). However, as summarized in [3], several studies had pointed out problems of monetary compensation from the viewpoint of moral or justice. In this stream, instead of money, public goods (roads, schools, hospitals, parks, etc.) came to be recommended as more acceptable compensations for public risk arising from NIMBY facilities. Especially, public goods (or services) directly contributing to reduce the risk were emphasized ([4] and [5]). This is the first time when the term "mitigation measures" appeared.

In the previous studies, mitigation measures were defined as engineering or institutional measures for reducing the risk. Engineering mitigations involve development and installation of risk reduction techniques. In today's case, for example, radioactive decontamination and radiation exposure examination for residents around the Fukushima Daiichi plant come under this category. For the other NPP sites, enforcement of seawalls, enforcements of reactors' resistance to earthquakes, pressure, and heat, and expansion of occasional sources of electricity would be included.

On the other hand, institutional mitigation consists of regulations on the operation of a facility (e.g., penalties for illegal operations or operational errors) or empowering local citizen for its risk management (e.g., revising safety agreements between electric power companies and local communities).

Unfortunately, except for [3] and [5], there seems to be little studies having attempted to quantitatively evaluate these measures in monetary term. The first contribution of our research is to fill this shortage.

In addition, we should also put a great importance on cultivation of citizens' knowledge for influence of radiation exposure on their health or for possibility of a similar accident in other plants in the future. Even if risks have been or will be reduced enough through the above measures, local economic losses would not necessarily be mitigated unless citizens learn correct knowledge of the risks. The reason is that citizens' risk perceptions are expected to affect their unease and consequently affect their economic welfare. For example, those who overestimate carcinogenic rate due to a certain level of radiation exposure or those who are quite ambiguous about the rate may feel additional welfare loss (See Fig. 4 for its concept illustration). Especially, "ambiguity" has been an important topic within the decision theory under uncertainty for a long time, and its negative effects on human welfare came to be confirmed empirically in recent years (e.g., [6] and [7]).

Actually, after the accident, shortage or confliction of risk information have seemed to fan public fear. In some cases, intemperate, inconsiderate, incorrect or spiteful information also spread through television programs, newspapers, magazines, books, internet, and social networking services. Especially, we are interested in negative effect of conflicting information. For instance, reference [8] empirically indicated that insurers less prefer a "conflicting situation" where all experts assessed the relevant risk precisely (i.e., they made point estimations of the probability that the hazard occur) but their assessments differ cross them to an "imprecise situation" where all experts had the same but imprecise risk assessments (i.e., interval estimations). According to [9], insurers dislike the confliction because they think that, in such a situation, at least some of experts have less information or such experts are unreliable and incompetent. However, these investigations were fictional (that is, the researchers ask the insurers to assume

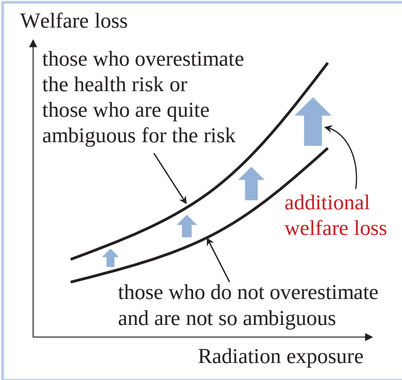

Fig. 4. Welfare Loss Due to Radiation Exposure and Influence of Risk Perception (a concept illustration)

hypothetical risks), and there has not been this kind of researches treating actual risks so far. We should note that the residents around the Fukushima Daiichi plant are faced with non-fictional risk.

In summary, improving citizens' risk perception would be important as well as engineering and institutional mitigations and should be included as a new category of mitigation measures. The second contribution of our research is to empirically investigate the relationship between risk perception of local residents living around NPPs and their economic welfare. In this process, we also intend to investigate the negative effect of conflicting information in the non-fictional situation.

4. Method I: land price analysis

To evaluate the effectiveness of engineering and institutional mitigations, we intend to watch the future fluctuation in property values around each area in Fig. 1. We can observe a semi-annual property value change by using the Prefectural Land Price Survey (a database of land prices assessed in every July 1) and the Published Land Price Survey (a database of land prices assessed in every January 1). Because, real estate appraisers use the same check sheet of attributes in both assessments, we can use these databases jointly in estimating the hedonic land price functions.

For each area, we analyze the semi-annual change while carefully considering status of implementation of mitigation measures: what kind of measures was implemented, to what extent, and when? That is "time series analysis for each area." Of course, we should also consider the possibility that the social unease would be going to calm down automatically as time goes by even if no measures were implemented. See Fig. 5 for a concept illustration of property value change around the Fukushima Daiichi plant, and also see Fig. 6 for other areas.

In this analysis, if two or more measures were implemented simultaneously in the same area, we cannot separate those effects. Thus, we also conduct "comparison analysis between areas," or more concretely, we regress area differences in property value change on area difference in status of implementation of mitigation measures. If the context of measures simultaneously implemented differs across areas, we can estimate the effect of each measure separately. This method is also called a meta-analysis, and [3] and [10] actually used it to investigate social factors causing regional differences in local property values across NPP sites in Japan and across Superfund sites in the U.S., respectively.

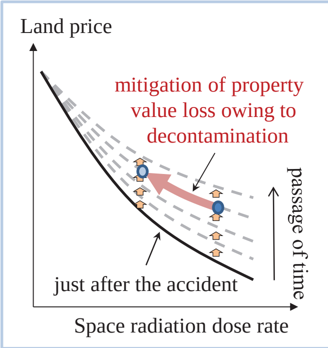

Fig. 5. Change in Property Value in AREA 4 (a concept illustration)

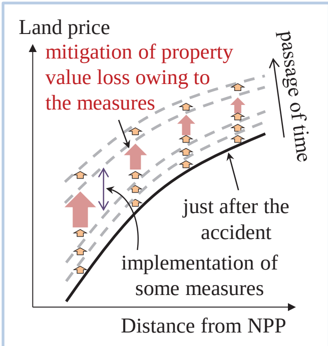

Fig. 6. Changes in Property Value in Other Areas (a concept illustration)

5. Method II: risk perception analysis

While the land price analysis would clarify a market value of each mitigation measure, it could not explicitly consider the risk perceptions for influence of radiation exposure on human health or for possibility of a similar NPP accident. Thus, we intend to conduct internet surveys for local residents around the Fukushima Daiichi plant and the other plants.

In the former survey, we use contingent valuation method (CVM) to estimate local residents' willingness-to-pay (WTP) for radioactive decontamination. If respondents state high WTPs, it is suggested that they feel those amounts of welfare losses for their present lives under contamination. We also ask their risk perceptions, that is, their subjective carcinogenic rates due to a certain level of radiation exposure (e.g., 5mSv). By including this information when estimating the WTP function, we could investigate the relationship between residents' risk perceptions (such as overestimation or ambiguity) and their welfare losses.

In the same survey, we also plan to set three hypothetical situations: (i) a "precise situation" where all experts have the same and precise risk assessments (e.g., all of them predict that carcinogenic rate will increase by X% due to radiation exposure of 5mSV), (ii) an "imprecise situation" where they have the same but imprecise assessments (e.g., all of them predict that the rate will increase by Y% to Z%), and (iii) a "conflicting situation" where they have precise but different assessments (e.g., while some of them predict that the rate will increase by Y%, the others predict that the rate will increase by Z%). By analysing how respondents change their risk perceptions and WTPs, we could investigate the effect of conflicting information.

For local residents around the other plants, we will conduct a similar survey while focusing on their perception for possibility of a similar accident in the plant and their WTPs for measures enforcing its safety.

6. Conclusion

The above plans are supposed to be conducted till the 2013 fiscal year with a financial support by Japan Science Technology Agency. However, regarding the land price analysis, it would be a too short period because the effect of each mitigation measure will appear slowly after its implementation. Therefore, we intend to continue this analysis over a longer period, and thus, we want to construct a proper framework for the future analysis within these two years.

In conclusion, we want to summarize political implications of our research. As mentioned previously, it would contribute to optimize mitigation measures in each NPP site from the view point of cost-benefit analysis. Also, if our research suggests a greatly high value of a certain measure such as radioactive decontamination while its cost is expensive, those results would motivate further technical developments to lower its cost. In addition, the risk perception analysis would indicate some guidelines for disseminating risk information or risk communication for local residents in the future: which is more problematic the overestimation or ambiguity, and does conflicting information make worse their ambiguity?

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