# Return Migration and Decontamination after the 2011 Fukushima Nuclear Power Plant Disaster

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Return migration is key to community recovery from many disasters. Japanese governments have conducted radiation decontamination efforts in the Exclusion Zone designated after the 2011 Fukushima nuclear disaster in order to encourage this outcome. Little is known, however, about the factors that influence post-disaster migrants to return, and if people are relatively unresponsive to decontamination, then the costs of promoting recovery may exceed the benefits. We exploit a unique survey of Fukushima evacuees to determine the factors that influence their decision to return after a disaster. Location-specific capital characteristics, such as housing tenure and the extent of property damage, are estimated to be strong factors. The radiation dose rate of the home location is found to be a statistically significant factor for intent to return, but its effect is small. We also found that households with various other characteristics were non-committal about the return option and likely to defer their decisions, which implies that "return" and "not-return" are asymmetric. Our simulation analysis found that the number of returnees encouraged by this decontamination was 12,882, or less than 8% of the total evacuees, while the decontamination cost per returnee was $3.36 million USD. This result implies that the government could have improved the well-being of evacuees at a lower cost by

policies other than decontamination.

## 1. INTRODUCTION

The Great Japan Earthquake of 2011 touched off a cascade of disasters, including catastrophic tsunami and associated flooding, culminating in the Fukushima Nuclear Power Plant Accident (Nagamatsu, 2014). Next to Chernobyl, this is the most severe nuclear accident to date. Although the amount of radionuclides released into the atmosphere was estimated as one-tenth that of Chernobyl (International Atomic Energy Agency [IAEA], 2015), the dispersion of radionuclides resulted in major contamination of the land, including soils, water, forests, and wildlife, as well as the North Pacific Ocean. Out of serious concern for the effects of the radiation, more than 160,000 people were forced or voluntarily evacuated to other areas of Japan at the peak of the out-migration. These situations are likely to increase in the future in the case of nuclear power plants, which number in the hundreds across the globe and are characterized by their technical flaws, age (often without adequate maintenance), vulnerability to many foreseen and some unforeseen disasters, and location near major population centers. Some analysts have noted the potential resurgence of support for nuclear power, especially because this form of electricity generation does not release greenhouse gases (see, e.g, Whitfield, Rosa, Dan, & Dietz, 2009), and due to rising costs of generation in many parts of the world (see, e.g., European Commission, 2010). Moreover, nuclear accidents do not seem to have a strong effect on public attitudes toward nuclear power in many countries, in part because prior beliefs about the technology are very important and not easily affected by real-world events (see, e.g., Siegrist & Visschers, 2013; but cf. Greenberg & Truelove, 2011).

The number of major disasters is on the rise worldwide, as population, economic growth, and in some cases, climate change increase exposure that outpaces efforts to reduce vulnerability through mitigation and resilience. The major issue is whether these migrations are best left permanent or whether repatriation is desirable. To great extent, this is a matter of individual choice, but societal concerns, such as ensuring survival of areas of cultural or economic importance, may be viewed as overriding them. Governments at various levels may then encourage repatriation by any of several policy instruments, including decree, incentives, environmental remediation of dangerous conditions, or clearing obstacles to return.

The specific characteristics of those who out-migrate following disasters varies based on the characteristics of the disaster, the affected population, and the degree of government support. Studies have shown that, in some cases, the poor are more likely to permanently or semi-permanently relocate in the immediate aftermath of a disaster because they are unable to return after mandatory evacuations or lack the financial capacity to repair their homes. In other cases, the wealthier portion of the population is able to move to safer areas while the poor are left behind. In both cases, the outflow of population can result in still further migration as the community is weakened by the reduction in the population. In such cases, return migration, or repatriation, is typically regarded to be an essential condition for community and economic recovery (Okuyama, 2015; duPont & Noy, 2015). However, population return has not been an easy undertaking in recent disasters, such as the Great Hanshin Awaji (Kobe) Earthquake of 1995 and Hurricane Katrina of 2005.

The objectives of this study are two-fold. First, we will explore what factors affect a Fukushima migrant's intention to return or not to return by an econometric analysis of a survey of Fukushima evacuees. Second, based on the empirical results, we evaluate the decontamination policy for repatriation of evacuees that was formulated by the Japanese national government. This study contributes to the literature on population repatriation by extending the standard dichotomous decision with regard to population return to include the indecision regarding the choice, which can reflect factors such as uncertainty, lack of readiness, and distrust of government. We also examine the effect of government efforts to reduce contamination on the decision to return. The methods are applicable to individual repatriation decisions for a broad range of disasters and to evaluating government policy regarding a range of environmental remediation efforts.

## 2. LITERATURE ON RETURN MIGRATION

Return migration after large disasters has been an issue of interest to many scholars in various fields (see, e.g., an early review by Hunter, 2005). The Hurricane Katrina disaster of 2005 and its slow recovery process triggered several important studies on the issue. Elliott and Pais (2006) investigated the effect of race and class on the intent to return to New Orleans by using Gallup poll data on Katrina survivors. They found that home ownership increased the likelihood of returning, and relatively high household income before the disaster decreased it.[1]

From an economic perspective, a theoretical model of return migration was proposed by Paxson and Rouse (2008). They built on the concept of “location-specific capital” (DaVanzo, 1981) and found that such variables as housing tenure and living in homes of relatives/friends had a significant effect on people’s intent to return, but that flood exposure is the single most important factor. Landry, Bin, Hindsley, Whitehead, and Wilson (2007) estimated the willingness to pay (WTP) of Katrina migrants to return home by modeling return probability as a function of wage differentials between their home (New Orleans) and host region (Houston). They found the differential was inversely significant, as expected, with an estimated WTP of $3,954. Yun and Waldorf (2016) presented a micro-level migration-income model, based on American Community Survey data of migrants affected by Hurricanes Katrina and Rita, and found that the forced migrants incurred an income loss as well as disaster damage, which they denoted as “double victimization.” With regard to other hurricanes, Xiao and van Zandt (2012) found a strong interdependence between businesses and households affecting the return after Hurricane Ike in Texas in 2008. They also found that housing damage and household income were inversely correlated with population return.

In contrast to Hurricane Katrina, fewer studies about population migration after the 1995 Kobe earthquake have been conducted. One exception is Chen, Maki, and Hayashi (2014), who identified three migration patterns after the disaster and determined how each pattern affected community resilience. However, their study did not focus on the motivation for the return migration. Aldrich (2011) found social capital (primarily family and institutional ties) to be the major factor affecting population return to Kobe following the 2005 earthquake, while Olshansky, Johnson, and Topping (2006) found community capital to be the major factor. Chang (2010) pointed out that population return to pre-disaster levels took 10 years and has been intertwined with structural and spatial

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[1]Other factors have been shown to affect population return, but are less pertinent to the Fukushima case. For example, Fussell, Sastry, and VanLandingham (2010) investigated the effect of race on returning after Katrina and found that black residents were more likely to return to their original (flooded) home than white residents. However, Reinhardt (2015) insisted that race does not have a direct impact on the intent to return, but rather works through political trust.

reconfigurations of Kobe, including the long-term downturn in port activity, shifts to service industries, and movement away from the urban center.

Due to their relative infrequence, migration behavior in response to nuclear accidents has not been investigated as much as other types of disasters. With regard to the 1986 Chernobyl nuclear power plant accident, the government of Belarus implemented a massive relocation program through 2000 for 13,616 people who lived in the highly contaminated area, with the entitlement of a new house and financial benefits such as an allowance and compensation for property loss. Because of the relocation, the contaminated region in Belarus experienced a large population decrease, especially among younger residents (World Bank, 2002). However, partly because of the decay of the radiation dose rate, some cities have been experiencing population recovery, with a significant decrease of out-migration. For example, in spite of the greatest population decline in Belarus since 1989, Rowland (2003) identified a population increase between 1999–2001 in the Narovlya Rayon (district), much of which lies in an "exclusion zone," supposedly due to return migration to the Rayon. However, the study did not identify the factors behind the return migration trend. Goldhaber, Houts, and Disabella (1983) determined the effect on residential mobility and population composition after the Three Mile Island nuclear accident of 1983. This study found demographic attributes of people who moved into the area were not different from those who had moved out.

Several studies of the Fukushima nuclear accident have focused on return migration. Orita et al. (2013) investigated the behavior of residents in Kawauchi village, only part of which was under the evacuation order. They used a logit model with 127 observations, of which 71 had not returned home, and found that the radiation dose rate and people's anxiety about radiation were independently associated with the intent to return. Munro and Managi (2017) investigated the effect of radiation on people's intention to return using a logit analysis based on personal interviews of 520 evacuees in the Fukushima and Miyagi prefectures. They found that the intent to return is only weakly responsive to decreases in ambient radiation levels, which implies that decontamination policy may have only a limited impact on eventual return migration. They also found that high-income individuals were more likely to return.

Our study of the return decision of Fukushima evacuees is much broader in scope, uses a much more extensive database, includes a larger number of explanatory variables, uses simulation methods to obtain predictions of repatriation if decontamination is undertaken, and obtains a wider range of new results. We also extend the binary repatriation decision by using a multinomial logit model to account for the possibility that respondents may remain undecided at the time of sampling. Specifically, our findings are that the intention to return or not to return are not symmetric with regard to several variables. Moreover, some of our other findings directly contradict previous results; for example, the effect of income on intention to return is negative.

## 3. FUKUSHIMA DAIICHI NUCLEAR POWER PLANT ACCIDENT OF 2011

### 3.1. Overview of the Event

The 2011 Fukushima Daiichi nuclear power plant accident, which was ranked as a "seven," the highest score on the International Nuclear and Radioactive Event Scale (INES), was one of the most serious nuclear disasters in human history. On March 11, 2011, a tsunami generated by a magnitude 9.1 earthquake flooded the basement of the plant's turbine buildings where the diesel generators and switchboards were located. This made the plant unable to provide electricity to cool the reactors and caused core meltdowns in reactors Nos. 1, 2, and 3, releasing significant amounts of radionuclides into the atmosphere. Following the emergency, an evacuation order was announced by the national government of Japan to the residents living in a 3-km radius area from the plant, but the area was subsequently expanded as the accident proved to be more serious.

On April 21, 40 days after the tsunami, the national government established several zones to control radiation. The "Evacuation Zone" (highlighted in blue in Fig. 1), in which no one except designated emergency responders was allowed to stay or visit, was set within a 20-km radius from the plant. A "Deliberate Evacuation Zone" (navy in Fig. 1) was established beyond the 20-km Evacuation Zone to include areas where the projected dose criterion of 20 mSv/year might be exceeded. Although the evacuation order had not yet been announced, the residents who lived in this area were required to move out within a month of the establishment of this zone. Finally, an "Evacuation Prepared Area in Case of Emergency" (orange in Fig. 1) was established to warn the people who live there to evacuate immediately if the situation at the plant were to become worse. Designation of this area was cancelled on September 30, 2011, as the condition of the damaged reactors became stable. Instead, as some areas outside the aforementioned evacuation zones were proven to have a projected dose rate above 20 mSv/year sporadically, the national government designated them as "Specific Spots Recommended for Evacuation" (IAEA, 2015).[2]

The "Evacuation Zone" and "Deliberate Evacuation Zone" had been strictly delineated under government control in March 2012. We henceforth term these combined areas as the "Exclusion Zone" in this study, because evacuation from these areas was mandatory. However, there were many other people who evacuated from areas outside the Exclusion Zone who primarily wished to protect themselves from the risk of radiation exposure. The national government, therefore, has distinguished these two types of evacuees – "mandatory evacuees" as the former and "voluntary evacuees" as the latter – and provided different categories of support programs. As of June 2012, approximately 164,000 people who had lived in Fukushima Prefecture evacuated at the peak. As of October 2014, 81,000 were estimated to have evacuated from the Exclusion Zone (mandatory evacuees), and the other 83,000 were from outside Exclusion Zone (voluntary evacuees) (Ministry of Environment, 2018). Among them, many people decided to remain far away from home. For example, the Futaba municipal government decided to temporarily relocate to Kazo city in Saitama, more than 200 km south, accompanied by 1,200 residents. According to the Ministry of Education, Culture, Sports, Science and Technology (MEXT), as of August 2011, about 56,000 people evacuated outside of the Fukushima prefecture; of these, 42,000 are mandatory evacuees, and 14,000 are voluntary.

[2]The threshold value of 20 mSv/year was set to the minimum value of the 2007 recommendation of the International Commission of Radiological Protection (International Commission on Radiological Protection [ICRP], 2007) on public exposure during emergency exposure situations.

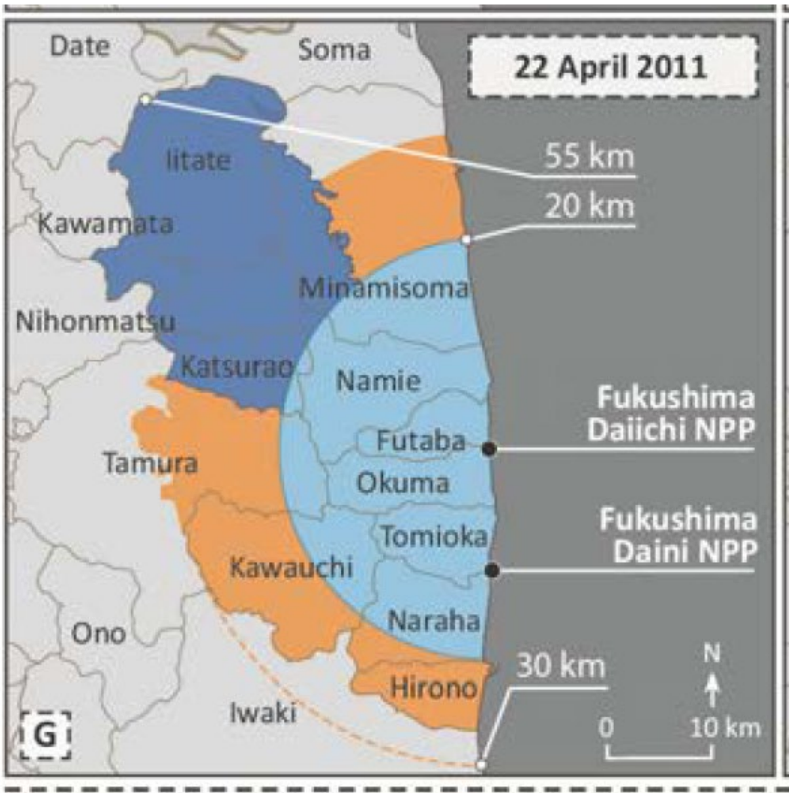


**Fig. 1.** Exclusion zones as of April 22, 2011.
Source: IAEA (2015).

### 3.2. Decontamination and Return Migration

The Fukushima prefectural government provided temporary housing units and job opportunities for those who evacuated from home. However, temporary housing was intended as short-term support until migrants returned to their hometowns (Maly, 2018). Job opportunities were also temporary, and most of them were part-time (Nagamatsu, 2014), in the expectation that the evacuees would return to their hometowns in the near future. However, returning home was a difficult decision for many of the evacuees that required careful consideration. Most of the radionuclide spread out from the plant was cesium-137, which has a half-life decay period of 30.1 years. It was long enough to make people doubtful of the full recovery of their hometowns. Many evacuees did not know if the decline in radiation could be accelerated by clean-up efforts. Further, even if it could, they still did not know how effective it would be, who could do it, and how. Partly because of such uncertainties, a significant number of people made up their minds not to return and to start life anew in the place to which they evacuated. Others did not make such a proactive decision, but many of them gradually found it difficult to return because they had rooted themselves in the community to which they evacuated.

For these reasons, cleaning up the contaminated area was considered by the national and local governments to be the most important and urgent task in both the Exclusion and non-Exclusion Zones, not only to eliminate the health risk, but also to encourage evacuees to return home. In particular, reducing the radiation dose rate in the Exclusion Zone was a necessary condition for lifting the evacuation order, repatriating the evacuees, and recovering peoples' livelihoods in the Zone.

In April 2012, the national government started to restructure the Exclusion Zone into three categories. The first area, where the radiation dose rate exceeded 50 mSv/year and was expected to be higher than 20 mSv/year even after 5 years, was named an "Area Where Returning is Difficult" in order to keep people away under evacuation order. The second area, where the radiation dose rate would possibly exceed 20 mSv/year and was planned to be under evacuation order for a while, was named a "Habitation Restricted Area." In this category, people were allowed to return home and stay for several hours, and to work on reconstruction of damaged infrastructure. The third area, where the radiation dose rate would certainly drop below 20 mSv/year, was named a "Preparation Area to Lift Evacuation Order." This area allowed people to return during the daytime and restart their businesses within the area. The revision to the area under evacuation order was completed in August 2013 (Ministry of Environment, 2018).

In addition to the categorization of the Exclusion Zone, the national government enforced the "Act on Special Measures" concerning decontamination in January 2012 (Ministry of Environment, 2018). Under this legal framework, the national government decided on a basic policy of decontamination in August 2012. This policy established a basic framework of decontamination where: 1) the national government was responsible for decontamination of the Exclusion Zone and for providing technical and financial support for municipal governments to implement the decontamination plan, and 2) in the areas where the radiation dose rate fell below 20mS/year (the "Preparation Area to Lift Evacuation Order"), the national government was responsible for decontamination work to lower the dose rate to less than 1mSv/year in the long term. Decontamination efforts in more contaminated areas (including both "Areas Where Returning is Difficult" and

“Habitation Restricted Areas”) were not designed to achieve a target dose rate; rather, their aim was to decrease the area of the restricted zone gradually and to start recovery work promptly. As of September 30,, 2017, the scale of the decontamination work undertaken and completed by the national government included 23,000 houses, 8,700 ha of farmland, 7,800 ha of forest, and 1,500 ha of roads (Ministry of Environment, 2018).

In spite of the fact that the official threshold value of radiation dose rate for exclusion was 20 mSv/year and above, this decontamination framework required the national government to perform greater clean up in many areas, as many people did not believe that exposure to 20 mSv/year was safe enough. Actually, the national government’s decontamination program has been successful in significantly decreasing the radiation dose rate in many areas, and evacuation orders have been lifted where the radiation dose rate was confirmed to be low enough. The lifting of the evacuation order has been implemented in a step-by step manner, and the Exclusion Zone is considerably smaller. The Exclusion Zone as of April 10, 2019, is shown in red and green in Fig. 2. The remaining Exclusion Zone mostly belongs to “Areas Where Returning is Difficult.” The area with green shading is where the evacuation order was lifted. The original population of the remaining Exclusion Zone was estimated at 22,973, about 23% of the number of initial mandatory evacuees.

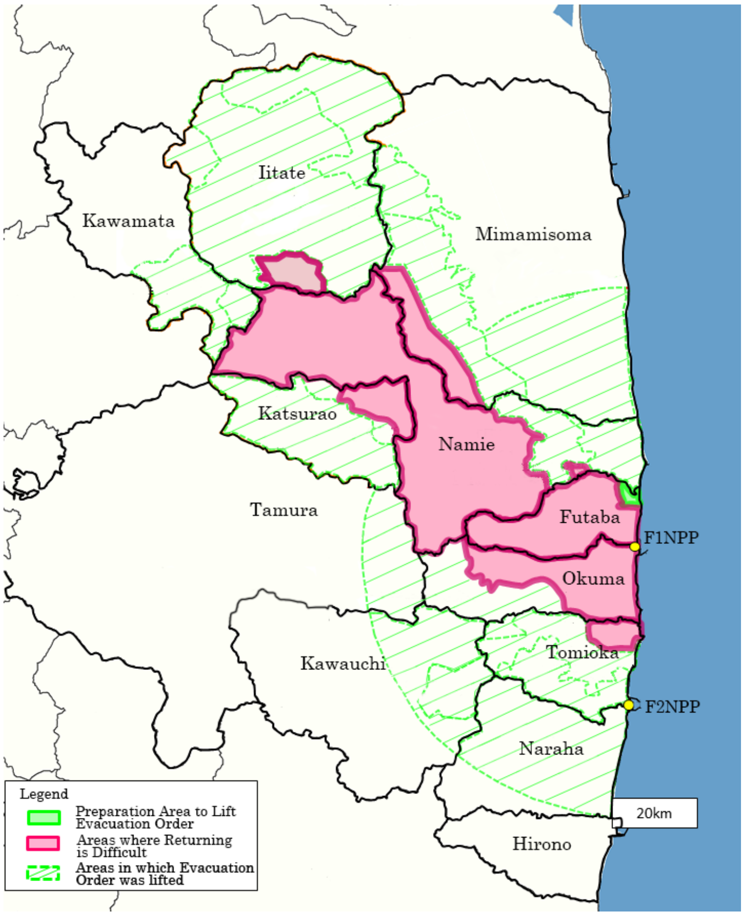


**Fig. 2.** Exclusion Zone as of April 2019.

Source: METI, edited by the authors

The decontamination work, on the other hand, has generated a serious issue of radioactive waste disposal. The Japanese government decided to construct an interim storage facility for preserving the waste in the towns of Futaba and Okuma, both of which were included in the "Difficult to Return" zone, and promised that the waste would eventually be disposed of outside of Fukushima (after about 30 years), expecting that the radioactivity of the waste would be reduced by half through natural decay. However, construction of the facility itself was not an easy task. For example, the national government needs to obtain ownership of the site, which requires them to contract with 2,360 landowners. However, only 64.4% of the buyouts had been made as of August 2018.

Table I shows the decontamination costs in the budgets of Japanese governments, both national and local. All costs are transformed in USD terms, assuming that $1 USD equals 112 JPY as of March 2016. The total cost of decontamination was estimated to be about $29.0 billion by March 2017, the end of fiscal year. The money actually spent was about $23.4 billion. In addition, the national government is estimating that $14.3 billion (16 trillion JPY) will be needed to construct the interim storage facility. The total cost of the treatment and storage of contaminated soil is estimated to be $43.3 billion (Ministry of Economy, Trade, and Industry [METI], 2016).

**Table I.** Decontamination Cost Covered by Japanese Governments (in USD)

Unit: million USD (USD1=JPY112)

| | Budget | | | Amout spent (closing) | | |
|---|---|---|---|---|---|---|
| | National | Municipal | Total | National | Municipal | Total |
| FY2011 discretionary | 140 | 1,713 | 1,857 | 121 | 1,716 | 1,838 |
| FY2011 supplementary | 847 | 935 | 1,783 | 122 | 766 | 888 |
| FY2012 initial | 2,391 | 931 | 3,322 | 2,287 | 904 | 3,190 |
| FY2013 initial | 2,633 | 1,812 | 4,445 | 2,582 | 1,782 | 4,364 |
| FY2013 supplementary | 4 | 714 | 718 | 4 | 714 | 718 |
| FY2014 initial | 1,061 | 1,245 | 2,305 | 1,022 | 1,211 | 2,233 |
| FY2015 initial | 2,155 | 1,571 | 3,727 | 2,075 | 1,561 | 3,636 |
| FY2015 supplementary | 59 | 640 | 699 | 59 | 640 | 699 |
| FY2016 initial | 2,607 | 2,080 | 4,688 | 1,379 | 2,079 | 3,458 |
| FY2016 supplemantary | 1,243 | 1,710 | 2,953 | 703 | 1,710 | 2,413 |
| FY2017 initial | 1,445 | 1,104 | 2,550 | | | |
| Total | 14,585 | 14,459 | 29,046 | 10,354 | 13,083 | 23,437 |

Source: Ministry of Environment(2018) Decontamination Projects for Radioactive Contamination Discharged by Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Station Accident, Table 3-7 on page 74 (in Japanese, traslated by the authors)

## 4. EMPIRICAL MODEL

The majority of the literature on post-disaster migration deals with displacement and resettlement, with fewer contributions focused on population return (see Section 2). Like post-disaster displacement and resettlement, the decision to return can be viewed based on a series of "push" and "pull" factors. Much like the decision about whether to leave an origin for a potential new destination, the decision about whether to leave one's new location for one's original home is driven by comparing the characteristics of one location to another. Previous case studies have identified many variables that are shown to influence the decision to resettle, including characteristics of the resettlement area, economic opportunity in the origin and potential destinations, and personal connections (see Section 2 for a summary of some previously identified variables).

However, the migration decision is more straightforward in the case of return migration than outflow migration in some senses. While a potential out-migrant might typically choose across a set of possible destinations with varying characteristics, a potential return migrant is only comparing her new location to her original home.

In order to understand how characteristics of a disaster migrant's new home and individual characteristics influence her likelihood of repatriating, we employ a series of discrete choice models that estimate the likelihood that a migrant will intend to return home. While we are unable to control for all location characteristics that could influence the repatriation decision, we include many economic and social variables that have been shown to be important in the outflow migration decision.

The return decision for the evacuees is not an easy task. Many migrants from the affected areas have to decide their future location under uncertainty about the recovery processes and the surrounding destination environment. In such cases, deferring the return decision could be a rational response. In this sense, return and not-return decisions are not necessarily two sides of a coin. Therefore, we should assume the decision processes are asymmetric between returning and not returning. To reveal such complexity, we employ a multinomial logit model in addition to the simple logit model used in most previous studies. Suppose that an individual has three options on the intention to return, denoted as $J$. We define that $J = 1$ if the individual "will return" to his/her home, $J = 2$ if the individual "will not return" to his/her home, and $J = 3$ if the individual "has not decided yet" about his/her repatriation decision.

In the multinomial logit model, the probability of individual $i$ choosing option $J$ can be given by the following formula:

$$P(Return_i = J) = \frac{\exp(x'_i\beta_J)}{1 - \sum_{J=1}^{3}\exp(x'_i\beta_J)}, \qquad J = 1, 2, \text{and } 3$$

where $x_i$ denotes an explanatory vector of variables of individual $i$, and $\beta_J$ denotes a vector of parameters relating to the intent to return option $J$. We include three types of variables in $x_i$: individual attributes, characteristics of the origin (property damage and radiation), and characteristics of the new home (distance from Fukushima). In general, we expect that the same types of characteristics that are important in traditional migration models will be important in return migration, and we use these variables to inform our selection of covariates in our model.

The impact of each of these factors on the migration decision will be influenced by personal characteristics of each potential migrant. For example, those who voluntarily left the region may be more concerned about radiation risks than those who left under a mandatory order. In order to understand how behavior varies across individuals, we separately estimate our logistic regressions with split samples between those who were under mandatory evacuation and those who relocated voluntarily.

## 5. DATA

Most of the data we use are from the Alternative Dispute Resolution Center for Nuclear Accident Disaster Compensation (ADR Center) dataset, which was established after the accident by the Japan Ministry of Education, Culture, Sports, Science, and Technology (MEXT). The dataset was created from a survey-based study conducted by the ADR Center. Its primary purpose was to identify whose, what type of, and how much loss was incurred due to the evacuation in order to provide basic data for remediation of disputes on compensation issues, including both economic and emotional. However, the broad set of variables collected is well suited to the range of questions we plan to address in our study. The questionnaire was distributed to evacuees who registered with the national government. The registration was primary for the sake of communication with the government concerning disaster recovery, and therefore, the registration was arbitrary. The database eventually included both mandatory evacuees and voluntary evacuees; however, some who voluntarily evacuated might have regarded themselves solely as out-migrants if they had no plans to return home in the future. So, the voluntary evacuees in the database might have a self-selection bias if such people who did not wish to repatriate also did not register as an "evacuee."

The survey was conducted from March 1 to 19, 2012. The number of target households was 41,754, and 24.1% (10,082 people) responded. To grasp the big picture of the data, we cross-tabulated it by two important variables: intent to return and evacuee group, as shown in Table II. Most of the answers to "intent to return" were one of the following: 1) "I have temporarily migrated, but I will go back to the place where I was,"

2) “I have temporarily migrated, and I will not go back to the place where I was,” and 3) “I have not decided yet, or I do not have an idea.” We henceforth denote them “return,” “not return,” and “not decided” respectively. The number of these three answers are approximately equally distributed. It is worth mentioning that more than one-third of the evacuees did not have a clear idea about whether to return home even after one year following the accident. This fact implies that they had faced too many uncertainties to commit to either return or not to return. Another interesting fact is that those who evacuated voluntarily were more inclined to return than mandatory evacuees. This is due to the self-selection bias of the target households.

**Table II.** Intent to Return by Evacuation Group

Q. Where are you going to live in the future?

| | Mandatory | Voluntary | Total |
|---|---|---|---|
| I have been temporarily migrated but I will go back to the place where I was. (Return) | 1,664 | 1,065 | 2,729 |
| I have been temporarily migrated and I will not go back to the place where I was. (Not Return) | 2,477 | 690 | 3,167 |
| I have not decided yet, or I do not have an idea. (Not Decided) | 2,358 | 873 | 3,231 |
| Total | 6,499 | 2,628 | 9,127 |

The “radiation dose rate” at the original location is an average value of dose rates across all grids that cover the entire jurisdictional area of a municipality, computed from the dataset of MEXT, USDOE, and NRA, and released in 2012 (Japan Atomic Energy Agency [JAEA], 2012). The reason for this refinement is that the ADR dataset does not identify the location where the respondent was before and after the accident more precisely than the municipal level.

The variable “distance” is a measurement of how far a respondent has migrated away from his hometown, which is measured as the length between city halls of the original municipality and the current one (Niedomysl, 2011). We expect that the distance from the original municipality would negatively affect the intent to return, as longer distances are likely to result in higher moving and resettlement costs. However, one suspects that distance from home is endogenous because people who intended to return soon would try to reduce the return cost and therefore would stay as near as possible to their home. The coefficient of distance on the likelihood of repatriation would be biased downward (more negative) because we would falsely believe that those who face larger return distances are returning less frequently, when in reality, these people face large return distances because they had already decided not to return.

One possible solution to the endogeneity issue is introducing instrumental variables that can predict distance but have no effect on the individual choice of returning, except through the effect of distance. However, most of the variables we have, such as migration cost and radiation dose rate at the current municipality, are unlikely to pass the exclusion restriction. We therefore introduce the historical migration trend from the Exclusion Zone to the municipality before the disaster, from 2005 to 2010, as an instrumental variable for distance. The rationale is as follows: the historical migration pattern is determined by several factors, such as industrial connectivity between two cities, but distance is undoubtedly a key factor. Fewer people migrate to an area if it is more distant from home. Thus, the distance of two locations is correlated to the past migration pattern to some degree. On the other hand, the historical migration pattern is exogenous to people's decisions on migration following the disaster (i.e., the migration patterns following the disaster did not *cause* people to move to those destinations between 2005 and 2010). While we might be concerned that moving to a distant destination after the disaster might indicate a lack of desire to return, the fact that a particular distant destination had close connections with the Fukushima region in previous years is uncorrelated with repatriation preferences because those movers did not have disaster repatriation in mind. This is a similar method to that used by Munro and Managi (2017), instrumenting current location by the average value of others who migrated from the same location. However, as they admit, there is some possibility that the intent to return is conditional on friends and neighbors, thus potentially biasing their results. Our method does not include such a possibility because we used the past migration pattern, which is independent from the disaster. We admit, however, that the historical migration pattern may also be influenced by factors that affect return decision, such as amenity of the place. We show the result of the first stage regression analysis in the Appendix to make sure that the historical migration pattern variable has a strong correlation with distance.

We include several additional explanatory variables in our statistical analysis. The choice of variables emanates from developed findings from the literature on repatriation and resettlement. At the same time, our choices are limited by the data collected in the ADR survey. Descriptive statistics of the variables and their sources are presented in Table III. Our dataset is not balanced because not every respondent answered every question in the ADR survey. The remainder of the variables not elaborated on above are self-explanatory.

## **Table III.** Data Description

| Variables | Description | N | Mean | St. Dev. |
|---|---|---|---|---|
| Return | Coded 1 if the respondent will return, 2 if not decided yet, 3 if will not return. | 9,127 | 2.06 | 0.81 |
| Male (dummy) | Coded 1 if the respondent was male. | 10,082 | 0.47 | 0.50 |
| Age over 60 (dummy) | Coded 1 if the respondent was 60 and over. | 10,082 | 0.22 | 0.41 |
| Children (dummy) | Coded 1 if the respondent's family have more than one children whose age was 12 and less. | 10,082 | 0.19 | 0.40 |
| Elderly (dummy) | Coded 1 if the respondent's family have more than one elder persons whose age was 70 and over. | 10,082 | 0.19 | 0.40 |
| Housing tenure (dummy) | Coded 1 if the respondent own house and land where he/she lived before the disaster. | 9,816 | 0.73 | 0.45 |
| House collapse (dummy) | Coded 1 if the respondent's house were totally collapsed / washed away by the earthquake / the tsunami. | 9,719 | 0.06 | 0.24 |
| House inundation (dummy) | Coded 1 if the respondent's house were inundated by the tsunami. | 9,611 | 0.50 | 0.50 |
| House contamination (dummy) | Coded 1 if the respondent's house were contaminated by radionuclides. | 9,611 | 0.05 | 0.21 |
| Self-employed (dummy) | Coded 1 if the respondent was self-employed worker. | 9,281 | 0.16 | 0.37 |
| Sales and restaurant (dummy) | Coded 1 if the respondent's business is either whole seller, retail seller, or restaurant. | 9,771 | 0.03 | 0.18 |
| Employer housing (dummy) | Coded 1 if the respondent lives in the house provided by his/her empoyler. | 9,777 | 0.03 | 0.16 |
| Distance | Distance between the respondents' home municipality and current municipality. | 9,443 | 1.23 | 1.64 |
| Exclusion zone (1=Yes, 0=No) | Coded 1 if the respondent lived in the exclusion zone before the disaster. | 10,082 | 0.71 | 0.46 |
| Income:JPY 2M to 4M (dummy) | | 9,226 | 0.32 | 0.47 |
| Income:JPY 4M to 6M (dummy) | | 9,226 | 0.26 | 0.44 |
| Income:JPY 6M to 8M (dummy) | Coded 1 if the respondent's income before the disaster was within the range. | 9,226 | 0.11 | 0.31 |
| Income:JPY 8M to 10M (dummy) | | 9,226 | 0.07 | 0.25 |
| Income:JPY 10M and over (dummy) | | 9,226 | 0.05 | 0.22 |
| Radiation dose rate at original place (mSv/y) | An average radiation dose rate of the municipality where the respondent lived before the disaster as of March 2012. | 9,860 | 29.38 | 22.11 |

# 6. FACTORS THAT AFFECT INTENT TO RETURN

## 6.1. Analysis of Intent to Return

We begin with the simple logit model to compare our result to existing studies. We created a dummy-dependent variable that takes the value of 1 if a person wishes to return ($J = 1$) and 0 if a person has not made a decision yet or has decided not to return ($J = 2$ or $J = 3$). The estimated results of this logit model are shown in Table IV. The column shown as Model 1 is the base. We also introduced cross terms between personal attributes and the radiation dose rate following Munro and Managi (2017), but we omit the result because no cross term was statistically significant. Model 2 employed second-stage estimation using the number of migrants from home before the disaster as an instrumental variable (IV) for distance, following the control function (CF) approach by using first-stage residuals rather than fitted values to estimate the impact of distance (Wooldridge, 2015). Finally, samples are split into two groups – mandatory evacuees (Model 3) and voluntary evacuees (Model 4) – and rely on our instrument for distance in both cases.

## **Table IV.** Results of Logit Models

| Model | **Model 1** | **Model 2** | **Model 3** | **Model 4** |
|---|---|---|---|---|
| Sample | All samples | All samples | Mandatory Evacuees | Voluntary Evacuees |
| IV for Distance | None | Historical migration trend | Historical migration trend | Historical migration trend |
| Male (dummy) | 0.227 *** | 0.232 *** | 0.300 *** | 0.181 |
| | (0.060) | (0.060) | (0.060) | (0.060) |
| Age over 60 (dummy) | 0.749 *** | 0.763 *** | 0.797 *** | 0.688 *** |
| | (0.070) | (0.070) | (0.070) | (0.070) |
| Children (dummy) | -0.294 *** | -0.325 *** | -0.397 *** | -0.337 ** |
| | (0.080) | (0.080) | (0.080) | (0.080) |
| Elderly (dummy) | 0.341 *** | 0.353 *** | 0.297 *** | 0.518 *** |
| | (0.070) | (0.070) | (0.070) | (0.070) |
| Housing tenure (dummy) | 0.779 *** | 0.792 *** | 0.729 *** | 0.881 *** |
| | (0.080) | (0.080) | (0.080) | (0.080) |
| House collapse (dummy) | -0.896 *** | -0.893 *** | -0.963 *** | -0.806 * |
| | (0.200) | (0.200) | (0.200) | (0.200) |
| House inundation (dummy) | -0.244 *** | -0.229 *** | -0.169 * | -0.316 ** |
| | (0.060) | (0.060) | (0.060) | (0.060) |
| House contamination (dummy) | 0.004 | 0.024 | 0.136 | -0.112 |
| | (0.210) | (0.210) | (0.210) | (0.210) |
| Self-employed (dummy) | 0.211 ** | 0.207 ** | 0.248 ** | 0.103 |
| | (0.080) | (0.080) | (0.080) | (0.080) |
| Sales and restaurant (dummy) | -0.464 ** | -0.517 ** | -0.501 * | -0.504 |
| | (0.160) | (0.160) | (0.160) | (0.160) |
| Employer housing (dummy) | 0.393 * | 0.299 | 0.260 | 0.423 |
| | (0.170) | (0.170) | (0.170) | (0.170) |
| Distance | -0.086 *** | -0.073 ** | 0.010 | -0.152 *** |
| | (0.020) | (0.000) | (0.000) | (0.000) |
| Exclusion zone (1=Yes, 0=No) | -0.578 *** | -0.533 *** | | |
| | (0.080) | (0.080) | | |
| Upper Low Income (dummy): | -0.154 | -0.143 | -0.261 * | 0.065 |
| JPY 2M to 4M | (0.090) | (0.090) | (0.090) | (0.090) |
| Lower Middle Income (dummy): | -0.243 ** | -0.242 ** | -0.525 *** | 0.272 |
| JPY 4M to 6M | (0.090) | (0.090) | (0.090) | (0.090) |
| Upper Middle Income (dummy): | -0.333 ** | -0.338 ** | -0.540 *** | 0.067 |
| JPY 6M to 8M | (0.110) | (0.110) | (0.110) | (0.110) |
| Lower High Income (dummy): | -0.586 *** | -0.569 *** | -0.754 *** | -0.237 |
| JPY 8M to 10M | (0.140) | (0.140) | (0.140) | (0.140) |
| Upper High Income (dummy): | -0.545 *** | -0.598 *** | -0.670 *** | -0.654 * |
| JPY 10M and higher | (0.150) | (0.150) | (0.150) | (0.150) |
| Radiation dose rate at original | -0.019 *** | -0.019 *** | -0.019 *** | -0.022 *** |
| place (mSv/y) | (0.000) | (0.000) | (0.000) | (0.000) |
| Constant | -0.668 *** | -0.805 *** | -1.237 *** | -1.066 *** |
| | (0.110) | (0.110) | (0.110) | (0.110) |
| Marginal effect of Radiation dose | -0.0033 *** | -0.0033 *** | -0.0029 *** | -0.0053 *** |
| rate at original place | (0.000) | (0.000) | (0.000) | (0.001) |
| Number of observation | 7102 | 6865 | 4991 | 1874 |
| Log likelihood | -4214.40 | -4082.65 | -2744.85 | -1258.08 |
| Psedo R-squared | 0.114 | 0.114 | 0.103 | 0.100 |
| AIC | 7509.37 | 7271.43 | 4959.59 | 2302.02 |
| BIC | 7646.74 | 7408.11 | 5083.38 | 2407.20 |

Note: *** p<.01, **p<.05, *p<.1

Robust standard errors are shown in parenthesis

Estimation results of Models 1 and 2 show the factors that encourage migrants' intention to return. With regard to personal attributes, "male" migrants, migrants who are in "age over 60," and the variable reflecting migrants who have an "elderly" family member are found to be likely to have a higher intent to return. On the other hand, migrants who have "children" have a negative impact on the intent to return.

Housing tenure encourages the migrants' intent to return, and this result is consistent with many existing studies (Elliott & Pais, 2006; Landry et al., 2007; Paxson & Rouse, 2008; Groen & Polivka, 2010; Reinhardt, 2015; Yun & Waldorf, 2016). With regard to housing damage, "house collapse" and "house inundation" have a negative impact on returning, which was also indicated in many existing studies (Elliott & Pais, 2006; Paxson & Rouse, 2008; Reinhardt, 2015). Interestingly, "house contamination" does not have any impact on intention to return. This is not surprising, however, because people are anxious about the radiation dose of not only their own houses but also those of their neighbors. This view is supported by the results that "radiation dose rate at the original place" is negatively significant.

Regarding the livelihood of the migrants, our preliminary analysis included several dummy variables to see if the industry in which the migrant had been working was influential for the return migration decision. Among them, "sales and restaurants" was the only significant sector. The result shows that working in this sector has a negative impact on return migration, probably because the industry is heavily dependent on local population and not likely to recover unless evacuees repatriate. However, this impact is not obvious when we split the sample (Models 3 and 4).

The variable "distance" has a negative impact on intention to return in Models 1 and 2. However, the absolute value of the coefficient in Model 2 is larger than that of Model 1, which implies that the endogeneity biases of the coefficients in the latter seem to be corrected by the instrumental variable in the former. The coefficients of the "exclusion zone" are very intuitive – they affect intentions to return negatively.

Coefficients of the income dummy variables above 4 million JPY ("lower middle," "upper middle," "lower high," and "upper high") are negative, which implies that wealthier people are less likely to plan on returning than those making below 2 million JPY per year. Point estimates become more negative as income rises, though the effects are not generally statistically different from one another. Existing studies do not necessarily have a consensus on how income affects a person's intent to return. For example, Landry et al. (2007) found a positive relationship between income and intent to return from an econometric analysis of Hurricane Katrina migrants. They explain that higher income enables people to have better resources to make the return trip, own homes in areas that are less likely to have been flooded, and have better resources to rebuild in the event that their home has been damaged. The study by Reinhardt (2015) yielded similar results. More notably, Munro and Managi (2017) found this was true for Fukushima evacuees. Our result here is the opposite of these studies but is consistent with Elliott and Pais (2006), who found a negative correlation between higher income and intent to return. Their explanation is that lower income affords less opportunity to pursue options elsewhere.

We next split the samples into two categories, mandatory evacuees (Model 3) and voluntary evacuees (Model 4). The two groups should have different attitudes toward radiation. We expect that the return decision process of voluntary evacuees is simpler than that of mandatory evacuees, because their primary concern would be the radiation dose rate. Our result is consistent with those expectations. Coefficients of dummies for "males" is not significant for voluntary evacuees. The "self-employed" variable also lost its significance. Interestingly, "income" dummies are all insignificant except for 8 to 10 million JPY, and 10 million JPY and higher. Interestingly, "distance" lost its significance for mandatory evacuees.

We could expect that the intent to return is affected by the "radiation dose rate" more for voluntary evacuees than for mandatory evacuees. For the sake of this comparison, we estimated the marginal effects of radiation dose rate for each estimation. The results are consistent with this expectation. The marginal effect of the "radiation dose rate" is -0.0029 for the mandatory evacuees and -0.0053 for voluntary evacuees. This result is also consistent with the estimation of Munro and Managi (2017). Their estimated coefficients are between -0.0034 to -0.0031, which are in-between our mandatory and voluntary evacuees estimates. This is because their analysis did not split the sample between these two groups.

### 6.2. Analysis of Return and Not-Return Decision

We next move to the analysis on both return and not-return decisions by applying multinomial logit analysis. We often regard the return decision as equivalent to the not-return decision. However, our interest here is to determine whether the intention to return or not return may not be two sides of a coin. Our analytical framework allows us to test this hypothesis: We set "not decided" as a base option for all evacuees. The choice between "return" and "not decided" for an evacuee can be understood as a question about the commitment to the option to return. In this sense, not choosing "return" does not necessarily mean a choice "not to return," and vice versa. It would be plausible to assume that people would rather defer their decisions than commit to a particular option if they face significant uncertainty.

The results of multinomial logit analysis are shown in Table V. The columns noted "R" show the model of return decision ("will return") vs. deferred decision ("not decided yet"), while the "NR" column presents the "not returning" decision ("will not return") vs. deferred decision ("not decided yet"). Parameters shown here are the marginal effects, with robust standard errors in parenthesis. The column titled "sym" represents the result of the z-test of the null hypothesis that marginal effects of the variable are symmetric between the return and not-return decisions ($H_0$: $\beta_i^R = -\beta_i^{NR}$, $H_1$: $not\ H_0$). If the null hypothesis is not rejected, we may be able to assume that the return and not-return decisions are almost the same.

**Table V.** Results of Multinomial Logit Models (Marginal Effects)

| R: Will return<br>NR: Will not return<br>Base: Not decided yet | Model 5<br>All samples | | | Model 6<br>Mandatory Evacuees | | | Model 7<br>Voluntary Evacuees | | |
|---|---|---|---|---|---|---|---|---|---|
| | R | NR | Sym | R | NR | Sym | R | NR | Sym |
| Male (dummy) | 0.041 | -0.033 | | 0.048 | -0.048 | | 0.037 | -0.011 | |
| | (0.011) | (0.012) | | (0.013) | (0.015) | | (0.022) | (0.021) | |
| Age over 60 (dummy) | 0.134 | -0.018 | *** | 0.128 | -0.022 | *** | 0.144 | 0.009 | *** |
| | (0.011) | (0.013) | | (0.012) | (0.015) | | (0.026) | (0.025) | |
| Children (dummy) | -0.057 | 0.055 | | -0.064 | 0.068 | | -0.071 | 0.046 | * |
| | (0.013) | (0.014) | | (0.018) | (0.018) | | (0.024) | (0.022) | |
| Elderly (dummy) | 0.062 | -0.046 | | 0.048 | -0.044 | | 0.108 | -0.053 | *** |
| | (0.012) | (0.015) | | (0.013) | (0.017) | | (0.027) | (0.028) | |
| Housing tenure (dummy) | 0.139 | -0.124 | | 0.117 | -0.110 | | 0.182 | -0.149 | |
| | (0.013) | (0.013) | | (0.016) | (0.016) | | (0.023) | (0.020) | |
| House collapse (dummy) | -0.153 | 0.162 | | -0.153 | 0.150 | | -0.156 | 0.208 | |
| | (0.036) | (0.033) | | (0.040) | (0.038) | | (0.075) | (0.064) | |
| House inundation (dummy) | -0.040 | 0.019 | * | -0.027 | 0.010 | | -0.066 | 0.038 | |
| | (0.011) | (0.012) | | (0.012) | (0.014) | | (0.025) | (0.023) | |
| House contamination (dummy) | 0.003 | -0.043 | | 0.022 | -0.036 | | -0.027 | -0.074 | |
| | (0.037) | (0.038) | | (0.042) | (0.044) | | (0.073) | (0.070) | |
| Self-employed (dummy) | 0.037 | -0.026 | | 0.040 | -0.036 | | 0.022 | 0.010 | |
| | (0.014) | (0.016) | | (0.015) | (0.019) | | (0.032) | (0.030) | |
| Sales and restaurant (dummy) | -0.089 | -0.003 | ** | -0.079 | -0.012 | ** | -0.104 | 0.013 | |
| | (0.029) | (0.030) | | (0.034) | (0.038) | | (0.057) | (0.047) | |
| Employer housing (dummy) | 0.053 | -0.002 | | 0.042 | -0.012 | | 0.091 | 0.014 | |
| | (0.030) | (0.033) | | (0.036) | (0.040) | | (0.063) | (0.055) | |
| Distance (predicted) | -0.013 | 0.010 | | 0.002 | -0.006 | | -0.031 | 0.022 | |
| | (0.004) | (0.004) | | (0.005) | (0.006) | | (0.008) | (0.005) | |
| Exclusion zone (1=Yes, 0=No) | -0.095 | 0.094 | | | | | | | |
| | (0.013) | (0.017) | | | | | | | |
| Upper Low Income (dummy): JPY 2M to 4M | -0.025 | 0.003 | | -0.042 | 0.030 | | 0.011 | -0.047 | |
| | (0.015) | (0.018) | | (0.017) | (0.023) | | (0.032) | (0.029) | |
| Lower Middle Income (dummy): JPY 4M to 6M | -0.043 | 0.035 | | -0.085 | 0.081 | | 0.055 | -0.061 | |
| | (0.016) | (0.019) | | (0.018) | (0.023) | | (0.034) | (0.032) | |
| Upper Middle Income (dummy): JPY 6M to 8M | -0.059 | 0.054 | | -0.087 | 0.087 | | 0.012 | -0.012 | |
| | (0.020) | (0.023) | | (0.022) | (0.027) | | (0.044) | (0.040) | |
| Lower High Income (dummy): JPY 8M to 10M | -0.100 | 0.076 | | -0.122 | 0.109 | | -0.052 | 0.006 | |
| | (0.024) | (0.025) | | (0.027) | (0.030) | | (0.051) | (0.044) | |
| Upper High Income (dummy): JPY 10M and higher | -0.102 | 0.133 | | -0.107 | 0.150 | | -0.129 | 0.139 | |
| | (0.027) | (0.028) | | (0.028) | (0.034) | | (0.069) | (0.052) | |
| Radiation dose rate at original place (mSv/y) | -0.003 | 0.002 | ** | -0.003 | 0.002 | * | -0.005 | 0.002 | ** |
| | (0.000) | (0.000) | | (0.000) | (0.000) | | (0.001) | (0.001) | |
| Number of observation | 6865 | | | 4991 | | | 1874 | | |
| Log likelihood | -7499.34 | | | -5375.94 | | | -2028.67 | | |
| Psedo R-squared | 0.069 | | | 0.058 | | | 0.073 | | |
| AIC | 14037.08 | | | 10202.42 | | | 3835.21 | | |
| BIC | 14310.45 | | | 10450.01 | | | 4045.57 | | |

Note: Column "Sym" represents z test results for the null hypothesis that marginal effects for R and NR are symmetric. *** p<.01, **p<.05, *p<.1
Robust standard errors are shown in parenthesis.

The estimation results of Model 5 reveal an interesting contrast in the decision-making processes between returning and not returning. Testing for symmetricity of the marginal effects of “age over 60,” “house inundation,” “sales and restaurant,” and “radiation dose rate at original place” are rejected at the 10% significance level. This means that these factors have asymmetric effects on returning and not-returning decisions. For example, being over 60 years old will increase the probability of commitment to return about 13.4%, while decreasing the probability of commitment not to return only about 1.8%. It is quite natural that older persons show attachment to their native place, which was also observed in Belarus (Marples, 1995). But this result adds a new insight. The older person is not likely to reduce his/her not-to-return commitment as much as the increased return commitment. In other words, the not-to-return commitment is not affected by age as much as the return commitment is. This is probably because a household headed by an elderly person has a strong desire for settling down as early as possible and living the rest of his/her life in peace, as well as the attachment to their native place. It is more interesting to note that in Model 7, the marginal effect of “age over 60” on the decision not to return is rather positive. This may imply that people’s desire for settling down overwhelmed the attachment to their place. This is a very plausible result for voluntary evacuees, because their “sense of home place” should be relatively weaker than mandatory evacuees.

Radiation dose rate also has an asymmetric effect on return and not-return intentions. A one mSv/year decrease of radiation dose rate in the original home area increases the probability of return commitment by 0.3%, but decreases the probability of not-to-return only 0.2%. This again implies the not-to-return commitment is not affected by the radiation as much as the return commitment is. The reason behind this is less clear than the influence of age; however, this would be a possible outcome if the future decrease of radiation dose rate is taken into consideration when a migrant commits to the “not-return” option.

Another interesting finding here is that households whose head had worked in the sales and restaurant industries have negative marginal effect on both R and NR, which implies that they reduce the probability of commitment to either option. This is probably because their decision is susceptible to future economic and demographic conditions. Their business was basically dependent on the local population, and hence their return decision was dependent on the economic recovery at their place of origin, which was still uncertain at that moment.

## 7. SIMULATION ANALYSIS OF THE DECONTAMINATION EFFECT ON INTENTION TO RETURN

Using the estimated parameters, we calculated how the intent to return would change if the radiation dose rate decreased. We simply substituted the variable of radiation dose rate as of March 2012 into that of October 2016, which is the latest dataset available, while other variables remained the same. This treatment can simulate how people's intent to return changes when the radiation dose decreases, assuming other factors being equal. We assume that an evacuee will return if his/her projected probability of returning exceeds 0.5. In more formal expression, we assume individual *i* will return home if

$$P(Return_i = 1 \mid dose_i = dose_i(2016)) \geq 0.5,$$

where $dose_i(t)$ denotes the radiation dose rate of individual *i*'s home at time *t*.

Table VI presents the simulation result for the municipalities in the Exclusion Zone, both totally and partially. From March 2012, the average dose rate decreased considerably, down 60.5% in Tamura and 77.9% in Tomioka. This is partly due to the cleanup efforts of the national government, but also partially because of the natural decay of radiation and weathering effects.

The results of our simulation are presented in the middle columns of Table VI. We limited this municipality-wise simulation of mandatory evacuees for the sake of comparison to the factual rate of return, because we do not have data on how many voluntary evacuees actually returned. The column [B]-[A] represents the increment of the return rate due to the radiation decrease. The result shows that the radiation effect on peoples' intention to return is very minor, from 2.9% in Kawamata to 19.5% in Iitate. Overall in the Fukushima prefecture, including both mandatory and voluntary evacuees, the results suggest that 10.6% of migrants decided to return because of the decrease of the radiation dose rate. It is interesting to note that radiation's effect on the return intention is larger for mandatory evacuees than for voluntary evacuees. As we have seen in Model

4 of Table IV, the marginal effect of radiation is larger for voluntary evacuees. However, because the decrease in radiation dose is higher in Exclusion Zone, where mandatory evacuees originated, the decrease in radiation has more benefits for the return migration of mandatory evacuees than of voluntary evacuees.

**Table VI.** Results of Simulation Analysis of Decontamination

| | | **Average radiation dose rate (mSv/year)** | | | **Percentage of returnees over evacuees.** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Simulation Results** | | | **Factural** | **Error** |
| Municipalities | | Mar. 2012 | Oct. 2016 | % change | March 2012 [A] | October 2016 [B] | [B]-[A] | 2016 [C] | [B]-[C] |
| Tamura | P | 3.582 | 1.414 | -60.5% | 61.3% | 66.5% | 5.2% | 64.3% a) | 2.2% |
| Minamisoma | P | 13.181 | 4.344 | -67.0% | 17.6% | 24.7% | 7.1% | 10.0% a) | 14.8% |
| Kawamata | P | 8.222 | 2.418 | -70.6% | 7.1% | 10.0% | 2.9% | 9.7% c) | 0.3% |
| Naraha | P | 6.826 | 1.903 | -72.1% | 24.5% | 27.9% | 3.4% | 29.3% a) | -1.4% |
| Tomioka | T | 25.584 | 5.643 | -77.9% | 4.9% | 21.5% | 16.5% | 16.0% b) | 5.5% |
| Kawauchi | P | 6.795 | 2.295 | -66.2% | 56.0% | 59.5% | 3.6% | 63.7% a) | -4.2% |
| Okuma | T | 44.729 | 12.365 | -72.4% | 0.3% | 11.9% | 11.6% | 11.4% b) | 0.5% |
| Futaba | T | 62.456 | 19.817 | -68.3% | 0.0% | 9.9% | 9.9% | 13.4% b) | -3.5% |
| Namie | T | 59.155 | 20.140 | -66.0% | 0.1% | 10.6% | 10.6% | 17.5% b) | -6.9% |
| Katsurao | T | 22.235 | 7.670 | -65.5% | 10.3% | 25.9% | 15.5% | 3.8% a) | 22.1% |
| Iitate | T | 23.650 | 6.911 | -70.8% | 6.8% | 26.3% | 19.5% | 33.5% b) | -7.2% |
| Fukushima pref. | | | | | 12.2% | 22.8% | 10.6% | | |
| Mandatory Evacuees | | | | | 6.2% | 17.3% | 11.1% | | |
| Voluntary Evacuees | | | | | 23.1% | 27.7% | 4.7% | | |

Note: "T" denotes that the municipality was totally designated as Exclusion Zone, whereas "P" denotes partially.
a) Percentage of those who have already returned.
b) Percentage of those who wish to return (Reconstruction Agency, 2017)
c) Percentage of those who have already returend as of April 1, 2017

In the last two columns, we compare the result with factual data from the census as of October 2016, or the nearest date to it, for each municipality. For those municipalities still in the Exclusion Zone, we cited the outcome of polls conducted by the Reconstruction Agency asking if evacuees will return or not. The simulation fits very well in some municipalities, such as Tamura, Kawamata, Naraha, and Okuma. However, there are large gaps between the simulation and the factual data seen in other municipalities, such as Minamisoma and Katsurao. This is largely because the evacuation order was lifted immediately before the census. The evacuation orders in Katsurao and Minamisoma were lifted on June 12 and July 12, 2016, respectively. This timing eventually would result in a lower percentage of return to each municipality. In this sense, our simulation provides fairly reasonable results and suggests that decontamination does not increase the intention to return very significantly. This implication becomes more solid if we consider the fact that the decrease of the radiation dose rate in Fukushima was achieved not only by decontamination, but also by natural decay and weathering effects.

From the estimates that we have derived, we can calculate the cost of decontamination for repatriating one person. As discussed earlier, the total number of evacuees is estimated as 164,000, of which 81,000 are mandatory and 83,000 are voluntary. Multiplying the estimated increment percentages of those who wish to return ([B] - [A] in Table V) to the number of evacuees yields the incremental estimate of the number who will return home. The results are 9,020 for the Exclusion Zone and 3,862 for the Non-Exclusion Zone. So, in total, 12,882 evacuees were estimated to return because of the radiation decrease between March 2012 to March 2016.

The cost for decontamination was estimated as $43.3 billion, including construction cost of the interim storage facility. Hence, the cost of decontamination per returning person is estimated as $3.36 million (370 million JPY).

## 8. CONCLUSION AND POLICY IMPLICATIONS

Our analysis of migrants' intention to return to contaminated areas of Fukushima revealed that housing tenure, house damage, and house inundation are the most significant factors. This is consistent with the theory of location-specific capital that Paxson and Rouse (2008) developed. Income, on the other hand, is also a powerful indicator that predicts higher income residents are less likely to return, which is consistent with the result of Elliott and Pais (2006), but contrary to Munro and Managi (2017). Our multinomial logit analysis demonstrated that return and not-return decisions are not symmetric processes. A household whose head was working in the Sales and Restaurant industries is more inclined to defer his/her returning decision, probably out of concern for uncertainty of their business environment. We also found that voluntary evacuees whose age is over 60 were more inclined to commit to either the return or not-return options rather than to remain undecided, probably because they prefer to settle down as early as possible.

Our regression results also found that the return decision of voluntary evacuees is more sensitive to the radiation dose rate than that of mandatory evacuees. This is a reflection of the structure of our samples. Mandatory evacuees included persons who would not leave unless the evacuation was compulsory, and therefore on whom the marginal effect of radiation would likely be very low. On the other hand, the sample of voluntary evacuees does not include such people. All of them evacuated primarily because they feared the accident and radiation, and therefore the marginal effect of radiation on their decision should be higher. In this sense, there are certain reasons why government should provide financial support to voluntary evacuees as they do to mandatory evacuees – the term "voluntary" does not necessarily mean their motivation and necessity to evacuate, including their loss of economic well-being caused by evacuation, is weaker than that of mandatory evacuees.

In the simulation analysis on the returning population, we found that the number of returnees encouraged by the decontamination work of the government was 12,882, or 7.9% of total evacuees. Decontamination cost per returnee was estimated as $3.36 million USD.

Repatriation is not necessarily the logical ending of the disaster odyssey (Rose, Eyer, & Nagamatsu, 2018). Even though the "sense of home" is a strong motivation of recovery for most evacuees, the large cost of decontamination would have allowed government to consider many other options for recovery. For example, according to the result of Model 2, the intent to return of the migrants will decrease if they have housing tenure in their current location, business opportunities for the self-employed, and annual income of more than 4 million JPY. Our analysis implies that the migrants' welfare is likely higher for many than it would be if they returned home. Thus, a government policy goal of complete repatriation is not necessary if the maximization of the economic well-being of all those affected is the end goal. Many are better off in their new locations, and others may benefit equally from other government policies, such as provision of houses, enhancing community ties, and individual support for the elderly. Moreover, these other policies may attain the goals of enhancing the well-being of evacuees at a much lower cost than would further decontamination in many geographic areas.

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## APPENDIX

Table A1 shows the results of the first stage regression for Instrumental Variable Method. The dependent variable here is “Distance.” Our instrumental variable “Historical Migration Trend” shows a positive coefficient and significance at 1%.

**Table A1.** First Stage Regression Results for IV Method

| Eq | Eq.3_1 | Eq.4_1 | Eq.5_1 |
|---|---|---|---|
| Sample | All samples | Mandatory Evacuees | Voluntary Evacuees |
| Male (dummy) | -0.026 | 0.026 | -0.043 |
| | (0.040) | (0.040) | (0.040) |
| Age over 60 (dummy) | -0.014 | 0.051 | -0.144 |
| | (0.040) | (0.040) | (0.040) |
| Children (dummy) | 0.239 *** | 0.132 ** | 0.242 * |
| | (0.050) | (0.050) | (0.050) |
| Elderly (dummy) | -0.136 *** | -0.079 | -0.213 * |
| | (0.040) | (0.040) | (0.040) |
| Housing tenure (dummy) | -0.153 ** | -0.107 * | -0.187 |
| | (0.050) | (0.050) | (0.050) |
| House collapse (dummy) | 0.054 | -0.025 | 0.655 * |
| | (0.120) | (0.120) | (0.120) |
| House inundation (dummy) | -0.112 ** | -0.057 | -0.167 |
| | (0.040) | (0.040) | (0.040) |
| House contamination (dummy) | -0.043 | 0.086 | -0.307 |
| | (0.130) | (0.130) | (0.130) |
| Self-employed (dummy) | 0.029 | -0.009 | 0.108 |
| | (0.050) | (0.050) | (0.050) |
| Sales and restaurant (dummy) | 0.231 | 0.052 | 0.505 |
| | (0.130) | (0.130) | (0.130) |
| Employer housing (dummy) | 0.188 | 0.080 | 0.574 |
| | (0.110) | (0.110) | (0.110) |
| Exclusion zone (1=Yes, 0=No) | -0.354 *** | | |
| | (0.050) | | |
| Historical migration trend | 0.000 *** | 0.000 *** | -0.001 *** |
| | (0.000) | (0.000) | (0.000) |
| Upper Low Income (dummy): | -0.060 | -0.053 | -0.094 |
| JPY 2M to 4M | (0.060) | (0.060) | (0.060) |
| Lower Middle Income (dummy): | -0.065 | 0.011 | -0.275 |
| JPY 4M to 6M | (0.060) | (0.060) | (0.060) |
| Upper Middle Income (dummy): | -0.257 *** | -0.197 *** | -0.452 ** |
| JPY 6M to 8M | (0.060) | (0.060) | (0.060) |
| Lower High Income (dummy): | -0.102 | -0.076 | -0.148 |
| JPY 8M to 10M | (0.080) | (0.080) | (0.080) |
| Upper High Income (dummy): | 0.030 | -0.128 | 0.746 |
| JPY 10M and higher | (0.100) | (0.100) | (0.100) |
| Radiation dose rate at original | 0.000 | 0.003 *** | -0.015 *** |
| place (mSv/y) | (0.000) | (0.000) | (0.000) |
| Constant | 1.963 *** | 1.320 *** | 2.420 *** |
| | (0.080) | (0.080) | (0.080) |
| Number of observation | 6865 | 4991 | 1874 |
| Log likelihood | -12983.3 | -8460.0 | -4071.3 |
| Adjusted R-squared | 0.1421 | 0.126 | 0.1657 |

Note: *** p<.01, **p<.05, *p<.1

Robust standard errors are shown in parenthesis

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