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Effective Boost to Fertility: Evidence from Operation of Nuclear Power Plants in Japan

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Effective Boost to Fertility: Evidence from Operation of Nuclear Power Plants in Japan

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Abstract We provide evidence of a boost to fertility caused by nuclear power plants' operation as such power plants create jobs in the surrounding area. We use household-level data from the Japanese population census (1980-2010) and link each household to granular location information. We exploit—plausibly exogenous—geographical variations in distance to a nuclear power plant from each household to identify the job creation effect. We find that the operation of a nuclear power plant leads to a 10% increase in fertility in the surrounding areas—which is an underpopulated area. We also find that marriage and employment increase in areas close to a nuclear power plant. The estimates of instrumented difference-in-difference method suggest that an additional employment leads to a higher probability of having children born. On top of that, this work sets out to investigate the effect of large subsidies provided to local governments after the constructions of nuclear power plants. We utilize observations of households located close to the borders of the municipality to identify the causal impact of local government spending on fertility decision. The results suggest that having a larger local government's budget and subsequent provision of better-quality public services contribute to higher fertility.

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1. Introduction

In economics, “fertility” is a term used to represent the choices that men and women make when having children. Having a child is the most basic form of a microeconomic decision: It starts the life of an economic agent whose decisions then propagate to economic outcomes such as productivity, growth, and poverty. Because of this, fertility is an economic- and policy-relevant topic. In developing countries, the fertility rate is high and parents allocate scarce resources across their children. As countries develop, the opportunity cost of having children and the demand for children's quality increases, so parents tend to have fewer children. An important policy concern in developed countries is that these economic trends have resulted in a low fertility rate. The total fertility rate in East-Asian and Western-European countries dramatically dropped during the 20th century and, currently, stands below replacement in several of these countries.

In order to tackle this issue, developed countries have provided fiscal benefits tied to fertility. In Canada, France, Germany, and Israel, tax incentives encouraging fertility have been implemented and have been ineffective. Evidence on the design and content of public and social policies effectively promoting fertility is scarce. Therefore, our main research question is: What kind of policy intervention effectively incentivizes fertility? More specifically, we test two hypotheses; firstly, increasing jobs leads to higher fertility. Secondly, providing better-quality public services contributes to higher fertility.

Both theories and data demonstrate the importance of financial conditions to one’s fertility decision. Since theoretical models describe fertility decision as reactions to bundles of “goods” and “prices”, it is crucial to identify and estimate the effect of the “prices” that determine people’s fertility decisions. Hotz et al. (1988) summarizes the methodologies to derive the reduced-form equations that model the relationship between “prices” and fertility decisions; solving endogeneity is the key issue in identification and estimation.

To solve the endogeneity problem, mainly three methodologies are applied in the literature: social experiments, instrumental variables and difference-in-differences. Amongst the social experiments literature, Maynard & Rangarajan (1994) analyzes the Teenage Parent Demonstration to evaluate the effect of case management in controlling repeated pregnancy of the welfare dependent teenager mothers. Their findings show that counseling and services fail to reduce the possibility of repeated pregnancy; the findings motivated researchers to study other factors that incentivize people’s fertility decisions, such as financial conditions. Policy interventions have provided researchers with good exogenous changes (IV) in people’s financial conditions. Examples of this approach include Black, Daniel, & Sanders (1996). They exploit the variation in the price of energy worldwide, and different types of coal and the variation in different price of coals in different counties in Kentucky. The variation in coal prices is a good IV because it will have a stronger impact on male wages than female wages. They find a strong positive effect of higher male wage on fertility. Their approach is closely related to ours. This paper provides empirical evidence to test the causal relationship between financial conditions and people’s fertility decisions by using difference-in-difference approach.

This study is closely related to the empirical literature that studies the relationship between employment situation and fertility decisions. Adserà (2004) uses country-level data of European countries and finds that a large share of public employment, by providing employment stability, and generous maternity benefits boosted fertility of 25-34 year old females. They argue that the employment insecurity of young people delayed marriage and childbearing. Other past studies also claim that unemployment, temporary employment, and economic uncertainty negatively affect fertility decisions or make people postpone parenthood (Adsera, 2005; Mills, Rindfuss, McDonald, & te Velde, 2011). Most of the studies, however, exploit country-level variation and not utilize variation based on micro-data. On top of that, the utilized period of European countries experiences not only a large amount of unemployment, but also major social changes such as dramatic increase of female employment. Thus, it is not easy to disentangle a pure job effect on fertility choices.

This paper is also related to the empirical literature of estimating the policy impact of financial incentives on fertility decisions. Based on Willis (1973)'s theoretical prediction, empirical studies have tested whether a decrease in the per-child price of quality such as a subsidy to school attendance increases fertility or not. The evidence indicates that child subsidies or childcare subsidies incentivize females to have children (Cohen, Dehejia, & Romanov, 2013; Haan & Wrohlich, 2011; Kalwij, 2010). This study contributes to the literature by analyzing how better-quality public services affect fertility decisions.

Likewise, this paper contributes to the empirical studies of the fertility issues in Asia. A rich literature has tried to explain the reason for the low fertility in Asian countries (i.e. Feeney (1991), Ronald R. & Minja Kim (2015)). As early as Hashimoto (1974), empirical literature has been taking a close look at the fertility issue in Japan, especially, the relationship between economic development and fertility change overtime. In his paper, Hashimoto provided evidence that supports the theoretical prediction of the relationship people's fertility-related behaviors and the fertility rate. Nakajima & Tanaka (2014) estimates the effect of municipality-sponsored prenatal policies on fertility. The study uses microdata of metropolitan areas between 2001 and 2004; it finds that self-selection by residents generate substantial upward bias in the estimate of the policy impacts. Recently, Suzuki (2019) uses the prefecture level data to analyze the determination factor of the decrease in fertility rate. To avoid endogeneity, she applies the Butz-Wald model. However, our paper utilizes individual-level observations of census data and exploits a plausibly exogenous source of variation, that is, the presence of nuclear power plant, to solve the endogeneity to the "price" of fertility, rather than applying structural estimations.

In this paper, we adopt an innovative approach to investigate the impact of job creation and better-quality public services on fertility choice by utilizing a policy intervention in Japan. The source of variation of fertility decision is the operation of nuclear power plants—a national project which gives an enormous impact on the local economy in rural areas. The area surrounding a nuclear power plant faces two types of benefits: a big demand of labor created by the nuclear power plant and large subsidies given to the local government from the central government. Those factors generate a variation in citizen's financial conditions in the area surrounding the nuclear power plant. We treat the variation as plausibly exogenous because it is not related to people's fertility decisions.

The data we use is created based on individual observations of Japanese population census; we transformed them into household-level data. We use four rounds of the survey (1980, 1990, 2000, 2010) to generate the data and supplementarily use 1995 data for obtaining granular location information. The census data allows us to use the information about the length of residency of each individual. This is important because self-selected move creates bias on the impact of the intervention. We use the operation of four nuclear power plants—as many plants as possible considering our identification strategy and the duration of the data available. By exploiting the plausibly exogenous variation of fertility choice caused by nuclear power plants' operation, we conduct difference-in-difference and instrumented DID analysis. For estimating the impact of the job creation, we instrument a household head's employment status with the presence of a nuclear power plant in the neighborhood. For estimating the impact of provision of better-quality public services, we instrument local government spending with large subsidies provided to local governments by the central government.

With respect to the analysis on the job creation effect, the results indicate that the operation of a nuclear power plants leads to an approximately 10% increase in number of children born in a household in the area surrounding the power plant. We find a positive impact on marriage status of females (a five percent increase); we also find that the probability of a household head to be employed increases by five percent. The IV estimates suggest that an additional employment provided for a household head leads to 30 percentage point increase of the probability of having an additional baby per year, though it is not conclusive.

With respect to the analysis on the subsidy effect, the results obtained by three types of identification strategies suggest that provision of large subsidies from the central government to the local government increased approximately 10% for households that have 25-34 years old women. The IV estimates suggest that 100% increase in the local government's expenditure—and subsequent provision of better-quality public services—leads to around 50% increase in number of babies born per year per household.

This paper proceeds as follows. Section 2 gives a brief background on nuclear power plants in Japan. Section 3 explains the process of generation of the data. Section 4 presents key potential channels of the increase of fertility decisions and the hypotheses. Section 5 presents the empirical models. Section 6 presents empirical results. Section 7 gives conclusions.

2. Context

2.1. Overview of nuclear power plants in Japan

The construction of the first nuclear power plant in Japan started in 1954. Currently the capacity of electricity generated by nuclear power plants is the third in the world; the first is the U.S. and the second is France (Miyoshi, 2009).

Nuclear power plants are located at fifteen places in Japan. In Figure 1, we show the location of all nuclear power plants in Japan. Many of the nuclear power plants in Japan were constructed in 1970s and 1980s. Due to the data constraint of the Japanese census, as for the intervention of interest, we use four nuclear power plants in four municipalities: Tomari-mura, Shika-cho, Rokkasho-mura[1], and Higashodori-mura. The year of the beginning of the operation of each facility is as follows: 1989 (Tomari-mura), 1993 (Shika-cho), 1992 (Rokkasho-mura), and 2005 (Higashidori-mura).

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[1] We follow the literature of nuclear power plants such as Nishikawa (2000) and include the facility to process nuclear fuel at Rokkasho-mura in our analysis. The facility does not generate electricity, but it is only an special facility which is important for the nuclear power plant's policy of Japan. The facility invited large subsidies and created jobs at the same level as nuclear power plants. Therefore, the past studies about nuclear power plants cover the facility at Rokkasho-mura.

The individual-level survey data of Japanese Census is currently available for 1980-2015. To use difference-in-difference approach, we must check the pre-trend. This is a severe constraint to use older nuclear power plants for analysis. Further, for 1980's census data, the granular location of survey respondents is not available. Thus, the available data does not allow us to exploit the variation caused by the rest of the nuclear power plants.

[INSERT FIGURE 1 HERE]

2.2. Determinants of the place to locate a nuclear power plant

Kobayashi (1971), who had become an executive director of the biggest Japanese electric power company (Tokyo Denryoku) in 1977, describes the conditions of the location of a nuclear power plant. The conditions include the following: (1) The population density of the municipality must be low enough (less than 300 people / km^2), (2) Railways must not pass close to a nuclear power plant, (3) A nuclear power plant must be located at the coast area to obtain large amount of water to cool nuclear reactor, (4) A nuclear power plant must not be located inside a national park, (5) The nature of the soil and strata of the location must be stable. There are not many locations which satisfy the conditions; Kobayashi states that more than eighty percent of the municipalities are dropped immediately. Based on the conditions, he lists seventy-three candidates of the place for locating nuclear power plants in Japan (the map is shown in Figure A1 in the Appendix). In fact, eight nuclear power plants are constructed at the places in his list.

In the U.S., a nuclear power plant is basically located at an uninhabited place neighboring large water area[2]. However, it is difficult to find a suitable uninhabited region in Japan because Japan is an island country and the coast areas often have higher population density than the mountainous areas. That was the motivation for Kobayashi to make the list of the location suitable for nuclear power plants where the population density is low enough. Because the Japanese government and electric power company cannot find uninhabited suitable place, they have to provide a large amount of financial compensation to the local community to let the community accept construction of a nuclear power plant. This is why the location of nuclear power plants in Japan is different from those in the U.S. The case of Japan is similar to those of European countries such as France.

After the central government and an electricity company agrees some candidates of the location of a nuclear power plant, the location is finally determined through the negotiation between the local communities and the electric power company. Local people such as local fishermen launch a severe opposition movement against a nuclear power plant. It takes a long time for a candidate village (or town) to become an agreed location for a nuclear power plant. In many municipalities, agreements were not reached; in some cases, even after the construction of nuclear power plants had started, electric power companies were forced to keep the plan on ice.

2.3. Benefits brought to local economy

A municipality which possesses a nuclear power plant—and the surrounding area—receives two types of benefit: large subsidies and a massive number of jobs (or business).

We combine three types of money inflow to the budget of the local government which possesses a nuclear power plant and collectively call them "subsidy" in this paper. The first source of money inflow is the subsidy from the

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[2] Which has to be also close to a large city to send electricity efficiently—this is the policy in the U.S..

central government, which is promised to continue for at least 40 years from the beginning of construction of nuclear power plants. It is understood as a compensation of the risk of a nuclear power plant's accident. The second source of money inflow is the property tax of the nuclear power plant paid by the electric power company. The payment begins after the completion of construction of the nuclear power plants. The payment continues for about 15 years. The third source of money inflow is the large amount of informal donation given by the electric power company to the municipality (local government).

Figure 2 shows local government spending per population in the area surrounding the four nuclear power plants of our interest. We show three groups of the municipalities: (1) the municipalities where nuclear power plants are located, (2) neighboring municipalities to the municipalities that have nuclear power plants, and (3) next-to-next municipalities surrounding the nuclear power plants. The year zero is fixed as the year of the beginning of the operation of the nuclear power plant in each area. The municipalities which have nuclear power plants receive large subsidies from the central government, and property tax and donations from electronic power companies. The amounts of subsidies are calculated based on the capacity of the electricity generated by each nuclear power plant. Neighboring municipalities also receive some amount of subsidy from the central government, but the magnitude of money inflow is very small and negligible. One can confirm it in Figure 2. Next-to-next municipalities receives no subsidy. In Figure 2, by comparing the local government spending of the three groups, one can find the dramatic increase of the local government spending for the municipalities where nuclear power plants are located. Money inflow to the neighboring municipalities can be found to be treated as negligible.

[INSERT FIGURE 2 HERE]

Thanks to the rich budgets, the municipalities with the nuclear power plants become able to provide generous supports to the people who live in the municipality. As shown in the first graph of Figure 2, after the beginning of the operation of the four nuclear power plants, the municipalities where the nuclear power plants are located increased their spending by around 50% at once. The second graph and the third graph show the increase of construction spending and service spending for each. For example, many public facilities (e.g. nursery school, recreation facility, health facility, agricultural facility, sanitary facility) were constructed or repaired. Municipalities also improved the quality of public service (e.g. subsidies to households or local companies, and improvement in educational services).

A nuclear power plant also creates a massive number of jobs in the local economy. In the area surrounding the nuclear plants, jobs in many types of the industries such as construction, retail, restaurant, food are created. The nuclear power plant needs a regular maintenance where a lot of labor is necessary. Local small companies receive orders related to maintenance and operation of the plant from the electric power company; local people are also employed for simple jobs at the nuclear power plant. Moreover, experts of the power industry frequently come to the local town from the urban area. Service jobs, which target people those who visit the nuclear power plants (e.g. retail, restaurant, food, accommodation) are also created.

In this paper, we call the two types of benefits explained above as the subsidy effect and the job effect for each. We define the subsidy effect as the effect that affects only the people who live inside the border of the municipality where a nuclear plant is located. On the other hand, we treat the job effect as something that affects people who live in the area surrounding a nuclear power plant; the effect may be spread over the border of the municipality.

We begin with illustrating the positive impact on fertility choices by cross tabulation tables of difference-in-difference. Table 1 shows a cross tabulation of the number of babies born in a respective year. It contrasts the area close to a nuclear power plant (within 40km) and the area far from a nuclear power plant (over 40km up until ≈150km). For calculation of this table, we define "After" as 1-10 years after the beginning of the operation; we define "Before" as 2-10 years before the beginning of the operation. The difference-in-difference value in the table implies that after the beginning of nuclear power plants' operation, in the area surrounding nuclear power plants, children born per household were increased.

The difference-in-difference value in Table 1 is possibly biased. The increase might be caused by people's self-selected move to a better place; we do not consider any location fixed effects nor time fixed effects. In this paper, we attempt to rigorously estimate the impact of the exogenous change on fertility choices caused by locating a nuclear power plant.

[INSERT TABLE 1 HERE]

3. Data

3.1. Census survey

We use the population census of Japan of the round 1980, 1990, 2000, and 2010; we reshape individual data to household-level observations. We added GPS information at the level of the small administrative area (Cho-Aza) to each observation[3]. Cho-Aza is a smaller unit than municipalities; there were 202,312 Cho-Aza in 1995 while the number of municipalities was 3,377. On average, a Cho-Aza had 218 households. On top of that, we added location information at more granular level for the places surrounding the nuclear power plants of our interest. Based on the papers of the census tract maps that can be obtained at the national statistics library, we created census tract-level location information for the limited area.

We mainly use the following household information of the census surveys: years of residence at the place where households lived at the time of the survey, status of household members such as educational level, marriage, job, and industries. In the descriptive table (Table 2), we list the variables that we use as outcome variables or control variables.

We restrict the samples by the following steps. Firstly, we restrict the samples to households those which had at least a female whose age was between 15 and 49. We also exclude special "households" that live together in dormitories, homes for the aged, hospitals, and other special facilities. Secondly, we restrict the sample by its location. We exclude samples in municipalities which are too far from the nuclear power plants of our interest. Especially, we drop municipalities located more than 150km away from the nuclear power plants of our interest[4]. Further, to avoid

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[3] Exceptionally, we use municipality-level GPS for observations of 1980 because Cho-Aza level GPS is not available for 1980. We use the 1995 GPS information provided by JORAS to construct the 1990 GPS data. This treatment (matching of GPS information) works for around 90 percent of the sample as a nationwide; for the rest we use less accurate GPS information such as "O-Aza". As for 2000 and later, we use the GPS information available at the government website.

[4] We define the set of samples at municipality-level. We use municipalities whose GPS point of the geographical center points—more exactly the point is calculated by population weighted average center—are within 150 km.

any contaminations, we remove samples whose location is too close—within 100 km—to the nuclear power plants which were active before the window of our analysis—the power plants that we do not use in this paper. If we have such samples, those could generate pre-trends in outcome variables. The histograms and cumulative distributions of the distance to the closest nuclear power plants and the travel time[5] to the closest plants are shown in Figure 3.

Last but not least, we restrict our sample to households whose household heads had lived at the municipalities from more than 10 years ago. This is for avoiding the bias by self-selection of the place to live. The information—the place where households stayed 10 years ago—is only available for the survey rounds of 1980, 1990[6], 2000, 2010, and 2015. Therefore, we do not use the survey rounds of 1985, 1995, and 2005.

[INSERT TABLE 2 HERE]

[INSERT FIGURE 3 HERE]

3.2. Outcome variables

We focus on the fertility decision of households. Thus, the main outcome variable of interest is the number of babies born in a respective year within a household. We also use marriage status and employment status as an outcome variable to go deep into the mechanism. Additionally, we study the effect of nuclear power plants to industries where local citizens work for so that we confirm our understanding of the consequence of the growth of the nuclear power plant industry (shown in Table A3 in the Appendix).

3.3. Control variables

We use age, gender, educational level of household members as control variables. Especially we control the attributes of females of age 15-49 and household head in each household. We also use some variables which represents the structure of a household: a dummy which takes one if there are more than two generations inside the household (i.e. kids, parents, and grandparents) and number of people whose age is 60 and above.

Those types of information is available only for the survey years. Meanwhile, in some of our analysis, we use year-level observations (i.e. not only 1990 and 2000, but also 1991, 1992, …, 1999). For such cases, to use control variables, we interpolate the information by exploiting the information at the time of surveys.

4. Key potential channel

4.1. Job effect

We focus on the *job effect* on fertility decisions caused by the operation of a nuclear power plant in this paper. The expected path of causality is as follows: (1) A newly located nuclear power plant creates jobs. (2) Stable employments—the government ensure that a nuclear power plant will continue operation for at least forty years—make the local people easier to get married. (3) Stable employments also encourage couples to have babies—make

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Therefore, the location of each household is not always inside 150 km. The maximum distance to nuclear power plants from households is 172 km.

[5] The travel time by car is calculated with 2010 road maps of Japan.

[6] In 1990, the questionnaire only asks about the residence of five years ago. Thus, we use it. Because of the lack of information, we do not use nuclear power plants which started to work in 1980-85.

the *price* of fertility decision lower. Moreover, employments in Japan has other benefits compared to self-employment; social security such as generous pension system, employment insurance, or medical insurance are available for only people employed.

4.2. Subsidy effect

Also, we conduct causal inference on the *subsidy effect* on fertility decisions caused by the operation of a nuclear power plant. The expected path of causality is as follows: (1) When a new nuclear power plant is located, large subsidies are brought to a local government. (2) At once, a local government begins to spend a larger expenditure and subsequently provide better-quality public services (e.g. subsidies to households or local companies, and improvement in educational services). (3) Better-quality public services encourage couples to have babies—make the *price* of fertility decision lower.

4.3. Hypotheses

The following hypotheses are tested in this paper:

H1: The operation of nuclear power plants leads to increase of jobs in the surrounding areas.
H2: The operation of nuclear power plants leads to higher fertility.
H3: Increasing jobs leads to higher fertility.
H4: Larger local government spending (and subsequent provision of better-quality public services) leads to higher fertility.

5. Empirical models

5.1. Empirical models for estimating job effect

In the following sections, we illustrate the empirical models that we use for estimating the job effect. Firstly, we explain the models for the geographical dynamics on fertility decisions surrounding the nuclear power plants. The models are utilized for defining the treatment group of this study. Figure 4, which shows the map around the Tomari nuclear power plant—one of the plants of our interest, would help one understand the idea. Secondly, we explain the difference-in-difference model. Thirdly, we show the models for event study. Fourthly, we cover the model for IV approach. We utilize instrumented difference-in-difference approach to show how far the employment created around nuclear power plants boosted fertility.

5.1.1. Geographical dynamics

We begin with estimating two dynamic specifications that allow us to capture the geographical dynamics of fertility decision of households. We set the reference point as the location far enough to the nuclear power plants of our interest—140 km away. In Figure 4, we graphically illustrate the idea of this model by showing the case of Tomari nuclear power plant. The first geographical dynamics' equation is the following:

$$(1)\quad y_{pmkit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + \sum_{k=1}^{k=7} \delta_k * \mathbb{1}(Location_k) + \sum_{k=1}^{k=7} \beta_k * \mathbb{1}(Location_k) * After_t + \epsilon_{pmkit}$$

where y_{pmkit} represents the outcome variables of interest—fertility decision and related variables—for household *i* of the survey round *t* (1980, 1990, 2000, 2010); *p* represents prefecture; *m* is municipality (city, district, town, and village). $\mathbb{1}(Location_k)$ is an indicator function taking the value of 1 if a household is located at the location k. Location *k* is defined by the direct distance to the closest nuclear power plant. Specifically, location 1 indicates 0-20 km to the plant; location 2 indicates 20-40 km; location 3 indicates 40-60 km; location 4 indicates 60-80 km; location 5 indicates 80-100 km; location 6 indicates 100-120 km; location 7 indicates over 120 km to the nuclear power plant. We normalize the coefficient in *k* = 8 to 0 (β_8= 0), so that we compare outcomes of before and after period relative to the place which is far enough to the nuclear power plant and not affected by its operation. $After_t$ takes zero if -15 ~ -2 years before the beginning of the closest nuclear power plant and takes one if 1 ~ 20 years after the event. X_{it} represents a set of control variables. Municipality specific time trend and squared trend are captured by t and t^2. α_{pt} is a set of dummies to control for prefecture by year specific unobservable events.

[INSERT FIGURE 4 HERE]

The second geographical dynamics' equation based on travel time is the following. In Figure 5, we graphically illustrate the idea of this model.

(2) $y_{pmjit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + \sum_{j=1}^{j=12} \delta_j * \mathbb{1}(Location_j) + \sum_{j=1}^{j=12} \beta_j * \mathbb{1}(Location_j) * After_t + \epsilon_{pmjit}$

$\mathbb{1}(Location_k)$ is an indicator function taking value 1 if a household is located at the location *j*. Location j is defined by the travel time—by car—to the closest nuclear power plant. Specifically, location 1 indicates 0-15 min to the plant; location 2 indicates 15-30 min; location 3 indicates 30-45 min; location 4 indicates 45-60 min; location 5 indicates 60-75 min; location 6 indicates 75-90 min; location 7 indicates 90-105 min; location 8 indicates 105-120 min; location 9 indicates 120-135 min; location 10 indicates 135-150 min; location 11 indicates 150-165 min; location 12 indicates 165 min over. We normalize the coefficient in *k* = 12 to 0 (β_{12}= 0), so that we compare outcomes of before and after period relative to the place which is far enough to the nuclear power plant and not affected by its operation. The rest of the components are common with the equation (1).

[INSERT FIGURE 5 HERE]

5.1.2. Difference in difference

To construct a model for difference-in-difference approach, we define the treatment group as households located within 40 km from the four nuclear power plants of our interest; the control group is composed of households located over 40 km from the four plants. By using $Treated_i$ which is an indicator for the treatment group and the control, we estimate the following difference-in-difference model:

(3) $y_{pmit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + \delta_1 * Treated_i + \delta_2 * After_t + \beta * After_t * Treated_i + \epsilon_{pmit}$

where y_{pmit} represents the main outcome variable of interest for household i and round t (1980, 1990, 2000, 2010); p is prefecture; m is municipality (city, district, town, and village). We choose a window of [-15,20] years around the beginning of operation of a nuclear power plant. $After_t$ takes zero if -15 ~ -2 years before the beginning of the closest nuclear power plant and takes one if 1 ~ 20 years after the event. Municipality specific time trend and squared trend are captured by t and t^2. α_{pt} is a set of dummies to control for prefecture by year specific unobservable events. $Treated_i$ takes one if the distance to the closest nuclear power plant from the location of a household is 0~40 km; it takes zero if the distance is over 40 km (up to around 150km). The coefficient of interest is β, which captures the effect of the beginning of operation of a new nuclear power plant on fertility decisions in the surrounding, relative to the control group. X_{it} represents a set of control variables. α_{pt} are time-by-prefecture dummies; by those and time trends (and squared trend) at municipality-level, we control for time-variant unobservables.

Secondly, we make another definition of the treatment group and the control group based on travel time by car to the four nuclear power plants of our interest. We define households located within 65 min to the plants as the treatment group; the rest is defined as the control group. Based on this, we construct the second difference-in-difference model. This model's equation is analogous to the equation (3); the only difference is whether the indicator function of the treatment group ($Treated\_v2_i$) is created by using travel time (min) instead of direct distance (km). The model is as follows:

$$(4)\quad y_{pmit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + \delta_1 * Treated\_v2_i + \delta_2 * After_t + \beta * After_t * Treated\_v2_i + \epsilon_{pmit}$$

To exclude the subsidy effect, we also utilize a subsample that does not include the four municipalities where the four nuclear power plants of our interest are located. Exploiting the subsample allow us to remove the subsidy effect from the estimates because only those four municipalities receives large subsidy.

5.1.3. Event study

We estimate two dynamic specifications that allow us to capture the dynamics of fertility decision of households relative to the year of the beginning of operation of the closest nuclear power plant. The basic event study equation is the following:

$$(5)\quad y_{pmit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + \theta * Treated_i + \sum_{k=-8}^{k=-1} \delta_k * \mathbb{1}(Event_k) + \sum_{k=1}^{k=10} \delta_k * \mathbb{1}(Event_k) + \sum_{k=-8}^{k=-1} \beta_k * \mathbb{1}(Event_k) * Treated_i + \sum_{k=1}^{k=10} \beta_k * \mathbb{1}(Event_k) * Treated_i + \epsilon_{pmit}$$

where y_{pmit} represents the outcome variable of interest; p is prefecture; m is municipality (city, district, town, and village). $\mathbb{1}(Event_k)$ is an indicator function taking the value of 1 if it is year k relative to the beginning of operation of the closest nuclear power plant. We choose a window of [-8,10] years around the beginning of operation of a nuclear power plant. We normalize the coefficient in k = 0 to 0 (β_0= 0), so that we compare outcomes of treated and control households relative to the year before of the beginning of operation. $Treated_i$ takes one if the distance to the closest nuclear power plant from the location of a household is 0~40 km; it takes zero if the distance is over 40 km. X_{it} represents a set of control variables. α_{pt} are time-by-prefecture dummies; by those—with time trends and squared trends at municipality-level, we control for time-variant unobservables.

The other dynamic equation that we estimate is as follows:

$$(6)\quad y_{pmit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + \theta * Treated\_v2_i + \sum_{k=-8}^{k=-1} \delta_k * \mathbb{1}(Event_k) + \sum_{k=1}^{k=10} \delta_k * \mathbb{1}(Event_k) + \sum_{k=-8}^{k=-1} \beta_k * \mathbb{1}(Event_k) * Treated\_v2_i + \sum_{k=1}^{k=10} \beta_k * \mathbb{1}(Event_k) * Treated\_v2_i + \epsilon_{pmit}$$

We define households located within 75 min to the plants as the treatment group; the rest is defined as the control group—the dummy variable is $Treated\_v2_i$. Based on this, we construct the second difference-in-difference model. This model's equation is analogous to the equation (5); the only difference is whether the dummy variable of the treatment group ($Treated\_v2_i$) is created by using travel time (min) instead of direct distance (km).

5.1.4. Instrumented difference-in-difference

In general, the relationship between fertility choice and employment is difficult to estimate because of the endogeneity. We can use the operation of a nuclear power plant as an instrument and utilize instrumented difference-in-difference method to control for the endogeneity. As excluded instrument, we use a dummy variable which takes one if there is a nuclear power plant within 40km ($After_t * Treated_i$). We use the equation (3) as the reduced form model; the endogenous variable is a dummy variable indicating employment of each household head.

A valid instrument should fulfil the exclusion restriction. In our case, at first glance, the exclusion restriction is likely to hold because a nuclear power plant's benefit on the local economy would be given to households eventually by having a job and getting the wage. However, there could be some violations. For example, employment would imply a possible wage increase in the surrounding area of a nuclear power plant. A wage increase might also affect the fertility decision—this is a potential detour which positively affect fertility decision. Thus, we admit that our identification strategy cannot separate an employment effect and a wage increase effect. In that sense, the estimates of employment on fertility decision are over estimated. We take the results on the estimates of the effect of employment with caution and call the results suggestive evidence at most.

A natural concern about the exclusion restriction is that positioning the construction site of a nuclear power plant is correlated with the future economic growth of the surrounding area of the site. This might be true in the U.S. because a nuclear power plant was created for sending electricity to a large city to prepare for the large electricity in the future; a nuclear power plant would be created somewhere close to a large city. In Japan, however, this is not the case. As we showed in the section 2, there are many requirements which must be satisfied by a location to have a nuclear power plant. The requirements include having a low population density and having no railways. Hence, we can say that the most suitable place is an underpopulated area for constructing a nuclear power plant.

5.2. Empirical models for subsidy effect

Next, we move on to estimating the subsidy effect. In order to estimate the subsidy effect, we use the third definition of treatment group. We define households that live in the municipalities where nuclear power plants are located as treated households. The rest of the households are defined as control group. In the following equations, $Treated\_v3_i$ is 1 for treated households and 0 for control group.

Currently, we exploit variation around the three nuclear power plants—Tomari, Shika, and Rokkasyo. Due to the data constraint, we do not use Higashidori for estimating the subsidy effect[7].

We estimate the subsidy effect by utilizing three approaches. We call them "border approach", "equal distance approach", and "equal drive time approach." To estimate the subsidy effect, one needs to control for the job effect (and other unobsersvables). The three approaches are designed to control for the job effect. The idea of the three approaches are graphically illustrated in Figure 6. Further, simplified pictures explaining the identification strategies are shown in Figure 7.

Firstly, the border approach restricts the samples to households located close to the border of the municipalities—Tomari, Shika, and Rokkasyo. By doing so, one can compare households that receive similar magnitude of the job effect. Also, one can expect that other environments among the sample households are similar. Still, households that live inside the border always receive larger job effects compared to households that live outside the border. To control such difference, we include log of travel time by car as a control variable.

Secondly, the equal distance approach control for the job effects by including the distance to the nuclear power plant as covariate. We compare households that are located at the same direct distance to the nuclear power plant. For example, we compare a household that is located at 3.5 km to the nuclear power plant with other households that are located within 0-5 km to the nuclear power plant.

Thirdly, the equal drive time approach control for the job effects by including the travel time by car to the nuclear power plant as covariate. The equal drive time approach is analogical to what we do in the equal distance approach. The only difference is that we use the travel time instead of the direct distance.

In all the following specifications, we choose a window of [-10,7] years around the beginning of operation of a nuclear power plant nearby. $After_t$ takes zero if -10 ~ -1 years before the beginning of the operation of the closest nuclear power plant and takes one if 0 ~ 7 years after the event.

[INSERT FIGURE 6 HERE]

[INSERT FIGURE 7 HERE]

5.2.1. Border approach

In this identification strategy, we restrict our samples to households that live close to the border of the three municipalities with nuclear power plants of our interest. By using treatment group and control group which is represented by $Treated\_v3_i$, we estimate the following difference-in-difference model:

$$(7)\quad y_{sqit} = \alpha_s + \omega_s t + \tau_s t^2 + \phi X_{it} + \delta_1 * Treated\_v3_i + \delta_2 * After_t + \beta * After_t * Treated\_v3_i + \gamma_q + \epsilon_{sqit}$$

where y_{sqit} represents number of babies born in year t in household i that is located close to the border of the municipality where nuclear power plant s is located. Area s is defined by the closest nuclear power plant s to each

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[7] Due to the COVID-19 pandemic, the national statistics library has been closed. To estimate the subsidy effect, one needs to obtain census tract maps of the area for analysis. The maps are only available in paper in the national statistic library. Currently we are not able to obtain the maps.

household. As we cover three nuclear power plants, s takes 1 to 3. Location q indicates which part of the border household i is located. For example, Shika town—one of the municipalities where the nuclear power plants of our interest is located—bordered with seven municipalities (before the mergers in 2004). In such a case, the border is divided into seven parts. Among the seven parts, location q indicates the part where household i lives. In other words, location q indicates which municipalities' border that household i faces. We choose a window of [-10,7] years around the beginning of operation of a nuclear power plant nearby. $After_t$ takes zero if -10 ~ -1 years before the beginning of the operation of the closest nuclear power plant and takes one if 0 ~ 7 years after the event. The coefficient of interest is β, which captures the effect of subsidies on fertility decisions of neighborhood, relative to the control group. The model includes area-specific year trend t and squared trend t^2 that control for time-variant unobservables. X_{it} represents a set of control variables. It includes log of travel time from the closest nuclear power plant in order to control for the job effect.

5.2.2. Equal distance approach

In this identification strategy, we restrict our samples to households that live within a certain distance from the closest nuclear power plants. We set the threshold at the distance to the furthest part inside the municipality where the nuclear power plant is located. For example, if the distance to the furthest part inside the municipality is 20km, then we use all the households within 20km from the nuclear power plant as the sample; those include both households live inside the municipality and outside the municipality. By using treatment group and control group which is represented by $Treated\_v3_i$, we estimate the following difference-in-difference model:

$$(8)\quad y_{swit} = \alpha_s + \omega_s t + \tau_s t^2 + \phi X_{it} + \delta_1 * Treated\_v3_i + \delta_2 * After_t + \beta * After_t * Treated\_v3_i + \eta_w + \epsilon_{swit}$$

where y_{swit} represents the main outcome variables of interest for household i located close to nuclear power plant s at location w in year t. Location w is defined by dummies representing the distance to the closest nuclear power plant. For example, one of the dummies indicates 0-5 km from the nuclear power plant, another dummy indicates 5-10 km, and so on. By having η_w in the model, one can compare households inside the municipality (with the nuclear power plant) and outside the municipality, while one also requires those to be located at the same distance to the nuclear power plant. In other words, η_w captures the job effect; we assume that the job effect is bigger for households located closer to the nuclear power plant. Moreover, as an alternative specification, we replace η_w with log of direct distance.

5.2.3. Equal travel time approach

In this identification strategy, we restrict our samples to households that live within a certain travel time—by car—from the closest nuclear power plants. We set the threshold at the travel time to the furthest part inside the municipality where the nuclear power plant is located. If the maximum travel time is 30 min, then we use all the households located within 30 min from the nuclear power plant; those include both households live inside the municipality and outside the municipality. By using the treatment group and the control group which is represented by $Treated\_v3_i$, we estimate the following difference-in-difference model:

$$(9)\quad y_{szit} = \alpha_s + \omega_s t + \tau_s t^2 + \phi X_{it} + \delta_1 * Treated\_v3_i + \delta_2 * After_t + \beta * After_t * Treated\_v3_i + \pi_z + \epsilon_{szit}$$

where y_{szit} represents the main outcome variables of interest for household i located close to nuclear power plant s at location z in year t. The location z is indicated by dummies π_z representing the travel time to the closest nuclear power plants. For example, one of the dummies indicates 0-5 minutes from the nuclear power plant, another dummy indicates 5-10 minutes, and so on. By having π_z in the model, one can compare households inside the municipality with the nuclear power plant and outside the municipality, while one also requires those to be located at the place where one can move from the nuclear power plant in the same time. In other words, π_z captures the mean job effect. Moreover, as an alternative specification, we replace π_z with log of travel time.

5.2.4. Event study

Based on the difference-in-difference approach whose specifications are (7)-(9), we estimate the following event study models:

$$(10)\, y_{sqit} = \alpha_s + \omega_s t + \tau_s t^2 + \phi X_{it} + \theta * Treated\_v3_i + \sum_{k=-10}^{k=-1} \delta_k * \mathbb{1}(Event_k) + \sum_{k=0}^{k=7} \delta_k * \mathbb{1}(Event_k) + \sum_{k=-10}^{k=-1} \beta_k * \mathbb{1}(Event_k) * Treated\_v3_i + \sum_{k=0}^{k=7} \beta_k * \mathbb{1}(Event_k) * Treated\_v3_i + \gamma_q + \epsilon_{sqit}$$

$$(11)\, y_{swit} = \alpha_s + \omega_s t + \tau_s t^2 + \phi X_{it} + \theta * Treated\_v3_i + \sum_{k=-10}^{k=-1} \delta_k * \mathbb{1}(Event_k) + \sum_{k=0}^{k=7} \delta_k * \mathbb{1}(Event_k) + \sum_{k=-10}^{k=-1} \beta_k * \mathbb{1}(Event_k) * Treated\_v3_i + \sum_{k=0}^{k=7} \beta_k * \mathbb{1}(Event_k) * Treated\_v3_i + \eta_w + \epsilon_{swit}$$

$$(12)\, y_{szit} = \alpha_s + \omega_s t + \tau_s t^2 + \phi X_{it} + \theta * Treated\_v3_i + \sum_{k=-10}^{k=-1} \delta_k * \mathbb{1}(Event_k) + \sum_{k=0}^{k=7} \delta_k * \mathbb{1}(Event_k) + \sum_{k=-10}^{k=-1} \beta_k * \mathbb{1}(Event_k) * Treated\_v3_i + \sum_{k=0}^{k=7} \beta_k * \mathbb{1}(Event_k) * Treated\_v3_i + \pi_z + \epsilon_{szit}.$$

$\mathbb{1}(Event_k)$ is an indicator function taking value 1 if it is year k relative to the beginning of operation of the closest nuclear power plant. We choose a window of [-10,7] years around the beginning of operation of a nuclear power plant. We normalize the coefficient in k = -1 to 0 (β_{-1}= 0), so that we compare outcomes of treated and control households relative to the year before of the event.

5.2.5. Instrumented difference-in-difference

The relationship between fertility choice and local government expenditure could be endogenous. We utilize large subsidies provided to municipalities with nuclear power plants as an instrument and use instrumented difference-in-difference method to control for the endogeneity. As excluded instrument, we use a dummy variable which takes one if households live at the municipalities with nuclear power plants after the beginning of the operation of the nuclear power plant ($After_t * Treated\_v3_i$). We use the equation (7), (8), (9) as the reduced form model; the endogenous variable is local governments' expenditure per household.

A valid instrument should fulfil the exclusion restriction. In this case, as the subsidy effect can only realize through local governments' expenditure, the exclusion restriction is likely to be satisfied. The required condition is that we control for the job effect by the design of each approach—border approach, equal distance approach, and equal drive time approach.

6. Empirical results

6.1. Empirical results for estimating job effect

The expected causal impact from having a job on fertility choices is most likely to be applicable for the people whose age is 20-39. Therefore, for the empirical analysis of this section, we restrict our sample households to those which have a member whose age is 20-39[8].

6.1.1. Geographical dynamics

6.1.1.1. Outcome variable: having children born

We begin with investigating the geographical dynamics of the job (creation) effect caused by operation of the four nuclear power plants of our interest. Figure 8 graphically shows the magnitude of the job effect on number of babies born per year per household, relative to the far enough place to the nuclear power plants. We show two graphs of geographical dynamics: on the left, a graph based on the estimates using direct distance to the nuclear power plants, and on the right, a graph based on the estimates using travel time by car to the nuclear power plants. The estimates are calculated based on equation (1) and (2).

From the graph on the right, one can find that the impact on number of babies is most prominent for households located within travel time of 65 min to the nuclear power plants. As getting further from the nuclear power plants, the effects become smaller. From the graph on the left, one can also find that the impact is larger for households located within 40 km to the nuclear power plants[9].

[INSERT FIGURE 8 HERE]

6.1.1.2. Outcome variable: marriage status and employment status

Next, to check whether the expected mechanism is supported or not, we investigate the geographical dynamics of the job effect on marriage- and employment- related outcome variables. Figure 9 and Figure 10 graphically illustrate that the magnitude of the effects depends on access to the nuclear power plants (for treatment group defined by direct distance in Figure 9 and treatment group defined by travel time in Figure 10). To make the mechanism clear, we restrict the sample households to those which have members aged 20-39. We show graphs based on the estimates of the impact on number of babies born per year per household, marriage status (number of females of age 15-49 married in household), a dummy variable which takes one if household head is employed, and a dummy which takes one if household head is searching a job.

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[8] On top of that, we restrict our sample to households whose household heads had lived at the municipalities from more than 10 years ago. We also restrict our sample household to those which have a female whose age is 15-49.

[9] The effects are also large in 100-120 km. This is not surprising because there are large cities in the zone. Japanese local governments' procurement rule uses a rank system to classify companies. Companies are classified as A-rank, B-rank, C-rank, and so on. The procurement target (building, service, and else) is also classified as A-rank, B-rank, C-rank, and so on. A-rank business is only available for A-rank companies. The business created due to operation of nuclear power plants includes A-rank or B-rank business. Such high-ranked procurement is only available for companies located in large cities. Therefore, it is reasonable to find that the operation of nuclear power plants also brings benefits to households living in large cities—those not too far from nuclear power plants.

The results support the mechanism that we expect. The shape of the geographical dynamics for number of babies, marriage status, and an indicator which takes one if household head is employed, are similar. The estimates on the coefficient of an indicator of searching a job by household head are larger—in absolute value—for the areas closer to the nuclear power plants.

[INSERT FIGURE 9 HERE]

[INSERT FIGURE 10 HERE]

6.1.2. Difference-in-difference

Based on the results of the estimates on the geographical dynamics, we define treatment group as households located within 40 km from the four nuclear power plants of our interest ($Treated_i$); we also define the other treatment group as households located within 65 min from the plants ($Treated\_v2_i$). We use equation (3) and (4) to estimate the causal impact of the operation of nuclear power plant on number of babies born per year per household.

Table 3 shows the estimates of the impact of operation of nuclear power plant on number of babies born per year per household obtained by difference-in-difference method. Column (1) and (3) show the estimates based on equation (3) and (4) for each. Those specifications utilize all the sample households. The interaction term's coefficients are the coefficients of interest. We see that the estimated coefficients are statistically significant, and the magnitude is around 0.005. The magnitude is approximately 10-15 percent increase in number of babies born per year per household. Column (2) and (4) show the estimates based on a subsample excluding households who are located at the four municipalities where the four nuclear power plants are located. This is for isolating the job effect from the subsidy effect. As the estimates are almost the same to those in column (1) and (3), the estimates of column (2) and (4) support the existence of the job effect.

[INSERT TABLE 3 HERE]

Table 4 shows the estimates of the impact of operation of nuclear power plant on other outcome variables: number of females (age 15-49) married in household, a dummy which takes one if any females (age 15-49) married in household, a dummy variable which takes one 1 if household head is employed, and a dummy variable which takes one if household head is searching a job. The estimates of column (1)-(4)—calculated by equation (3) using the treatment indicator based on direct distance to nuclear power plants—are consistent to what we graphically see in Figure 8 that shows geographical dynamics. Number of females who are married increased; more importantly, number of household heads who are employed increased as well. Meanwhile, column (5)-(8)—calculated by equation (4) using the treatment indicator based on travel time to nuclear power plants—do not show statistically significant results. Overall, however, the sign of the point estimates of column (5)-(8) are reasonable.

[INSERT TABLE 4 HERE]

On top of that, in the Appendix (Table A3), we show the estimates on the impact of nuclear power plants' operation on household heads' jobs' industries. Again, we use equation (3) and (4) to restricted sample households that have members aged 20-39. In Table A3, one can find that household heads who work for construction industry, retail, restaurants, and other service industries increased in the treatment group.

6.1.3. Event study

Difference-in-difference estimates require the common trend assumption to be treated as causal. We explore the dynamics of the effects on fertility decisions around the year of the beginning of operation of the closest nuclear power plant. We use equation (5) and (6) for event study. Figure 10 displays the point estimates of the event study over the window of [-8, 10] years, where we normalize the coefficient in the year of the beginning of the nuclear power plant[10]. The figure provides a visual test of our identification strategy. In a difference-in-difference approach, in the pre-period, we should not observe a different pre-trend between the treatment group and the control group. This means that pre-period point estimates should not be statistically different from zero. Basically, this is what we observe for fertility decisions shown in Figure 11. Thus, Figure 11 supports the assumption of our identification strategy—there is no pre-trend.

[INSERT FIGURE 11 HERE]

6.1.4. Instrumented difference-in-difference

In Table 5, we show the results obtained by instrumented difference-in-difference method. Based on equation (3) as a reduced form, we use distance to the closest nuclear power plant as an instrument to estimate the effect of employment on number of babies per year per household. The coefficient of interest shown in Column 1 implies that an additional employment provided for a household head leads to 30 percentage point increase of the probability of having an additional baby per year. The IV is weak because Kleibergen-Paap rk Wald F statistic shows a value of 4.317 which is lower than the critical value of ten. Thus, we show Anderson-Rubin statistics p-value. The Anderson-Rubin statistics p-value supports the validity of the estimates. However, the estimate is likely to be biased because the exclusion restriction is probably not be satisfied. A possible scenario of violation of the exclusion restriction is that the benefit of job creation by a nuclear power plant is delivered to a household through employment of household members other than the household head. Overall, the results of instrumented difference-in-difference approach suggest that additional employments lead to additional babies, though we cannot be conclusive on this point due to possible violation of exclusion restriction.

[INSERT TABLE 5 HERE]

6.2. Empirical results for estimating subsidy effect

6.2.1. Reduced form

Table 6 shows the estimates of difference-in-difference method based on equation (7)-(9)—border approach, equal distance approach, and equal drive time approach. To illustrate the possible impact of large subsidies as clear as possible, we restrict the sample households to those which have females aged 25-34. The estimates on the coefficient

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[10] We do not show the estimates of the window of [6, 10] because those estimates utilize only three nuclear power plants out of four. The fourth nuclear power plant—Higashidori—began its operation in 2005, while we use the data until 2010. Therefore, our data has only 5 years of observations for households around Higashidori nuclear power plant. To consistently use all the four nuclear power plants in our estimates, we do not show the point estimates of [6, 10].

of the interaction term is of interest to us. The estimates the coefficient of most of the specifications are around 0.01. This is approximately 10% increase of the number of children born per household per year (mean is 0.13).

[INSERT TABLE 6 HERE]

6.2.2. Instrumented difference-in-difference

Table 7 shows the estimates of instrumented difference-in-difference approach. Many of the estimates of the coefficient of the log of local government expenditure are around 0.07. By using this number, we can interpret the results as follows. For every 1% increase in the expenditure of the local government, fertility rate increases by 0.0007. Thus, for every 100% increase in the expenditure of the local government, fertility rate increases by 0.07. As the mean number of children born is around 0.13 for women aged 25-34, 100% increase in the local government's expenditure leads to around 50% increase in number of babies born per year per household.

[INSERT TABLE 7 HERE]

6.2.3. Event study

Difference-in-difference estimates require the common trend assumption to be treated as causal. We explore the dynamics of the effects on fertility decisions around the year before the beginning of the operation of the closest nuclear power plant. We use equation (10)-(12) for event study.

The results of event study do not strongly support the validity of the causal identification strategy. Basically, the graphs do not show a clear pre-trend. However, the change after the treatment is not graphically clear. Moreover, two out of three graphs show negatively significant estimates at the period [-2]. This is prominent and unusual.

One might argue that the period [-2] has to be removed from the "before" period used in difference-in-difference approach. We provide the results of the estimates based on the alternative specifications—the before period is defined as years of [-10, -3]—in Table A1 and A2 in the Appendix. Statistical significance level of the difference-in-difference estimates changes. The estimates become marginally significant at most. Therefore, we conclude that the results obtained by the subsidy effect analysis is suggestive evidence which implies possible causal relationship between local government spending and fertility decisions.

7. Conclusion

Existing studies have been struggling in finding a policy intervention which effectively boosts fertility. Especially, the impact of creating jobs is difficult to estimate because in most cases such an intervention is endogenous. This study exploits a plausibly exogenous variation of employment and fertility caused by the operation start of nuclear power plants. Nuclear power plants bring a massive number of jobs to the rural economy; because the government ensures that the nuclear power plants' industry will continues at least 40 years, the newly created local employments would change the forecast of local households' financial condition in the future. Also, employment in Japan has other benefits such as strong social security; it can encourage people to become more positive in fertility decisions. By this causal path, we argue that fertility choice is affected by a new nuclear power plant.

We admit that the *job creation effect* of our estimate includes the effect of a possible wage increase or other changes. The new jobs brought to a local economy also accompanies the impression of stability—people would think that it is a stable job. In those respects, the job created is something different from the job existed before in the local area.

The causality from the increase of local government budgets (and its spending) on fertility choices is not easy to argue because the growth of local government spending is closely related to the local economic growth. In this study, we find suggestive evidence that increase of local government spending and subsequent provision of better-quality public services lead to higher fertility. We admit, however, that the results are not conclusive as the estimates are marginally significant.

We do not argue that construction of a nuclear power plant is a good boost to fertility. Our main finding is: creating jobs can be a good boost to fertility—though our finding is only effective for the area surrounding nuclear power plants and people who are compliers to the instrument.

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Tables

Table 1 Cross-tabulation of Fertility decisions (number of babies born per year per HH) by treatment status

Treatment: distance from the closest nuclear power plant (40-≈150 km VS 0-40 km)

	All HHs		
	Distance from the closest nuclear power plant (40-≈150 km VS 0-40 km)		
	Control	Treated	Difference
Before	0.0548	0.0589	0.00410
	(6.47e-05)	(0.000253)	(0.000261)
After	0.0482	0.0550	0.00684
	(5.60e-05)	(0.000235)	(0.000241)
Difference	-0.0066	-0.0039	0.00274***
			(0.000356)

Notes: "After" and "Before" indicate the relative year to the beginning of operation of the four nuclear power plants. We define "After" as 1-10 years after the event. We define "Before" as 2-10 years before the event. Standard errors are in parentheses. Significance level is only shown for difference-in-difference values: *** p<0.01, ** p<0.05, * p<0.1.

Table 2 Descriptive table

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
Num of females of age 15-49 in HH	6,927,959	1.214	0.487	1	7
Num of females of age 15-19	6,927,959	0.159	0.403	0	6
Num of females of age 20-24	6,927,959	0.150	0.377	0	4
Num of females of age 25-29	6,927,959	0.170	0.384	0	4
Num of females of age 30-34	6,927,959	0.180	0.388	0	4
Num of females of age 35-39	6,927,959	0.185	0.390	0	3
Num of females of age 40-44	6,927,959	0.187	0.391	0	3
Num of females of age 45-49	6,927,959	0.184	0.388	0	3
Num of females of age 50-54	6,927,959	0.0716	0.258	0	3
Num of females of age 55-59	6,927,959	0.0599	0.238	0	3
Num of married females of age 15-49	6,927,959	0.717	0.463	0	5
Num of females of age 15-49 who graduated from university/graduate school	6,927,959	0.0686	0.256	0	4
Num of females of age 15-49 who work full-time	6,927,959	0.512	0.583	0	6
Num of females of age 15-49 who work part-time	6,927,959	0.183	0.396	0	4

Table 2 continued.

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
1 if household head is male	6,927,959	0.793	0.405	0	1
1 if HH head is graduated from university/graduate school	6,927,959	0.152	0.359	0	1
1 if HH head searched a job in the last 7 days	6,927,959	0.0229	0.150	0	1
1 if HH head is a regular employee/temporary employee/part-time worker	6,927,959	0.657	0.475	0	1
1 if HH head is an executive officer	6,927,959	0.0525	0.223	0	1
1 if HH head is self-employed and have employees	6,927,959	0.0410	0.198	0	1
1 if HH head is self-employed without having an employee	6,927,959	0.105	0.306	0	1
1 if HH head works on a family business	6,927,959	0.00444	0.0665	0	1
1 if HH head is a sideline worker at home	6,927,959	0.00110	0.0332	0	1
1 if HH head works in Agriculture	6,927,959	0.0529	0.224	0	1
1 if HH head works in Forestry, hunting	6,927,959	0.00445	0.0666	0	1
1 if HH head works in Fishery	6,927,959	0.00979	0.0984	0	1
1 if HH head works in Mining	6,927,959	0.00405	0.0635	0	1
1 if HH head works in Construction	6,927,959	0.125	0.331	0	1
1 if HH head works in Manufacturing	6,927,959	0.119	0.324	0	1
1 if HH head works in Electricity, gas, water	6,927,959	0.00741	0.0858	0	1
1 if HH head works in Transportation (communication)	6,927,959	0.0806	0.272	0	1
1 if HH head works in Retail (restaurant)	6,927,959	0.170	0.376	0	1
1 if HH head works in Finance, insurance	6,927,959	0.0215	0.145	0	1
1 if HH head works in Real estate (leasing)	6,927,959	0.00767	0.0872	0	1
1 if HH head works in Service	6,927,959	0.203	0.402	0	1
1 if HH head works in Public service	6,927,959	0.0508	0.220	0	1
1 if HH head works in Unclassified	6,927,959	0.00866	0.0927	0	1

Table 2 continued.

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Num of baby of age 0 in HH	6,927,959	0.0501	0.220	0	4
Number of people in HHs	6,927,959	3.608	1.561	1	20
1 if HH members who are adult include two generations	6,927,959	0.119	0.324	0	1
Num of people of age 60 and above	6,927,959	0.391	0.704	0	8

Sources: Japanese population census 1980 / 1990 / 2000 / 2010

Table 3 Job effect: difference-in-difference; dependent variable: number of babies per year per household

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Distance w/in 40km = 1				Travel time w/in 65min = 1			
	Round-level data		Year-level data		Round-level data		Year-level data	
treatment * after	.00945**	.00956***	.00732***	.00707***	.00745**	.00748**	.0044***	.00411**
	(.00366)	(.00363)	(.00199)	(.00199)	(.00372)	(.0037)	(.00168)	(.0017)
Observations	2,295,589	2,284,007	12,825,257	12,772,720	2,269,495	2,257,913	12,681,598	12,629,061
R-squared	.0349	.0348	.032	.032	.0348	.0348	.032	.032
year*prefecture	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
municipality-level year trend and squared trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
excluding towns where NP located	-	Yes	-	Yes	-	Yes	-	Yes
Mean	.071	.071	.075	.075	.071	.071	.075	.075

Notes: Sample households are those 1) which include a female whose age is 15-49, 2) which have members of age 20-39, and 3) whose household heads had lived at the municipalities from more than 10 years ago. Control variables are follows: number of females of age 15-19 / 20-24 / 25-29 / 30-34 / 35-39 / 40-44, number of females of age 15-49 who graduated from university/graduate school, a dummy variable which takes one if HH members—who are adult—include two generations, number of people of age 60 and above, a dummy variable which takes one if HH head is graduated from university/graduate school, and a dummy variable which takes one if household head is male. Standard errors are clustered at municipality level. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 4 Job effect: DID; dependent variable: other outcome variables

Treatment:	Distance w/in 40km = 1				Travel time w/in 65min = 1			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	1 if any females (age 15-49) married in HH	1 if HH head is employed	1 if HH head is searching for a job	1 if HH head searching for a job / housework / others	1 if any females (age 15-49) married in HH	1 if HH head is employed	1 if HH head is searching for a job	1 if HH head searching for a job / housework / others
treatment * after	.0347***	.0337**	-.00265	-.01*	.0253***	.0335***	-.00213	-.00394
	(.0096)	(.0162)	(.00239)	(.00595)	(.00715)	(.0124)	(.0022)	(.00446)
Observations	2,295,589	2,295,589	2,295,589	2,295,589	2,269,495	2,269,495	2,269,495	2,269,495
R-squared	.292	.177	.00647	.187	.293	.176	.00651	.187
year*prefecture	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
municipality-level year trend and squared trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	0.696	.671	.023	.129	0.696	.671	.023	.129

Notes: Sample households are those 1) which include a female whose age is 15-49, 2) which have members of age 20-39, and 3) whose household heads had lived at the municipalities from more than 10 years ago. Control variables are as follows: number of females of age 15-19 / 20-24 / 25-29 / 30-34 / 35-39 / 40-44, number of females of age 15-49 who graduated from university/graduate school, a dummy variable which takes one if HH members—who are adult—include two generations, number of people of age 60 and above, a dummy variable which takes one if HH head is graduated from university/graduate school, and a dummy variable which takes one if household head is male. Standard errors are clustered at municipality level. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 5 Job effect: Instrumented difference-in-difference; dependent variable: number of babies per year per household

VARIABLES	(1) Distance w/in 40km = 1	(2) Drive time w/in 65min = 1
1 if HH head is employed	.28***	.223**
	(.107)	(.0954)
Observations	2,295,589	2,269,495
year*prefecture	Yes	Yes
municipality-level year trend and squared trend	Yes	Yes
Mean	.071	.071
Kleibergen-Paap rk Wald F statistic	4.336	7.316
Anderson-Rubin Statistics p-value	0.0105	0.0464

Notes: Sample households are those 1) which include a female whose age is 15-49, 2) which have members of age 20-39, and 3) whose household heads had lived at the municipalities from more than 10 years ago. Control variables are as follows: number of females of age 15-19 / 20-24 / 25-29 / 30-34 / 35-39 / 40-44, number of females of age 15-49 who graduated from university/graduate school, a dummy variable which takes one if HH members who are adult include two generations, number of people of age 60 and above, a dummy variable which takes one if HH head is graduated from university/graduate school, and a dummy variable which takes one if household head is male. Standard errors are clustered at municipality level. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table 6 Subsidy effect analysis (women aged 25-34); dependent variable: number of babies born per year per household

	Border approach				Equal distance approach		Equal drive time approach	
	(1)	(2)	(3)	(4)	(1)	(2)	(1)	(2)
VARIABLES	W/in 1km	W/in 2km	W/in 3km	W/in 4km	Log	Dummies	Log	Dummies
treatment	.0093	.00375	-.00103	.00213	.00585	.00463	.00885**	.0091**
	(.0125)	(.00835)	(.00623)	(.00534)	(.0044)	(.00444)	(.00395)	(.00429)
after (year 0~7=1 -10~-1=0)	-.0295	-.0279**	-.0361***	-.0319***	-.019***	-.019***	-.015***	-.015***
	(.0207)	(.0132)	(.0103)	(.00815)	(.00567)	(.00567)	(.00396)	(.00396)
treatment * after	-.0166	.0125	.0222**	.0158**	.012*	.0122*	.0116**	.0114**
	(.0174)	(.0122)	(.00928)	(.00777)	(.00639)	(.00639)	(.00566)	(.00567)
Observations	7,402	17,597	28,956	44,634	77,180	77,180	158,973	158,973
R-squared	.0112	.00878	.0084	.00853	.00859	.00873	.00855	.00864
year trend and squared trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log distance / drive time	Yes	Yes	Yes	Yes	Yes	-	Yes	-
Dummies of distance / drive time	-	-	-	-	-	Yes	-	Yes
Mean	.134	.134	.134	.134	.137	.137	.133	.133

Notes: Sample households are restricted to those which have females aged 25-34. Control variables are as follows: number of females of age 15-19 / 20-24 / 25-29 / 30-34 / 35-39 / 40-44, number of females of age 15-49 who graduated from university/graduate school, a dummy variable which takes one if HH members—who are adult—include two generations, number of people of age 60 and above, a dummy variable which takes one if HH head is graduated from university/graduate school, and a dummy variable which takes one if household head is male. Standard errors are clustered at municipality level. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

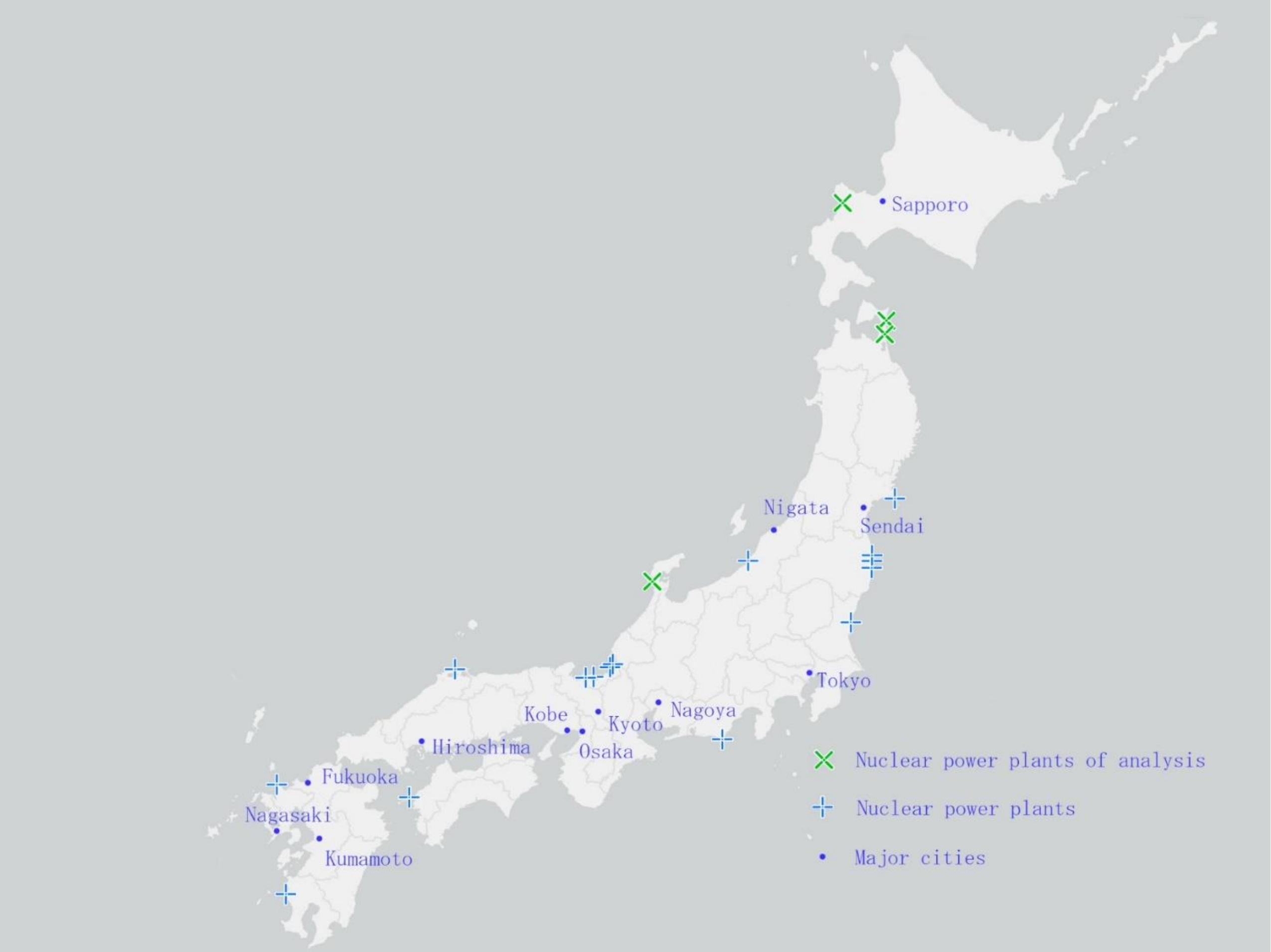
Table 7 Subsidy effect analysis: IV (women aged 25-34); dependent variable: number of babies born per year per household

	Border approach			Equal distance approach		Equal drive time approach	
VARIABLES	1 W/in 2km	2 W/in 3km	3 W/in 4km	4	5	6	7
Local government expenditure (log/MA)	.0749	.138**	.0968**	.0767*	.075*	.0601*	.0597*
	(.0732)	(.0579)	(.0477)	(.0408)	(.0394)	(.0311)	(.0313)
treatment	-.00112	-.0076	-.00333	-.000542	-.0024	.00154	-.000639
	(.0116)	(.00803)	(.00711)	(.00681)	(.00706)	(.007)	(.00809)
after (year 0~7=1 -10~-1=0)	-.0358**	-.0521***	-.0453***	-.0349***	-.0345***	-.027***	-.0269***
	(.0172)	(.014)	(.0119)	(.0113)	(.011)	(.00803)	(.00805)
Observations	17,597	28,956	44,634	77,180	77,180	151,998	151,998
R-squared	.00489	.0021	.00361	.00456	.00449	.00483	.00461
year trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes
control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	.134	.134	.134	.137	.137	.133	.133
Log distance / drive time	Yes	Yes	Yes	Yes	-	Yes	-
Dummies of distance / drive time	-	-	-	-	Yes	-	Yes
F statistic for weak identification	794.6	1202	1693	840	1108	1610	2151

Notes: Sample households are restricted to those which have females aged 25-34. Control variables are as follows: number of females of age 15-19 / 20-24 / 25-29 / 30-34 / 35-39 / 40-44, number of females of age 15-49 who graduated from university/graduate school, a dummy variable which takes one if HH members—who are adults—include two generations, number of people of age 60 and above, a dummy variable which takes one if HH head is graduated from university/graduate school, and a dummy variable which takes one if household head is male. Standard errors are clustered at municipality level. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

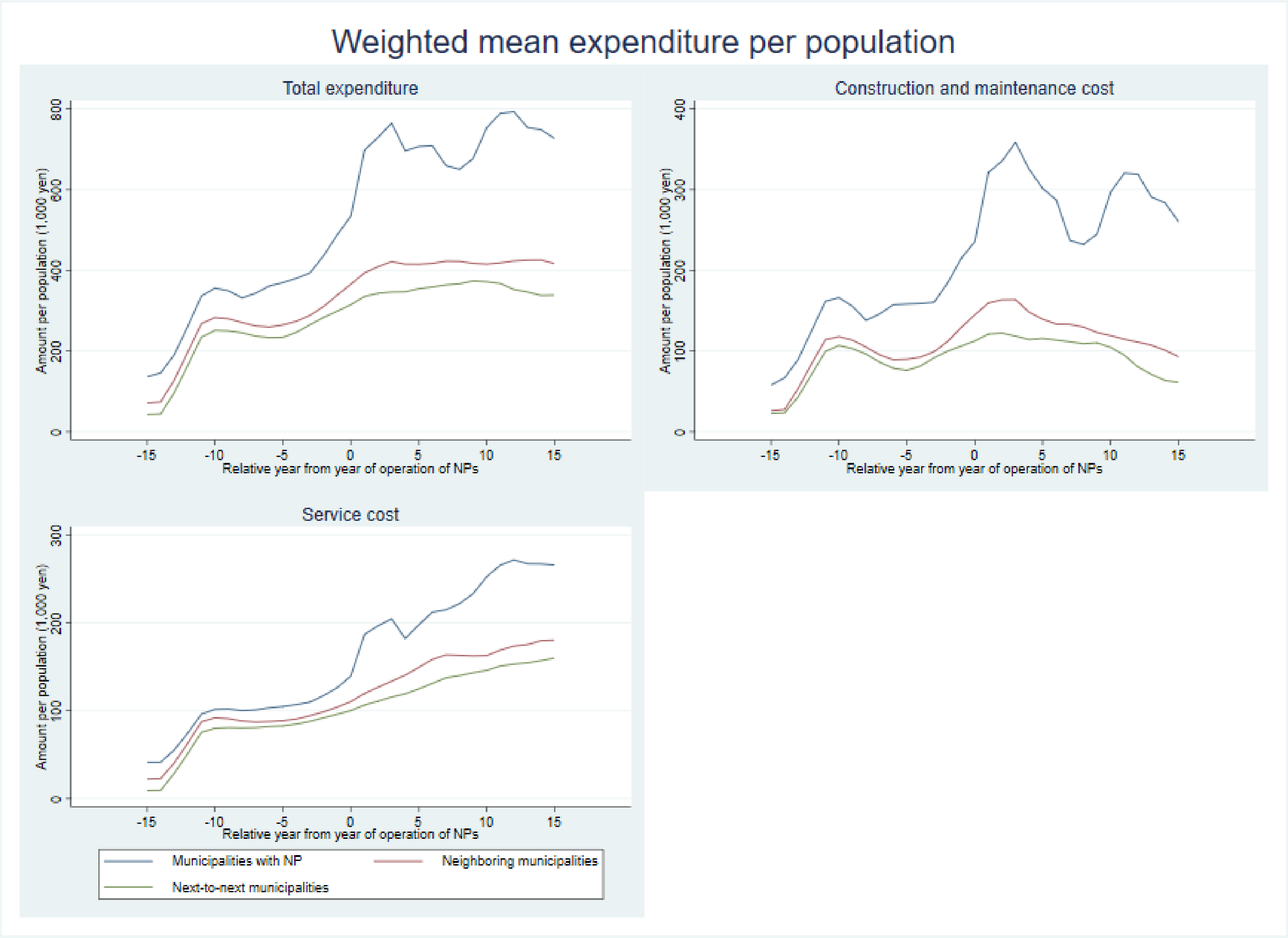
Figure 1 Map of nuclear power plants

#	year	Name
1	1970	Mihama
2	1970	Tsuruga
3	1971	Fukushima1
4	1974	Shimane
5	1974	Takahama
6	1975	Genkai
7	1976	Hamaoka
8	1977	Igata
9	1978	Tokai
10	1979	Ooi
11	1982	Fukushima2
12	1984	Sendai
13	1984	Onagawa
14	1985	Kashiwazaki
15	1989	Tomari
16	1992	Rokkasyo
17	1993	Shika
18	2005	Higashidori



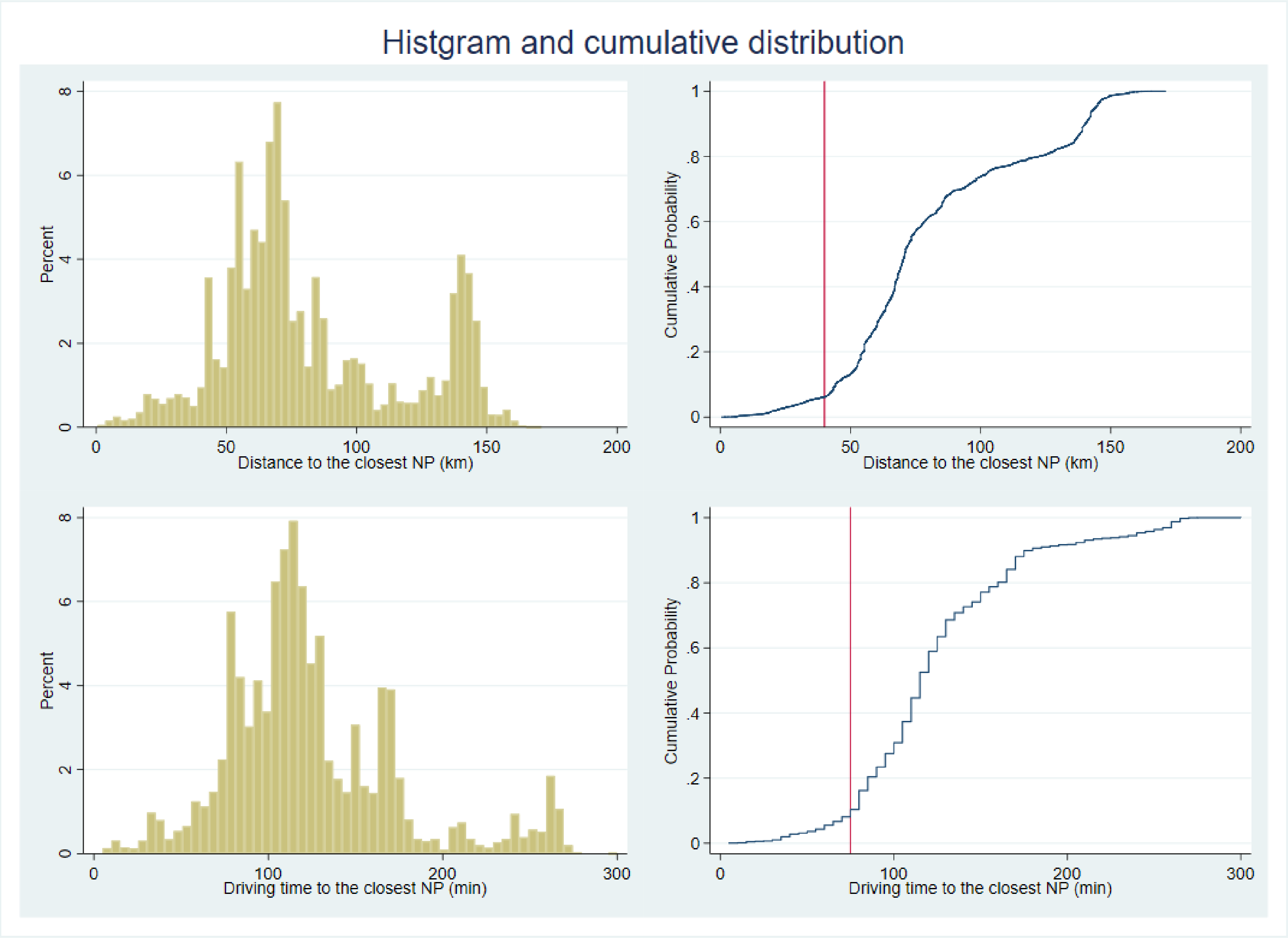
Notes: The years of the beginning of the business operation are shown.
Source: National Land Numerical Information download service

Figure 2 Local government spending in the areas surrounding nuclear power plants



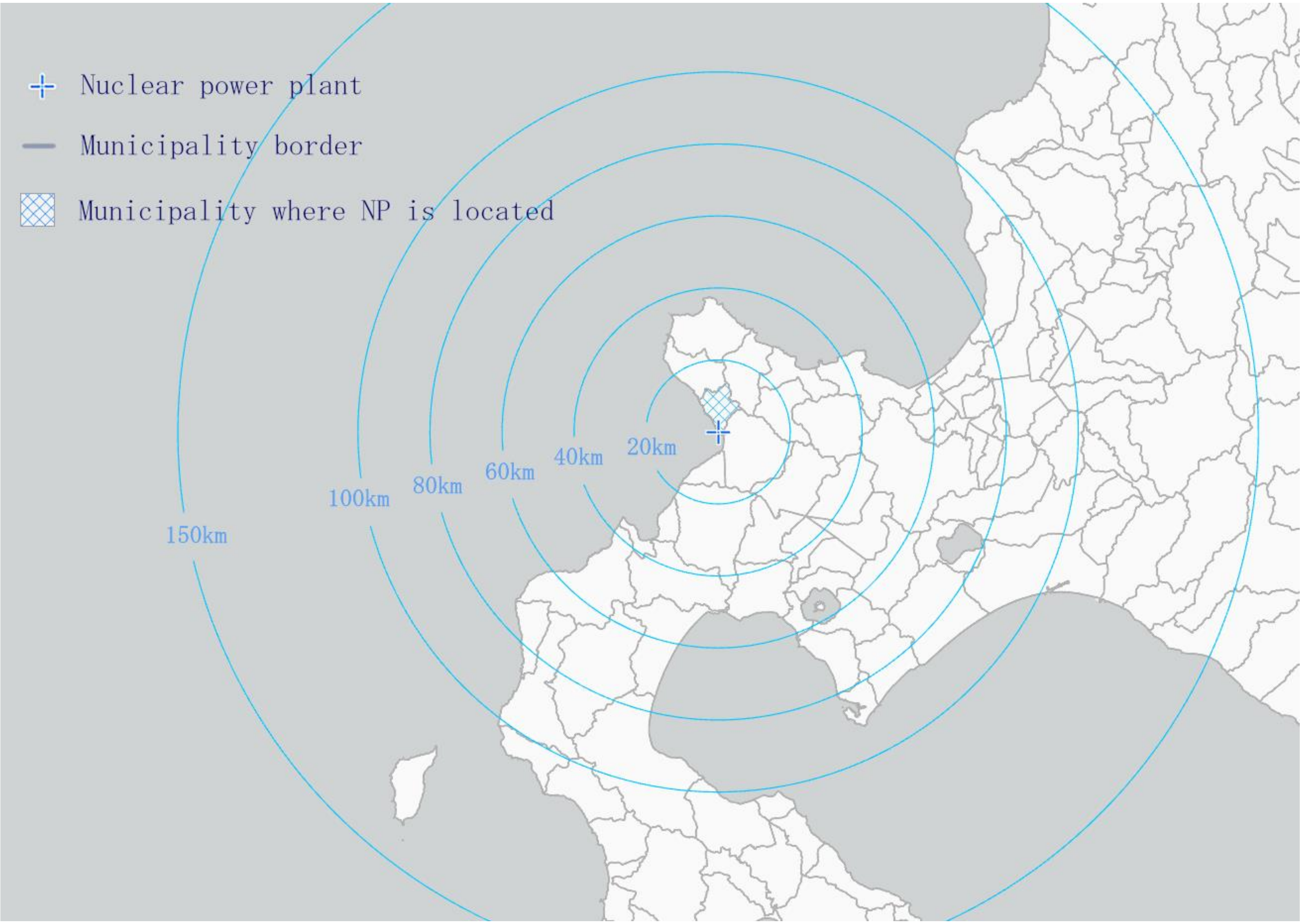
Notes: The expenditures are calculated as follows: (a) Three years moving average based on expenditures per population is used; (b) Nominal spending is converted into real values by national-level consumer price index. (c) Population weighted average values are calculated based on municipality-level data. Total expenditure can be divided into three parts: (1) construction and maintenance cost, (2) service cost, and (3) local civil servants' salary. We use three nuclear power plants: Tomari, Shika, and Rokkasyo. Currently, we exclude Higashidori from this graph because the year of the beginning of Higashidori's operation is 2005; it overlaps with the period of municipal mergers. The mergers make it not easy to draw a graph.

Figure 3 Histogram and cumulative distribution of observations

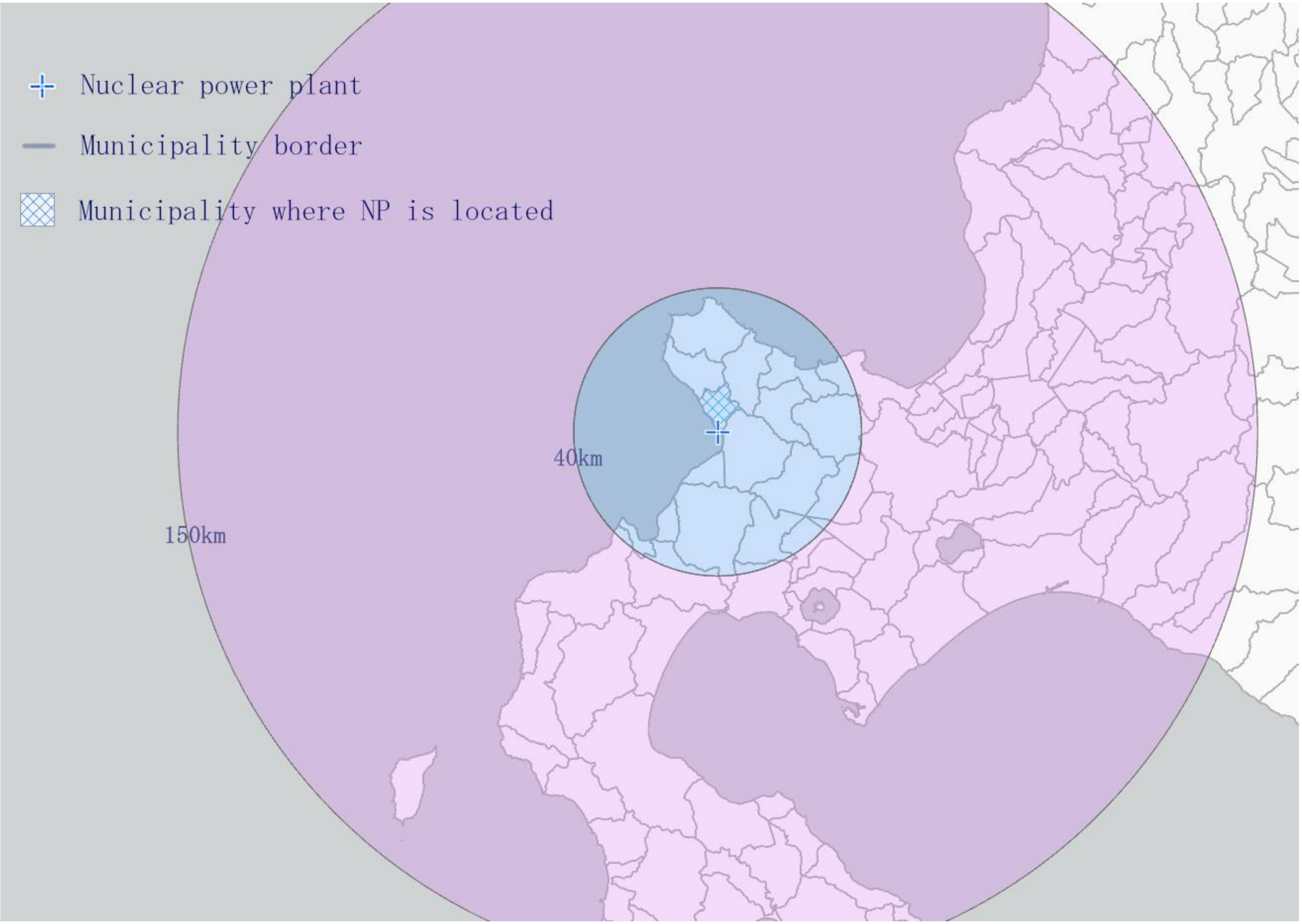


Notes: NP stands for nuclear power plant. Travel time by car was estimated in 5-minute increments. Red lines point 40km and 65min.

Figure 4 Image of job effect: direct distance

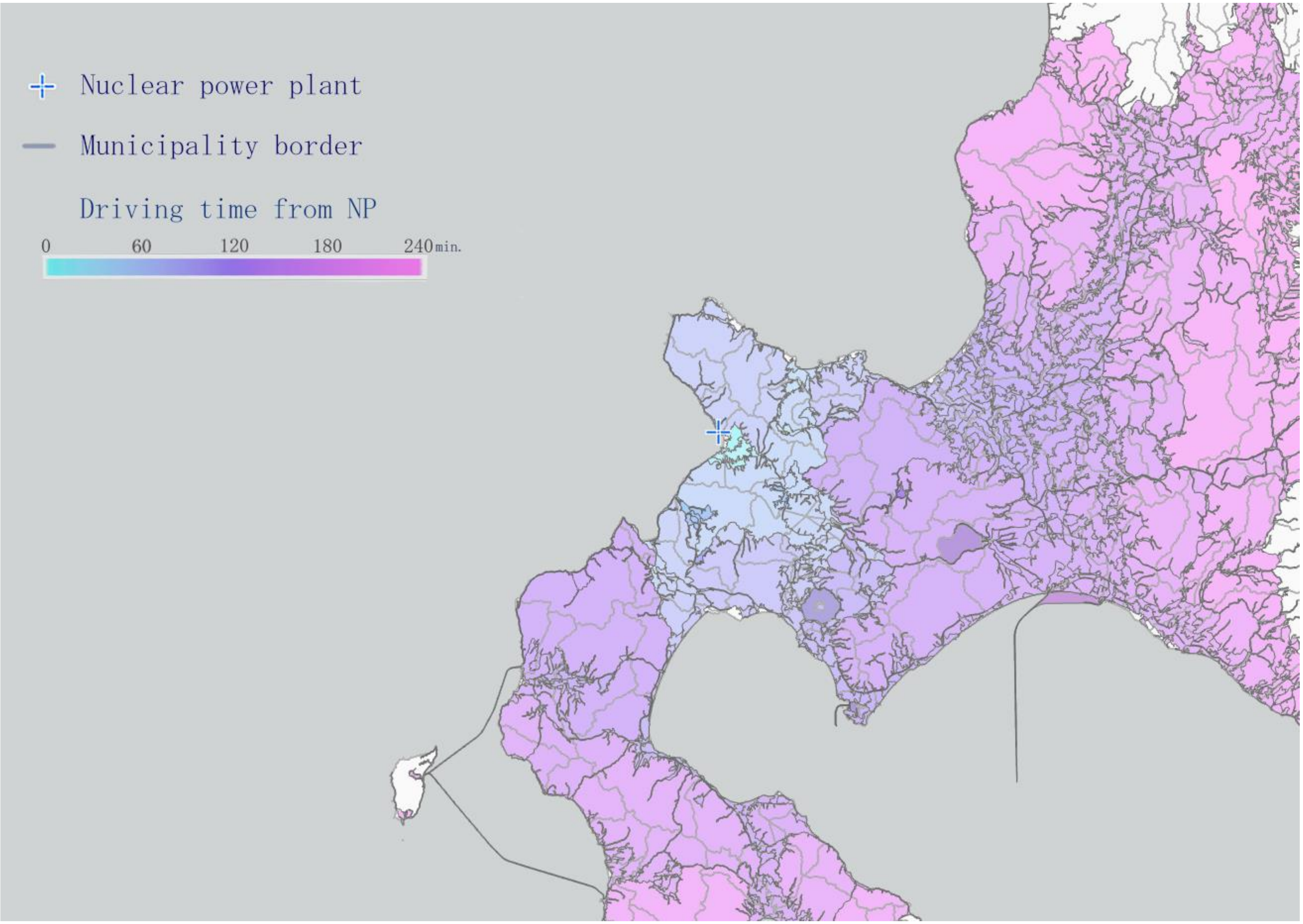


Notes: The location of Tomari nuclear power plant is shown.

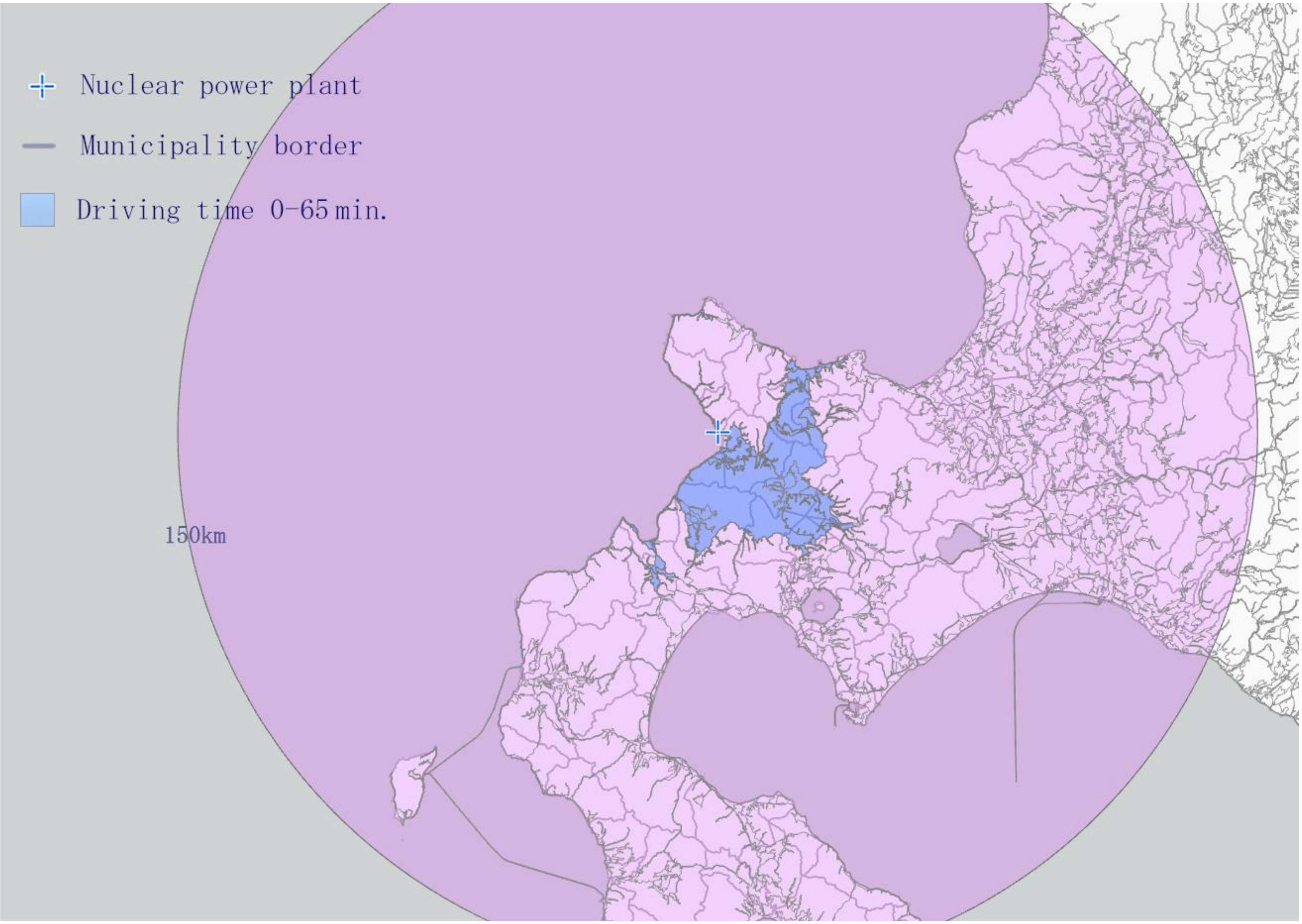


Notes: The location of Tomari nuclear power plant is shown.

Figure 5 Image of job effect: travel time by car



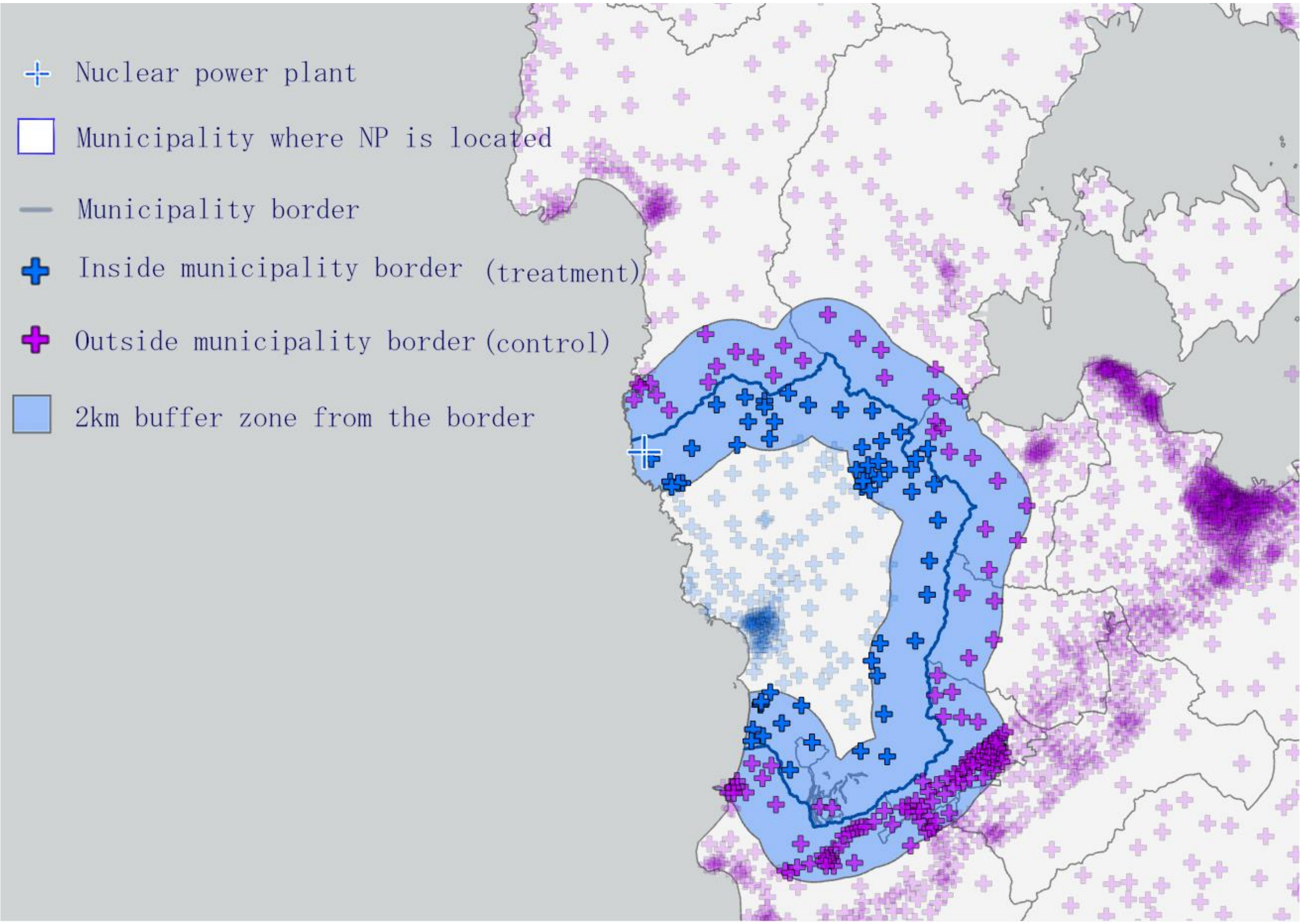
Notes: The location of Tomari nuclear power plant is shown.



Notes: The location of Tomari nuclear power plant is shown.

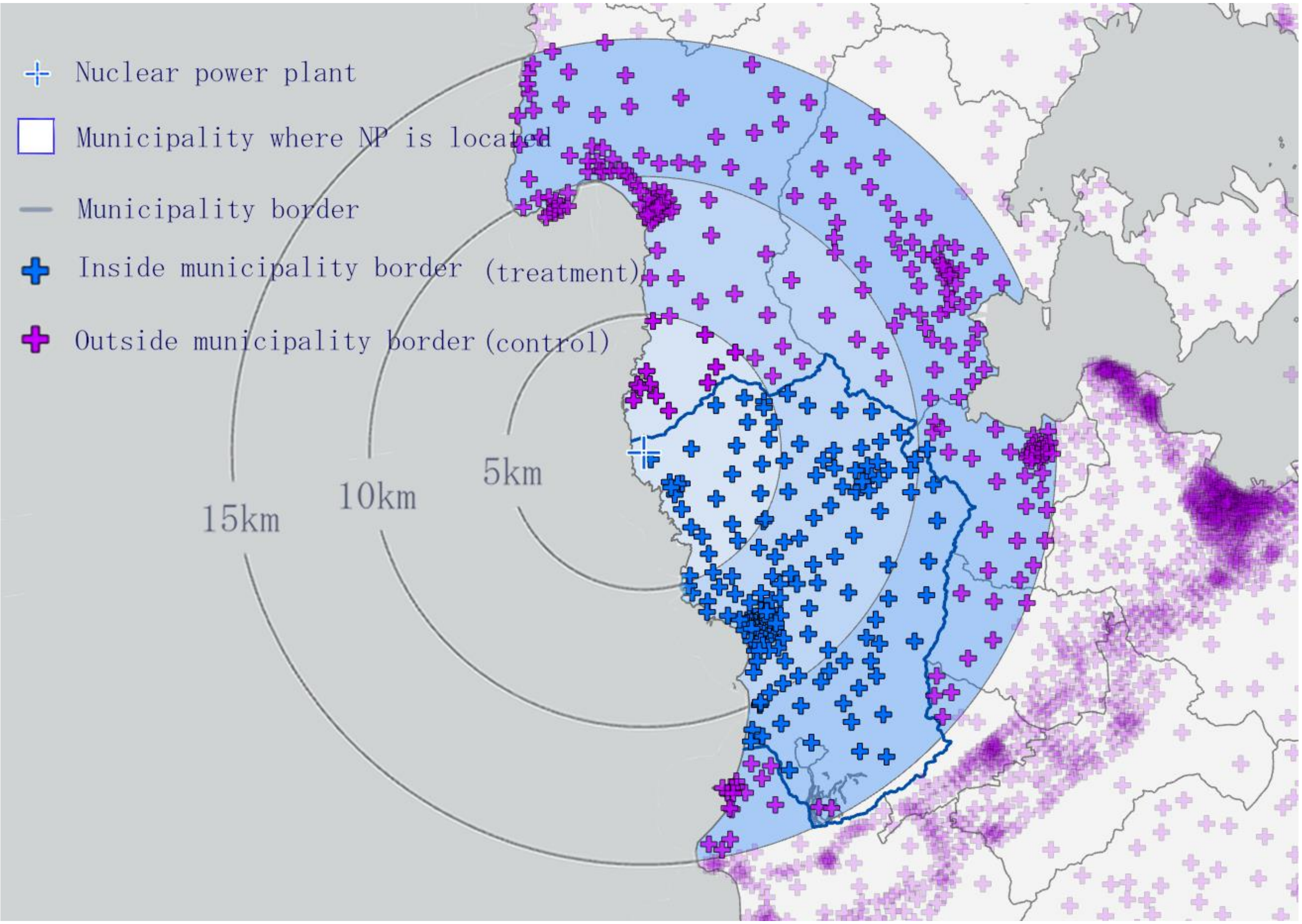
Figure 6 Three identification strategies for estimating subsidy effects

a. Border approach



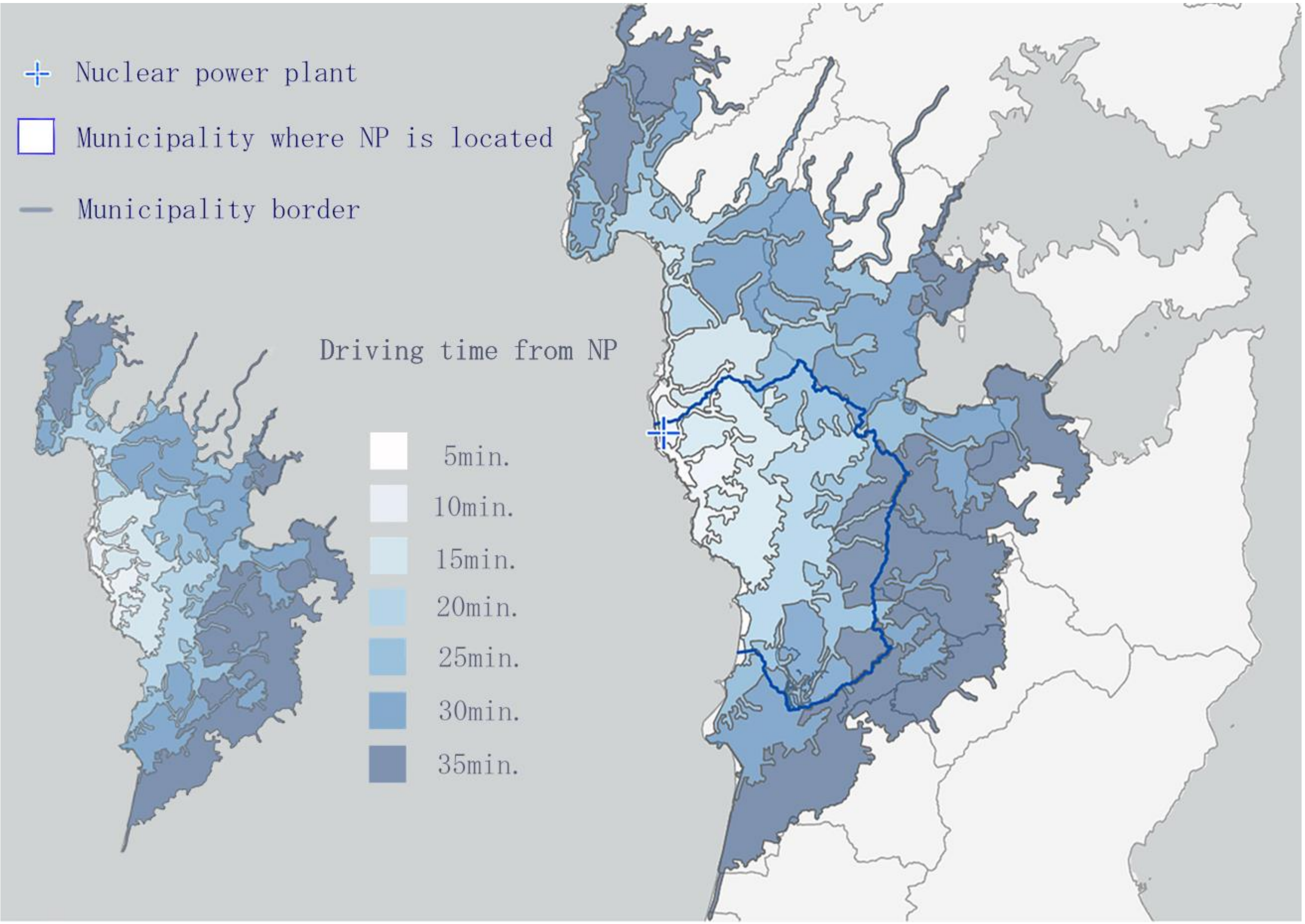
Notes: The location of Shika nuclear power plant and the area of Shika-cho is shown.

b. Equal distance approach



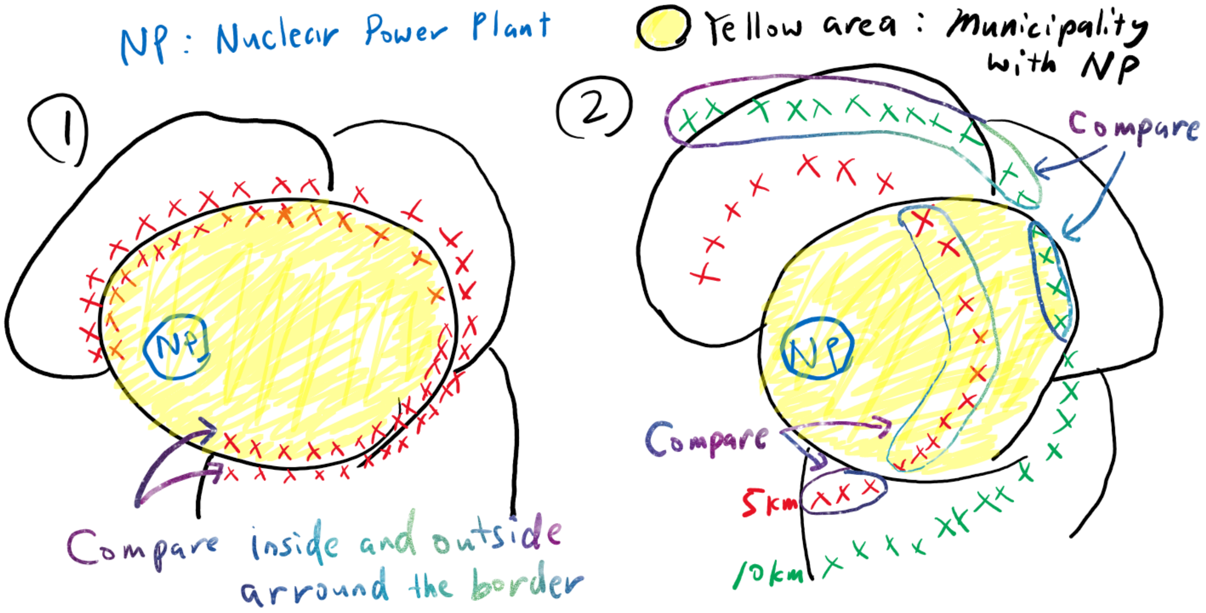
Notes: The location of Shika nuclear power plant and the area of Shika-cho is shown.

c. Equal drive time approach



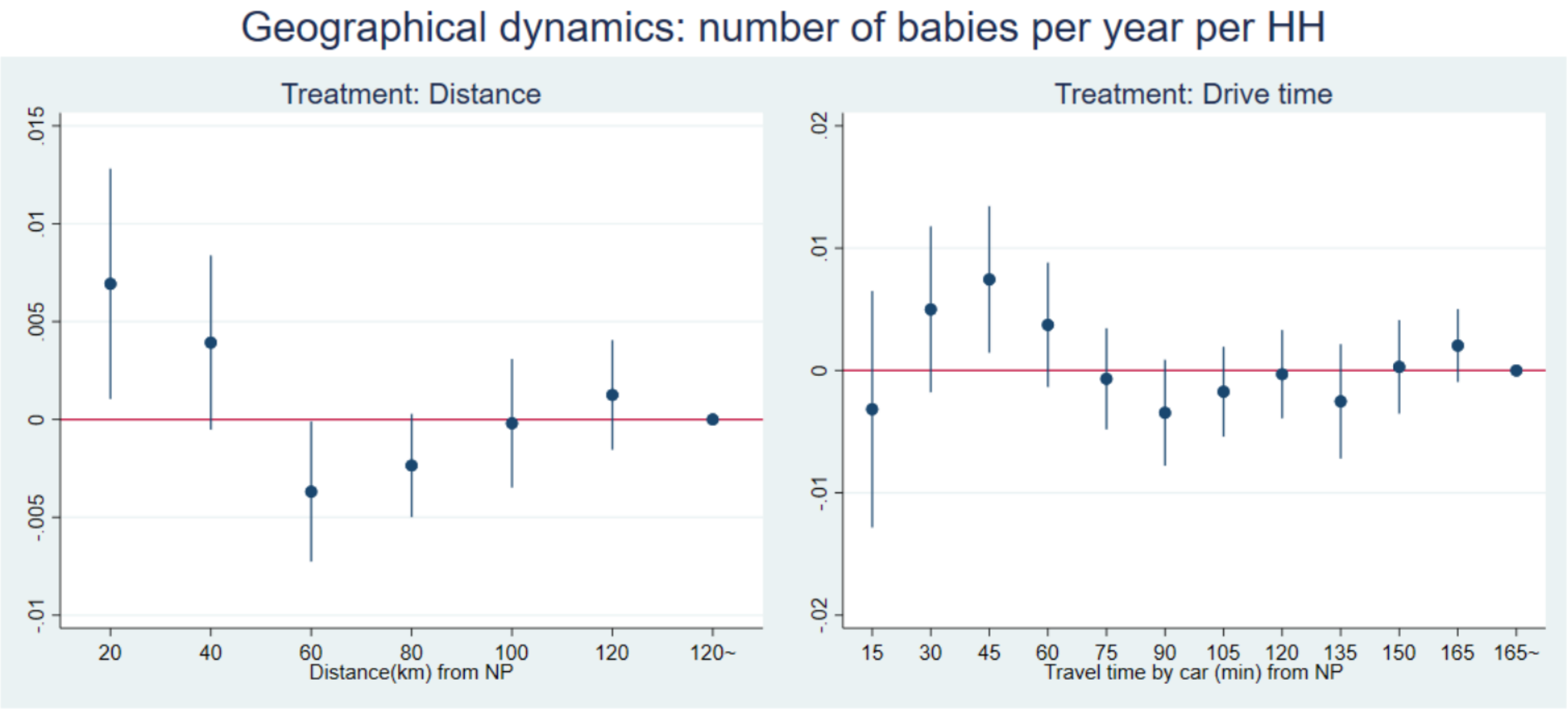
Notes: The location of Shika nuclear power plant and the area of Shika-cho is shown.

Figure 7 Simplified picture: Border approach and equal distance approach



Notes: #1 explains the idea of the border approach. #2 explains the idea of the equal distance approach.

Figure 8 Geographical dynamics

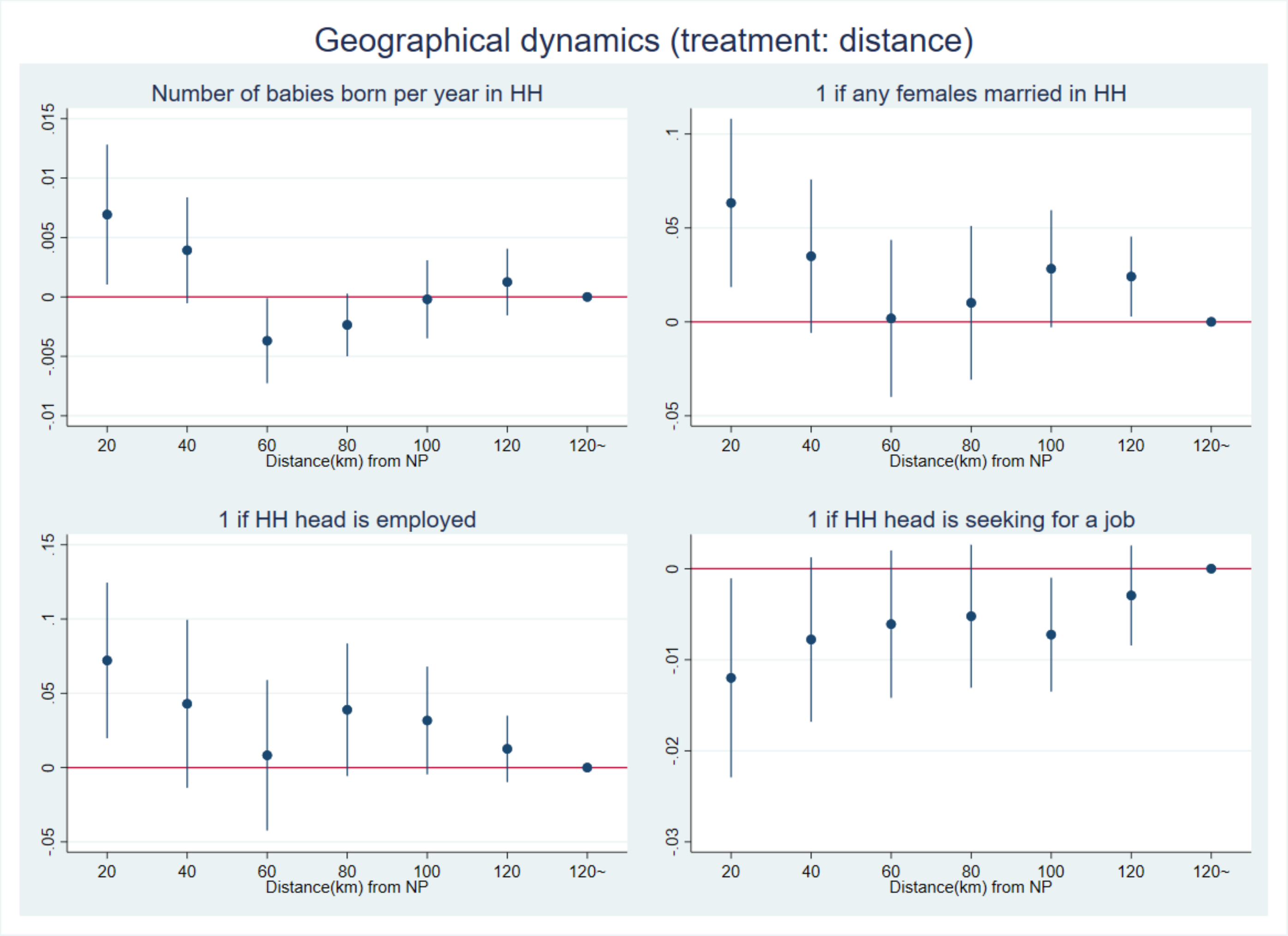


Notes: Sample households are those 1) which include a female whose age is 15-49, 2) which have members of age 20-39, and 3) whose household heads had lived at the municipalities from more than 10 years ago. Together with 95% confidence intervals, the figures report the geographical dynamic coefficients obtained from the specification of the equation (1) and (2) in the main text. The equations are as follows:

$$(1)\quad y_{pmkit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + \sum_{k=1}^{k=7} \delta_k * \mathbb{1}(Location_k) + \sum_{k=1}^{k=7} \beta_k * \mathbb{1}(Location_k) * After_t + \epsilon_{pmkit}$$

$$(2)\quad y_{pmjit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \sum_{j=1}^{j=12} \delta_j * \mathbb{1}\left(Location_j\right) + \sum_{j=1}^{j=12} \beta_j * \mathbb{1}\left(Location_j\right) * After_t + \epsilon_{pmjit}$$

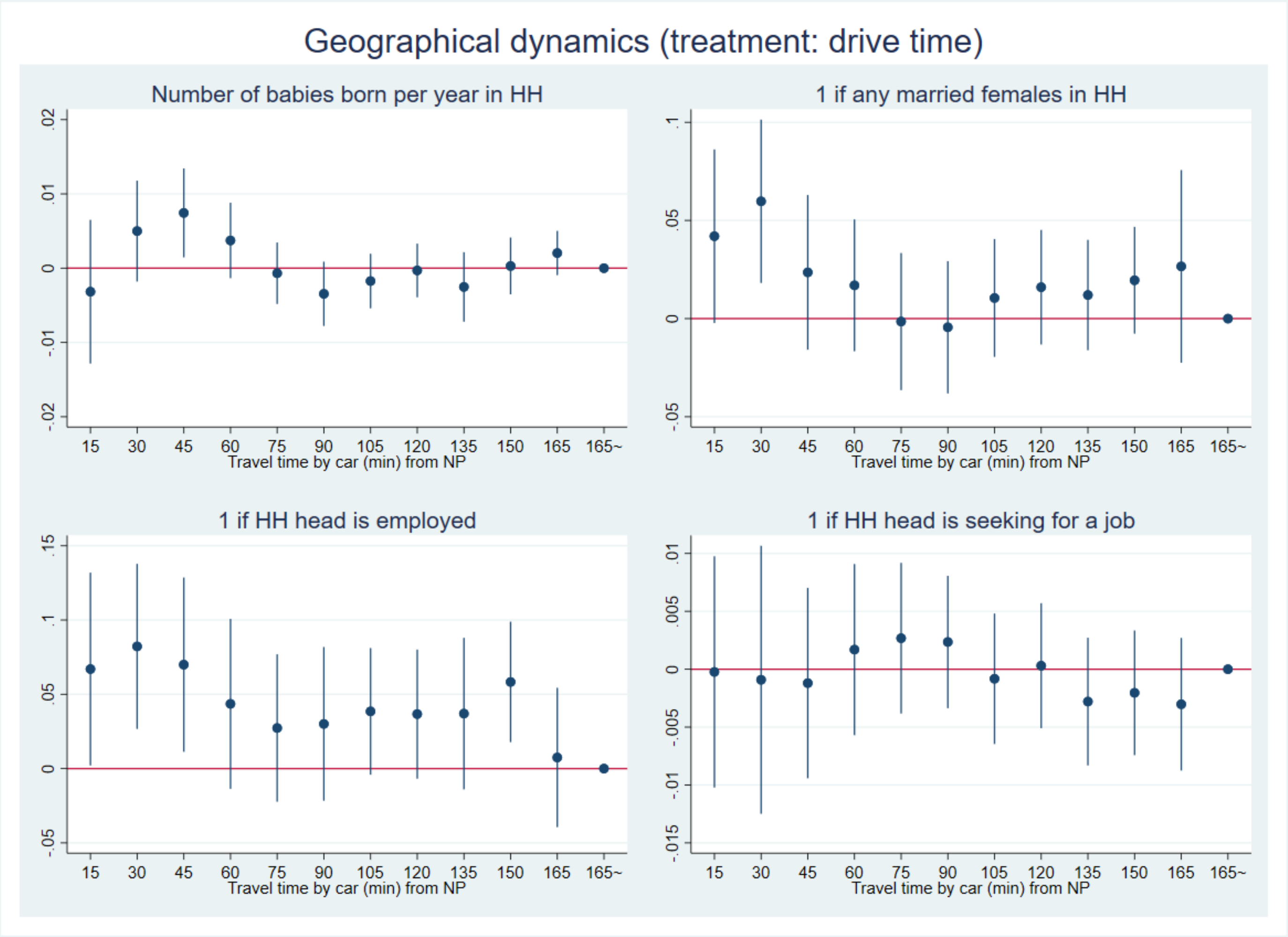
Figure 9 Geographical dynamics: treatment defined by distance



Notes: Sample households are those 1) which include a female whose age is 15-49, 2) which have members of age 20-39, and 3) whose household heads had lived at the municipalities from more than 10 years ago. Together with 95% confidence intervals, the figures report the geographical dynamic coefficients obtained from the specification of the equation (1) in the main text. The equations are as follows:

$$(1)\quad y_{pmkit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + \sum_{k=1}^{k=7} \delta_k * \mathbb{1}(Location_k) + \sum_{k=1}^{k=7} \beta_k * \mathbb{1}(Location_k) * After_t + \epsilon_{pmkit}$$

Figure 10 Geographical dynamics: treatment defined by travel time by car

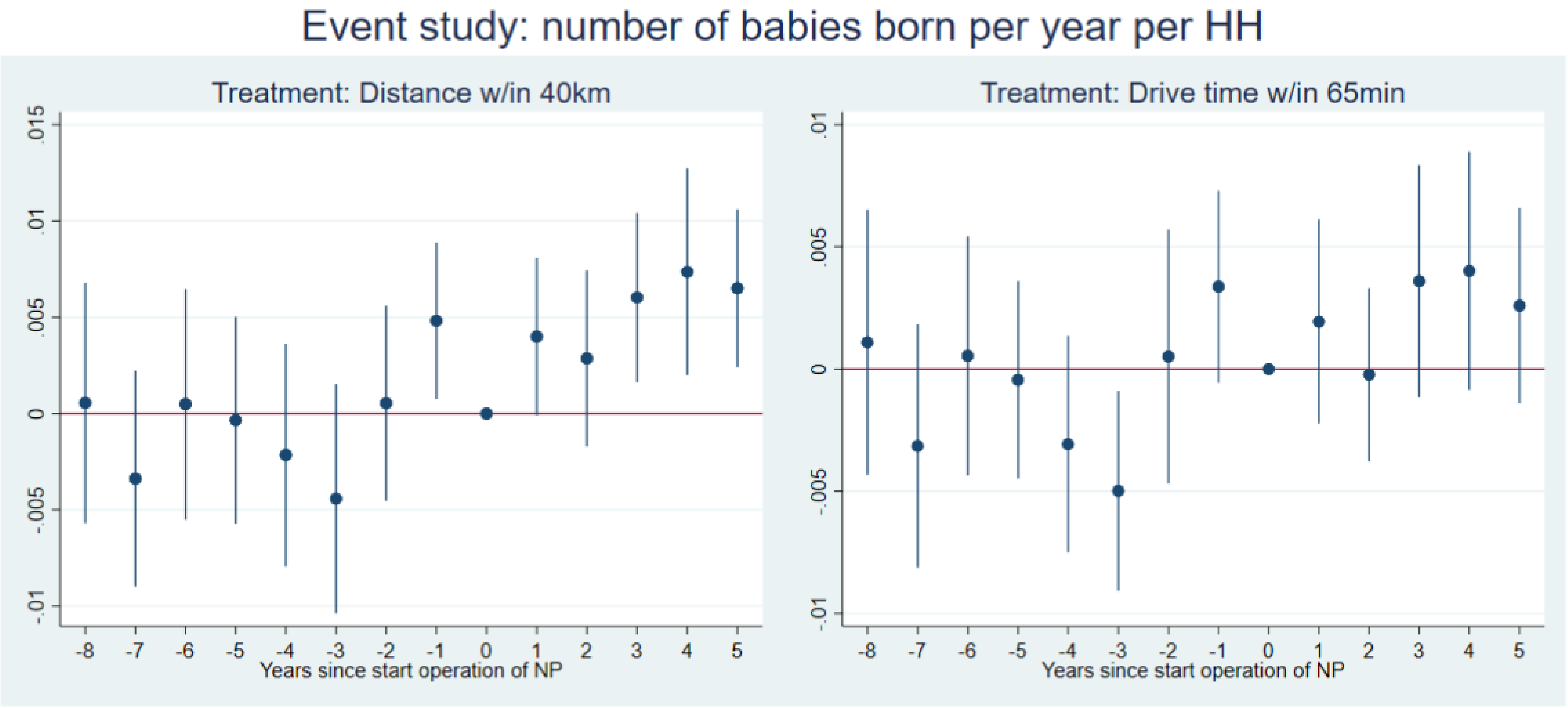


Notes: Sample households are those 1) which include a female whose age is 15-49, 2) which have members of age 20-39, and 3) whose household heads had lived at the municipalities from more than 10 years ago. Together with 95% confidence intervals, the figures report the geographical dynamic coefficients obtained from the specification of the equation (2) in the main text. The equations are as follows:

$$(2)\quad y_{pmjit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + \sum_{j=1}^{j=12} \delta_j * \mathbb{1}(Location_j) + \sum_{j=1}^{j=12} \beta_j * \mathbb{1}(Location_j) * After_t + \epsilon_{pmjit}$$

Figure 11 Job effect: event study

Left: distance w/in 40km =1 Right: drive time w/in 65km = 1



Notes: Sample households are those 1) which include a female whose age is 15-49, 2) which have members of age 20-39, and 3) whose household heads had lived at the municipalities from more than 10 years ago. Standard errors are clustered at municipality level. Together with 95% confidence intervals, the figures report the dynamic coefficients obtained from the specification of the equation (5) and (6) in the main text. The equations are as follows:

(left) $y_{pmit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + Treated_i + \sum_{k=-8}^{k=-1} \delta_k * \mathbb{1}(Event_k) + \sum_{k=1}^{k=10} \delta_k * \mathbb{1}(Event_k) + \sum_{k=-8}^{k=-1} \beta_k * \mathbb{1}(Event_k) * Treated_i + \sum_{k=1}^{k=10} \beta_k * \mathbb{1}(Event_k) * Treated_i + \epsilon_{pmit}$

(right) $y_{pmit} = \alpha_{pt} + \tau_m + \omega_m t + \gamma_m t^2 + \phi X_{it} + Treated\_v2_i + \sum_{k=-8}^{k=-1} \delta_k * \mathbb{1}(Event_k) + \sum_{k=1}^{k=10} \delta_k * \mathbb{1}(Event_k) + \sum_{k=-8}^{k=-1} \beta_k * \mathbb{1}(Event_k) * Treated\_v2_i + \sum_{k=1}^{k=10} \beta_k * \mathbb{1}(Event_k) * Treated\_v2_i + \epsilon_{pmit}$

Figure 12 Event study: Subsidy effect analysis (women aged 25-34); dependent variable: number of babies born per year per household

Notes: Together with 95% confidence intervals, the figures report the dynamic coefficients obtained from the specification of the equation (10), (11), and (12) in the main text. "Distance" stands for "equal distance approach" explained in the main text. "Drive time" stands for "equal drive time approach." "Border" stands for "border approach." Standard errors are clustered at municipality level.

Appendix

Table A1 Subsidy effect analysis (women aged 25-34); dependent variable: number of babies born per year per household

	Border approach				Distance		Drive time	
	(1)	(2)	(3)	(4)	(1)	(2)	(1)	(2)
VARIABLES	W/in 1km	W/in 2km	W/in 3km	W/in 4km	Log	Dummies	Log	Dummies
treatment	.0136	.0119	.00363	.00441	.00773	.00692	.00943**	.0102**
	(.0135)	(.00904)	(.00671)	(.00577)	(.00476)	(.0048)	(.00425)	(.00461)
after (year 0~7=1 -10~-3=0)	-.116	-.121	-.0392	-.0426	.00779	.00772	.00422	.00413
	(.103)	(.0756)	(.0427)	(.035)	(.0127)	(.0127)	(.013)	(.013)
c.treatment#c.after	-.0189	.00708	.0175*	.0134*	.00993	.0101	.0109*	.0108*
	(.0181)	(.0128)	(.00962)	(.00808)	(.00668)	(.00668)	(.00586)	(.00586)
Observations	6,704	15,896	26,159	40,334	69,309	69,309	143,871	143,871
R-squared	.0125	.0113	.0101	.0102	.0102	.0103	.00979	.00986
year trend and squared trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log distance / drive time	Yes	Yes	Yes	Yes	Yes	-	Yes	-
Dummies of distance / drive time	-	-	-	-	-	Yes	-	Yes
Mean	.134	.134	.134	.134	.137	.137	.133	.133

Notes: "Before" is defined as the time period [-10, -3]. Sample households are restricted to those which have females aged 25-34. Control variables are as follows: number of females of age 15-19 / 20-24 / 25-29 / 30-34 / 35-39 / 40-44, number of females of age 15-49 who graduated from university/graduate school, a dummy variable which takes one if HH members—who are adults—include two generations, number of people of age 60 and above, a dummy variable which takes one if HH head is graduated from university/graduate school, and a dummy variable which takes one if household head is male. Standard errors are clustered at municipality level. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table A2 Subsidy effect analysis: IV (women aged 25-34); dependent variable: number of babies born per year per household

	Border approach			Distance		Drive time	
	1	2	3	4	5	6	7
VARIABLES	Drive time W/in 2km	Drive time W/in 3km	Drive time W/in 4km	Equal Distance	Equal Distance	Equal Drive time	Equal Drive time
Local government expenditure (log/MA)	.0428	.106*	.0791*	.0549	.0543	.0517*	.0519*
	(.0773)	(.0583)	(.0477)	(.0369)	(.0361)	(.0298)	(.0302)
treatment	.00952	-.00033	.000677	.00436	.00309	.00419	.00281
	(.012)	(.00813)	(.00725)	(.0063)	(.00653)	(.00672)	(.00778)
after (year 0~7=1 -10~-3=0)	-.115	-.0379	-.041	-.0196	-.0192	-.0203	-.0203
	(.0751)	(.0429)	(.035)	(.0227)	(.0223)	(.0195)	(.0195)
Observations	15,896	26,159	40,334	69,309	69,309	137,554	137,554
R-squared	.00801	.00517	.00575	.00655	.00632	.00591	.00566
year trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes
control	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean	.134	.134	.134	.137	.137	.133	.133
Log distance / drive time	Yes	Yes	Yes	Yes	-	Yes	-
Dummies of distance / drive time	-	-	-	-	Yes	-	Yes
F statistic for weak identification	715.6	1207	1690	957.2	1244	1720	2238
Anderson-Rubin Statistics p-value	0.579	0.0689	0.0973	0.137	0.132	0.0824	0.0861

Notes: “Before” is defined as the time period [-10, -3]. Sample households are restricted to those which have females aged 25-34. Control variables are as follows: number of females of age 15-19 / 20-24 / 25-29 / 30-34 / 35-39 / 40-44, number of females of age 15-49 who graduated from university/graduate school, a dummy variable which takes one if HH members—who are adults—include two generations, number of people of age 60 and above, a dummy variable which takes one if HH head is graduated from university/graduate school, and a dummy variable which takes one if household head is male. Standard errors are clustered at municipality level. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table A3 Job effect analysis; dependent variables: industries that HH head works for

	Agriculture		Forestry, hunting		Fishery		Mining	
	1	2	3	4	5	6	7	8
VARIABLES								
treatment * after	-.00938	-.00674	.00162	.00335	.00237	.00431	-.000832*	-.000396
	(.00877)	(.00893)	(.00148)	(.00289)	(.00745)	(.00945)	(.000448)	(.000431)
Observations	2,295,589	2,269,495	2,295,589	2,269,495	2,295,589	2,269,495	2,295,589	2,269,495
R-squared	.181	.181	.0244	.0249	.106	.108	.0716	.073
year*prefecture	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
municipality-level year trend and squared trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Treatment	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1
Mean	.056	.056	.004	.004	.01	.01	.003	.003

Notes: Sample households are those 1) which include a female whose age is 15-49, 2) which have members of age 20-39, and 3) whose household heads had lived at the municipalities from more than 10 years ago. Control variables are as follows: number of females of age 15-19 / 20-24 / 25-29 / 30-34 / 35-39 / 40-44, number of females of age 15-49 who graduated from university/graduate school, a dummy variable which takes one if HH members—who are adult—include two generations, number of people of age 60 and above, a dummy variable which takes one if HH head is graduated from university/graduate school, and a dummy variable which takes one if household head is male. Standard errors are clustered at municipality level. Significance level: * p<0.1, ** p<0.05, *** p<0.01.

Table A3. Continued.

	Construction		Manufacturing		Electricity, gas, water		Transportation (communication)	
	9	10	11	12	13	14	15	16
VARIABLES								
treatment * after	.0166**	.0207**	-.00735	-.0115	.000777	-.000246	-.00318	.00812**
	(.0082)	(.0102)	(.00878)	(.0112)	(.000695)	(.000476)	(.00739)	(.00388)
Observations	2,295,589	2,269,495	2,295,589	2,269,495	2,295,589	2,269,495	2,295,589	2,269,495
R-squared	.0442	.0443	.0576	.058	.0033	.00331	.0356	.0357
year*prefecture	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
municipality-level year trend and squared trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Treatment	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1
Mean	.13	.13	.119	.119	.007	.007	.081	.081

Table A3. Continued.

	Retail (restaurant)		Finance, insurance		Real estate (leasing)		Service		Public service	
	17	18	19	20	21	22	23	24	25	26
VARIABLES										
treatment * after	.00768	-.000645	.00231*	.00181	-2.56e-06	-.000913*	.00489	-.00262	-.00517	-.0102
	(.00616)	(.00805)	(.0012)	(.00158)	(.000502)	(.000472)	(.00497)	(.00523)	(.00755)	(.00726)
Observations	2,295,589	2,269,495	2,295,589	2,269,495	2,295,589	2,269,495	2,295,589	2,269,495	2,295,589	2,269,495
R-squared	.0315	.0315	.00918	.00923	.00596	.00599	.0586	.0587	.0291	.0292
year*prefecture	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
municipality-level year trend and squared trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Treatment	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1	Distance w/in 40km = 1	Travel time w/in 65min = 1
Mean	.175	.175	.021	.021	.008	.008	.203	.203	.05	.05

Figure A1 Location candidates for nuclear power plants in Kobayashi (1971)[11]

図４・６・２　原子力適地位置図

Source: Kobayashi (1971)

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[11] The suitable locations in Hokkaido prefecture, Aomori prefecture, Miyazaki prefecture, and Kajoshima prefecture are not shown because Kobayashi (1971) does not argue them.