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Dreams of urbanization: Quantitative case studies on the local impacts of nuclear power facilities using the synthetic control method ☆

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ABSTRACT

This paper uses the synthetic control (SC) method to examine how the establishment of nuclear power facilities (NPFs) in Japan in the 1970s and 1980s has affected local per capita income levels in the municipalities in which they were localted (NPF municipalities). Eight quantitative case studies using the SC method clarify that the effects of NPF establishment on per capita taxable income levels are highly heterogeneous. The estimated effects are often economically meaningful and in some cases huge: the income level was 11% higher on average and 62% higher in one municipality in 2002 when compared with counterfactual units. On the other hand a few of the NPF municipalities have received only weak or negligible effects from NPF establishment. The post-estimation comparisons of employment between the NPF municipalities and the SC units suggest that the size of the direct labor demand shocks and subsequent indirect employment effects on nontradable service sectors have contributed to the increase in per capita income levels.

You know, municipalities where nuclear power plants are located are all poor areas. Okuma town has a mild climate and it's comfortable to live there. But the main industry was agriculture and many people looked for jobs in large cities during the winter. In the winter, fathers had to leave home. Families had to live apart. [At the time we thought] "If a nuclear power plant comes, we won't have to leave home during the winter. We can get better jobs with steady incomes, instead of relying on volatile agriculture. We can receive education in nice school buildings. Grants will make the town rich." Nuclear power was called "the energy of the future".

-Toshitsuna Watanabe, mayor of Okuma town, Fukushima prefecture[1]

1. Introduction

Since the Fukushima Daiichi nuclear disaster in 2011, it has been widely recognized in Japan that municipalities which have accepted the location of nuclear power facilities (NPFs) receive large employment opportunities and NPF-related fiscal benefits such as central grants and revenues from local property taxes. The quote above clearly expresses local residents' hope that NPF establishment would realize industrialization and urbanization in their municipality.

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[1] This passage is quoted from an interview with Toshitsuna Watanabe in Japanese at *Diamond Online* http://diamond.jp/articles/-/16605. The article was published on March 15, 2012 and accessed on June 20, 2014. The sentences are translated into English by the author. All the citizens in Okuma town were evacuated from their homes after the accident at the Fukushima Daiichi (I) Nuclear Power Plant on March 11, 2011.

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The local economic development of municipalities with NPFs (subsequently "NPF municipalities") is not an issue belonging only to the past. After the Fukushima disaster, *Zengenkyo*, the association of all NPF municipalities and several other neighboring municipalities, has clearly stated that it continues to support the utilization of nuclear energy and the promotion of a nuclear fuel cycle policy in Japan.[2] At first glance Zengenkyo's firm political support for nuclear energy may seem incomprehensible, as all of the NPF municipalities in Fukushima, which have been devastatingly affected by the nuclear disaster, belong to this association. But considering the fact that the local economy of NPF municipalities is heavily dependent on the NPF industry, it is not strange for NPF municipalities to have held fast their essential political principles concerning nuclear energy even in the face of the Fukushima disaster.

In light of the ongoing debate in Japan about the nation's post-Fukushima nuclear energy policy, it is increasingly important to understand the socio-economic impacts of NPF establishment on surrounding areas in order to assess the costs and benefits of NPFs to local communities. In this regard it should be informative to examine how NPF establishment can be a successful place-based economic policy and how it affects the living standards of local residents.[3]

It is, nevertheless, not clear how the establishment of NPFs has promoted local economic and income growth in Japan. Several official reports point out that the benefit of NPF establishment on local communities is generally weak.[4] On the other hand, there is a stereotype that the economy of NPF municipalities depends heavily on the nuclear power industry. The following question then arises: does NPF establishment really lead to a significant increase in local income levels? In order to tackle this question, I examine the impact of the establishment of NPFs in the 1970s and 1980s on local per capita taxable income in Japan.

From an econometric point of view, however, it is not an easy task to estimate the impact of NPF establishment on local income levels. As in many studies that focus on the effects of specific economic shocks on economic outcomes, estimation strategies based on difference-in-differences (DID) approaches may be applicable, but there are several challenges concerning the application of DID estimation in this study.

First, because NPF sites are not randomly assigned but determined by various geographical, political and socio-economic factors (Aldrich, 2008a,b), the common trend assumption of simple DID may not be plausible. In addition, it is hard to control for confounding time-varying covariates because NPF establishment changes local socioeconomic situations in various ways and controlling for these endogenous factors is problematic. Second, the number of "treated" municipalities is small: in Japan, there are only 22 NPF municipalities and my limited dataset allowed me to examine only eight NPF establishment events. Although the time dimension of the dataset is relatively large (from 1972 to 2002), the small number of treated units could make it difficult to consistently estimate an average effect of NPF establishment and implement plausible inference.

Third, different characteristics of different NPF locations could also result in misleading conclusions: the timing of NPF establishment, periods of construction and operation, numbers and scales of NPFs differ considerably in each NPF municipality. Impacts of NPFs are also not uniform over time because construction and operation involve different economic activities and the revenue from local property tax based on NPF-related assets decreases gradually due to depreciation once NPF operation starts. The estimated average treatment effect of the small number of NPF locations could thus be hard to interpret without taking into account this heterogeneity.

To deal with these problems, I adopt the synthetic control (SC) method that was firstly proposed by Abadie and Gardeazabal (2003) and then further developed by Abadie et al. (2010) and Abadie et al. (2014). The idea underlying the SC method is intuitively clear: a combination of control units is used to construct a "counterfactual" unit (called *synthetic control unit*) of a treated unit and the outcome of this counterfactual unit is then compared with the realized outcome of the treated unit. The construction of a synthetic control unit is based on the weighted average of control units, where weights are in general obtained so that the weighted average of the outcome variable and the relevant covariates of control units in pre-intervention periods are as close as possible to those of the treated unit.

One notable feature of the SC method is that the required number of treated units is only one. This means that using the SC method, I can investigate the effect of NPF establishment on per capita income, focusing on *individual* NPF municipalities as quantitative case studies. Although this makes it difficult to apply standard inference techniques to examine the statistical significance of my findings, this method allows me to investigate the magnitudes and mechanisms of the effects of NPF establishment as historical case studies, which may be more informative for policy makers and researchers who have an interest in not only *average* treatment effects of NPF establishment but in individual and historical consequences of NPF establishment given limited quantitative and qualitative information.

In addition, a permutation-like test proposed by Abadie et al. (2010) and some extensions of this test can be used as complementary methods of statistical testing. Another interesting feature of the SC method is that the common trend assumption in DID could be relaxed under relatively nonrestrictive conditions, as is discussed in Section 4.

Using the SC method, I find that NPF establishment makes per capita taxable income in NPF municipalities about 11.1% higher on average and around 61.7% higher as a maximum while the estimated effects are very heterogeneous and sometimes negligible.

This study will contribute to the following two research strands in economics. First, this study contributes to the literature on economic analysis of NPF establishment. To my knowledge, previous studies on the socio-economic impact of NPF establishment largely fall into two groups. The first group studies the effect of NPF establishment on property prices around NPFs, mostly using a hedonic approach such as Nelson (1981), Gamble and Downing (1982), Clark and Nieves (1994), Clark et al. (1997) and Folland and Hough (2000). Though not restricted to NPFs, Davis (2011) recently studied the effect of power plants on local housing values and rent in comparison to neighborhoods with similar characteristics. The second group of studies, such as Pijawka and Chalmers (1983), McGuire (1983), Lewis (1986), and Glasson et al. (1988) examines the impact on local industry and employment, using Keynesian multiplier models.[5] Because little research has examined the economic consequences of NPF location from a quasi-experimental perspective, this paper can provide new insights into the study of NPF locations.

Second, this study is also related to the increasing literature in economics on the effects of energy-related industry or large plants establishment on local economies using some natural or quasi-experimental approaches, such as the effects of pipeline

[2] For example, in a petition concerning nuclear power generation issued in May 22th 2014, Zengenkyo argues that Japanese central government should unwaveringly promote nuclear power generation.

[3] See Glaeser and Gottlieb (2008) and Neumark and Simpson (2015) for recent literature reviews on place-based policies.

[4] For example, see the introduction of METI (2011).

[5] When it comes to Japanese NPFs, Nishikawa (2000) studies the fiscal impact of NPFs in Japan using simple regression analysis.

construction on the local labor market (Carrington, 1996), the effects of a coal boom and bust on local employment and earnings (Black et al., 2005), the effects of large plant openings on total factor productivity of incumbent plants (Greenstone et al., 2010), the effects of a large gold mine on various local economic outcomes (Aragón and Rud, 2013), and the effect of the Tennessee Valley Authority (TVA) on local economic development (Kline and Moretti, 2014).

In addition to these contributions to the existing literature, this paper tries to examine the causal mechanism of the effects of NPF establishment by comparing how the employment situation changes differently in a treated unit and a synthetic unit after NPF establishment. I also introduce some extensions of the placebo test that is suggested by Abadie et al. (2010).

The rest of the paper is organized as follows. In Section 2 I provide a simple conceptual framework to aid in understanding how NPF establishment affects local income levels. Section 3 briefly describes the historical background of Japan's NPF locations, then explains the dataset that I use for estimation and presents simple difference in differences (DID) estimation. Section 4 explains the issues of identification and inference with the SC method and also presents various specific settings in the SC method used in this paper. In Section 5 estimation results are presented and examined along with placebo studies and further analysis. Section 6 concludes.

2. Conceptual framework

2.1. Setup

Although it might be difficult to disentangle the precise mechanism of NPF effects on local income levels, the conceptual frameworks in Moretti (2010, 2011) provide useful guidance. In this section, I briefly describe how the establishment of NPFs can affect local income levels based on the simpler framework in Moretti (2010). My framework is akin to that of Aragón and Rud (2013), which also adopts the conceptual framework used in Moretti (2010) to investigate the local effects of a large gold mine in Northern Peru.

First, I suppose two groups of municipalities, both of which include competitive local economies that use homogeneous labor to produce nationally traded goods and nontraded goods. The price of nationally traded goods is set on the national market, but the price of nontraded goods is determined locally. Both local labor supply and local housing supply is upward sloping unless labor and housing supplies are infinitely elastic.

When it comes to the location of NPFs, these facilities have often been located in rural municipalities as I will describe in Section 3. In rural areas, the labor supply is generally limited and therefore an upward sloping labor supply is plausible. Housing supply, on the other hand, can be relatively elastic because rural areas often have abundant land available for use.

2.2. Direct effects on local income levels

I then consider a labor demand shock caused by NPF establishment in one of these groups of municipalities, which I call ''NPF municipalities''. The direct effect of this labor demand shock is an increase in NPF-related employment for NPF construction, operation and maintenance. This shock may also increase other forms of employment directly linked to NPFs. If the local labor supply is not infinitely elastic, the wages of all local workers also increase as a result of general-equilibrium effects. As a result, the local per capita income level is expected to be increased by this labor demand shock.

2.3. Indirect effects on the nontradable sector

If the above initial effects are sizable, there may also be positive indirect effects on nontradable industries. Because the incomes of local people increase due to more local jobs and higher wages, the local demand for nontradable goods such as restaurants, shops, and personal services may increase and it could result in more jobs and higher wages in these sectors. According to Moretti (2010), the magnitude of this indirect effect depends on several factors such as consumer preference, the technology in the nontradable sector, the types of new jobs in NPF industries, and offsetting general equilibrium effects on wages and prices which depend on the elasticity of local labor and housing supplies.

In reality, the types of new jobs created in NPF industries can be divided into two categories: skilled jobs that require specialized knowledge and skills in nuclear technology and unskilled jobs that are related to non-technical work such as plant construction and maintenance.[6] If NPF establishment causes an inflow of skilled workers with high wages from no-NPF municipalities, the indirect effect on local nontradable industries should be high. In addition, because NPFs are often located in rural and low-income areas, even relatively unskilled jobs such as NPF construction could have significant indirect effects on local nontradable industries.

2.4. Indirect effects on the tradable sector

On the other hand, indirect effects on tradable industries are a priori unclear. First, due to the overall increase in labor costs caused by the labor demand shock from NPF establishment, production in some tradable industries may be shifted to different areas in the long run. This may lead to the reduction of labor demand for these tradable industries in NPF municipalities and could partially cancel out the positive effects of NPF establishment.

Second, if NPF establishment increases the local demand for some intermediate tradable goods, this may generate some indirect effects on these tradable industries. These effects should be limited if the market for these tradable goods is national or global, but there is a possibility that purchases of local goods will be prioritized because the construction and operation of NPFs are not purely private initiatives but public projects which are also meant to be place-based policies to encourage local economic development.

Third, if NPF establishment causes urbanization and agglomeration in a local economy, it may result in an overall increase in local economic activity and income levels. Agglomeration, however, may not be easily realized in municipalities in which NPFs are located as these municipalities are often rural.

2.5. Effects through public expenditure

In addition to the above direct and indirect effects via the local labor market, NPF establishment also affects local per capita income through public expenditure, which may be substantially increased by NPF-related grants and tax revenues. Fig. 1 illustrates the amounts of fiscal transfers and property tax revenues in a model municipality before and after NPF construction and operation. This figure shows that the total amount of grants increases sharply when construction of an NPF starts. Then, just after the NPF begins operating, increased local property taxes start to flow into the municipality's coffers while several grants expire or shrink. Revenue from property taxes

[6] In fact, there should be a more gradual classification of labor based on skill, but I use this distinction for simplicity.

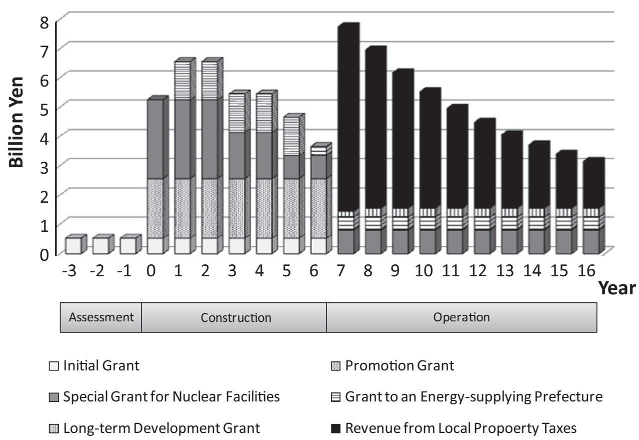

Fig. 1. NPF-related grants and property taxes in a model case. Notes: Estimates are based on a model case (output = 1.35 GW, construction cost = 450 billion yen, construction period = 7 years). Institutional and budgetary settings are based on fiscal year 2003. Grants for neighboring municipalities and the prefecture are included, but property taxes and long-term development grants are estimated only for the NPF municipality. Some other NPF-related grants and tax revenues are not considered here. *Source:* Ministry of Economy, Trade and Industry: METI (2004).

gradually decreases year by year because of the depreciation of NPF-related property.

The resulting increase in public investment and other public expenditures may increase local labor demand and local productivity and therefore local income levels in NPF-sited municipalities.[7] In particular, before 2003, major NPF-related subsidies were restricted to the construction of municipal public facilities and some of them were designed to be used for the promotion of local business activities. Even if they did not make a long-term positive contribution to local business productivity, these grants should at least have contributed to increasing local employment in the short term through public investment projects.

At the same time, a large part of the increase in local tax revenue is in general canceled out by a decrease in fiscal equalization grants, so-called ordinary Local Allocation Tax (LAT) grants.[8] It is therefore not certain whether increases in NFP-related revenues always lead to significant increases in public expenditure. I will come back to this issue when I examine the mechanism of the impact of NPF establishment in Section 5.

3. Cases and data

3.1. Historical background

According to a report from the Japan Atomic Industrial Forum, JAIF (1984), NPF establishment was in general welcomed and accepted by local municipalities and local residents during the 1960s, when the construction and operation of the oldest nuclear power plants started in Tokai, Tsuruga, Mihama, and Fukushima.

NPF establishment became more controversial for local communities in the early 1970s, when several NPF-related accidents happened in Japan. Since then, the perception that NPFs pose risks to those living in their vicinity has become stronger.[9]

In addition, it became more apparent that it was not clear to what extent NPFs made an economic contribution to local communities. New jobs created by NPF establishment and their indirect effects were often attractive for local residents, but even in the late 1960s and early 1970s, when only one NPF was operating in Japan, several official reports by a governmental committee pointed out that the economic impact of NPFs on the local economy was relatively small and unsustainable[10]: First, NPF-sited regions are usually unsuitable for industrial development and it is implausible to expect that other factories or business offices will move into regions with new NPFs. Second, demand for local labor during plant construction is not very high in general, if it exists at all, and is limited to relatively low-skilled work.

Recognizing the perceived risks and limited benefits of NPFs, the committee suggested that several fiscal measures were necessary to encourage the development of NPF-sited municipalities. With a strong political initiative by then Prime Minister Kakuei Tanaka, this suggestion led to the famous power source siting laws being passed in 1974.[11] These laws have enabled municipalities with power plants to receive several kinds of transfers and other benefits from the central government.

Since these laws were implemented, the central government and energy companies have been equipped with strong fiscal compensation schemes that help to subdue local anti-NPF movements. Although it is not clear to what extent these laws contribute to the promotion of NPF establishment, there were 54 nuclear plants located in 21 municipalities and several nuclear fuel cycle facilities in one municipality (Rokkasho village) in 2010 as shown in Fig. 2.

3.2. Selection of cases

Table 1 presents basic information about the eight NPF municipalities I use for quantitative case studies in the following analysis. Among the selected municipalities, only Rokkasho in Aomori prefecture has no nuclear power plant but is instead the location of four nuclear fuel cycle facilities. The other seven municipalities have at least two nuclear power reactors but no other large-scale nuclear facilities such as nuclear fuel cycle facilities.[12]

This difference between Rokkasho and the other NPF municipalities is important because the presence of nuclear fuel cycle facilities in Rokkasho has caused inflows of affiliated companies and

[7] The impact of public investment on local or regional economic growth has been extensively studied using the framework of local production function and other approaches. See a recent literature review by Romp and De Haan (2007).

[8] In Japan, 75% of revenue-capacity increase in major taxes is taken into account in the fiscal equalization scheme and the LAT grants are reduced instead. Roughly speaking, tax revenue increase by 100 in LAT-received municipalities will lead to total revenue increase by 25 due to decrease in the LAT grants by 75. Exceptions are rich municipalities which do not receive any LAT grants. For no-LAT-received municipalities, increase in tax revenue means one-to-one increase in total revenue.

[9] For example, people may believe that NPFs could potentially damage health through exposure to low-level radiation, ruin health in the event of severe nuclear accidents, contaminate agricultural and fishery products through radiation, and cause consumers to boycott local agricultural and fishery products due to fears of contamination. Considerable uncertainty about the likelihood and magnitude of these risks is another negative aspect of NPFs. See also Lesbirel (1998), Aldrich (2008a,b) and Dusinberre and Aldrich (2011) for NIMBY (Not-in-My-Back-Yard) facility siting in Japan, including NPF location. Hirabayashi (2013) also investigated unsuccessful candidate sites and anti-nuclear movement in Japan.

[10] Shimizu (1991a,b) reviews the committee's findings.

[11] Act on Tax for Promotion of Power-Resources Development, Law on Special Accounts for Electric Power Development Acceleration Measures, and Act on the Development of Areas Adjacent to Electric Power Generating Facilities. Shimizu (1991b) discusses the early development and amendment of these laws.

[12] Nuclear fuel cycle facilities in Rokkasho are owned and operated by Japan Nuclear Fuel Limited and the seven other nuclear plants are owned and operated by different private electric power companies: Hokkaido Electric Power Company (Tomari), Tohoku Electric Power Company (Onagawa), Tokyo Electric Power Company (Naraha, Tomioka, Kashiwazaki, Kariwa) and Hokuriku Electric Power Company (Shika). Despise NPF ownership and operation differing across NPF municipalities, NPF municipalities receive similar fiscal benefits under the power source siting laws mentioned in Section 3.1, such as intergovernmental grants to municipalities and electricity price reduction for local citizens and companies. METI (2004, 2011) provide detailed information about these fiscal benefits.

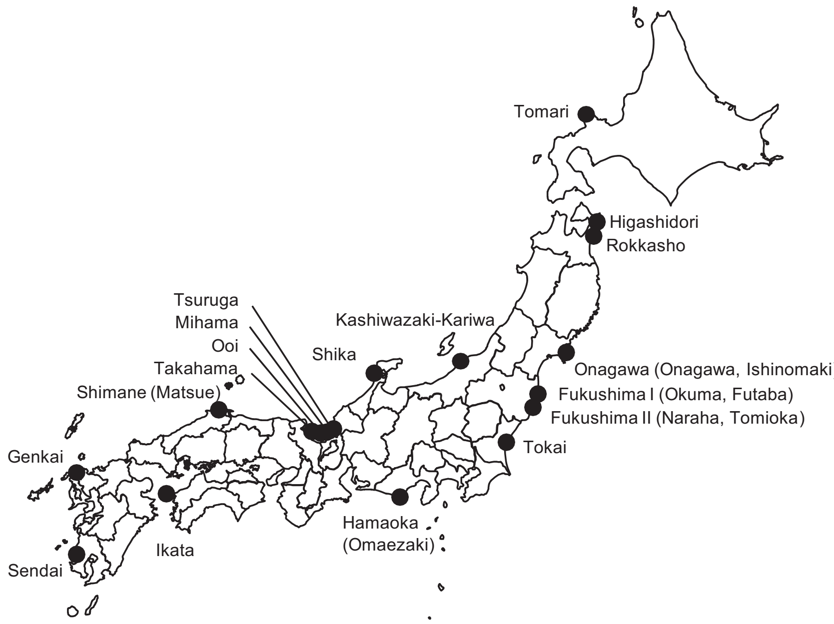

Fig. 2. Location of nuclear power facilities in Japan, 2010. Notes: When the names of NPFs are not identical with the names of municipalities, the latter are shown in parentheses.

Table 1
Municipalities used for quantitative case studies.

Municipality	Name of NPFs	Region	First NPF location year	Intervention year	Number of nuclear plants (2010.3)	Total power (MW) (2010.3)
1.Rokkasho	Nuclear Fuel Cycle[a]	Tohoku	1986	1986	–[a]	–
2.Tomari	Tomari	Hokkaido	1984	1984	3	2070
3.Onagawa	Onagawa	Tohoku	1979	1979	3	2174
4.Naraha	Fukushima II	Tohoku	1975	1975	2	2200
5.Tomioka	Fukushima II	Tohoku	1980	1975	2	2200
6.Kashiwazaki	Kashiwazaki–Kariwa	Hokuriku	1978	1978	4	4400
7.Kariwa	Kashiwazaki–Kariwa	Hokuriku	1983	1978	3	3812
8.Shika	Shika	Hokuriku	1988	1988	2	1746

Notes: "Year" is the Japanese fiscal year that runs from April to March. Rokkasho's "Fiscal NPF establishment year" is the year when land reclamation for nuclear fuel cycle facilities started. For the other municipalities, "Fiscal NPF establishment year" is the first year of NPF construction based on official records. "Intervention year" is identical to the "Fiscal NPF location year" for most municipalities, but Tomioka's and Kariwa's intervention years are defined as Naraha's and Kashiwazaki's intervention years respectively. This is done because Tomioka and Naraha share the Fukushima Daini (II) nuclear plant near their border and it is expected that Tomioka is influenced by Naraha's first NPF location. Kariwa should similarly be affected by Kashiwazaki's first NPF construction. Each "total power (MW)" is calculated based on METI (2011).
[a] In Rokkasho, four nuclear fuel cycle facilities have been established so far. That is, a Uranium Enrichment Plant, Reprocessing Plant, Vitrified Waste Storage Center, and a Low-level Radioactive Waste Disposal Center. See Rokkasho Village (2008) for further details.

highly skilled workers that the other NPF municipalities have not experienced.[13] The overall impact of NPF establishment on Rokkasho may thus be larger than the impact of nuclear plant establishment on other municipalities.

The eight selected municipalities are NPF municipalities in which the construction of the first NPF took place between 1975 and 1988. The reasons that I exclude the other 14 NPF municipalities from my analysis are: (1) the first NPF construction happened before 1972 and my dataset (from 1972 to 2002) has no pre-intervention period (*Futaba, Okuma, Tokai, Hamaoka, Tsuruga, Mihama, Takahama, Ooi, Kashima,* and *Genkai*), (2) the first NPF construction started in 1973 and the pre-intervention period is only one year (*Ikata*), (3) the first NPF construction started in 1998 and the post-intervention period is only 4 years (*Higashidori*), (4) the first NPF construction took place in 1978 but the confounding effect of a fossil fuel plant established in the 1970s cannot be eliminated (*Sendai*) and (5) no tangible fixed assets such as nuclear reactors are located within the area and a confounding idiosyncratic shock (the stagnation of a major industry, whaling, after the 1970s) cannot be controlled for (*Oshika*).

Table 1 shows different patterns of NPF establishment. The timing of the first NPF construction and the number and total power output of NPFs are considerably different in each NPF site. One commonality across NPF municipalities is that most of them are so-called peripheral areas. Rokkasho was a frontier village located at the northern end of Honshu (Japan's main island) and geographically isolated from the center of Aomori prefecture. Tomari was a small village in Hokkaido prefecture whose economy once relied on fishery and mining. Onagawa was also a small fishery town located in the Tohoku region of Honshu. Naraha and Tomioka, home to Fukushima Daini (II) Nuclear Power Plant, are located on the coastal side of Fukushima prefecture. Along with neighboring Futaba and Okuma, where Fukushima Daiichi (I) Nuclear Power Plant is located, these areas are sometimes called "Tibet in Fukushima" because they are geographically and socio-economically isolated

[13] Rokkasho village (2008) presents a list of more than 80 companies that have moved to or have been established in Rokkasho, most of which are directly or indirectly related to NPF establishment. Akimoto (2003) also provides detailed statistics in Rokkasho before and after the NPF location.

from urban areas in Fukushima prefecture by mountains. Kashiwazaki and Kariwa, which are located in Niigata prefecture, are also peripheral and the official history of Kashiwazaki (*Kashiwazaki-shi-shi*, published in 1990) refers to this city as "an isolated island in the land" even though it was a relatively industrialized city compared with other NPF municipalities even before NPF establishment. The last municipality, Shika, is a rural town located on the Noto Peninsula in Ishikawa prefecture whose main industries had been agriculture and fishery, although a certain level of manufacturing also existed even before NPFs were established.

3.3. Descriptive statistics

The panel data that I use for the following analysis cover all the municipalities across Japan and consist of three types of variables, namely, per capita taxable income based on registration data (1972–2002, fiscal year), socio-economic variables based on Census data (1960, 1965, 1970, ..., 2000), and fiscal variables based on municipality fiscal statistics (1975–2002, fiscal year).[14]

My primary outcome variable of interest is per capita taxable income. Per capita taxable income is a better indicator of the average income level of local people than per capita local GDP because the latter includes business income, which does not necessarily result in income for local people.[15] One fault of using taxable income as a proxy for local income level is that it may not properly reflect income levels of those who have more discretion in reducing the amount of taxable incomes by using income deduction, such as the self-employed. Another defect in this variable is that the range of "taxable" income varies depending on the year due to tax policy changes at the national level, but it should not seriously affect the cross-municipality income variation. For pre-determined covariates, Census data before the establishment of the first NPF is used.

The left-hand side of Table 2 shows the summary statistics of these variables in the 1970s and 2000 for the eight NPF municipalities I use as treated units in my analysis employing the SC method. The right-hand side of this table presents the counterpart statistics for the coastal municipalities that do not have NPFs located nearby. The reason I limit the sample to coastal municipalities is that all of the nuclear power plants in Japan are located along the sea and all nuclear fuel cycle facilities are also sited in a coastal municipality, Rokkasho.[16] It is therefore reasonable to assume that all the "comparable" municipalities are in coastal areas.

When I compare the variables of NPF and non-NPF municipalities, there are some noticeable differences between them. First, average per capita taxable income in NPF municipalities is lower than in non-NPF municipalities in 1972, but it exceeds of its counterpart in 2000. The growth rate in per capita taxable income between 1972 and 2000 in NPF municipalities is around 129% and about 38.1 percentage points higher than in non-NPF municipalities.

Second, NPF municipalities have smaller populations and lower Densely Inhabited Districts population[17] ratios than non-NPF municipalities both in 1970 and in 2000. Population growth from 1972 and 2000 in the NPF municipalities is slightly positive on average but it is also smaller than that of the non-NPF municipalities. Average population ratios in all age cohorts (Age 0–15, 16–64, and 65–) are very similar in both 1970 and 2000. When it comes to ten-year population growth rates in 1970, those for the 0–15 years old and 16–65 years old age groups are more negative in the NPF municipalities, but the same ten-year growth rates in 2000 do not show clear differences between the NPF municipalities and the non-NPF municipalities.

Third, the industrial structure of NPF municipalities was more dependent on the primary sector (e.g., agriculture and fishery) in 1970 and the ten-year growth rates of secondary industries (e.g., manufacturing) and tertiary industries (e.g., retail and services) in 1970 were lower in the NPF municipalities than those in the non-NPF municipalities. However, the growth rates from 1970 to 2000 of the secondary sector ratio and the tertiary sector ratio for NPF municipalities are higher than in the non-NPF municipalities.[18]

Fourth, focusing on more detailed sectoral industry ratios, many NPF municipalities were more dependent on fishery both in 1970 and 2000 and less on wholesale, retail and other services. The most rapidly growing sector in its sectoral ratio for the NPF municipalities was "other services"[19] and its average sectoral ratio increases from 10% in 1970 to 26% in 2000. The sectoral ratio of construction also doubles from 9% to 19% in the NPF municipalities.

Fifth, when it comes to fiscal variables, the most noticeable feature is a high growth rate (1141% on average) in per capita tax revenue from 1975 to 2000 in NPF municipalities while the counterpart rate in the non-NPF municipalities is only 160%. The growth rate in per capita expenditure is more moderate due to a decrease in the fiscal equalization grants (LAT grants), which are lump-sum redistributive grants that give less to municipalities with higher fiscal capacity,[20] but at 296% it is still markedly higher than the 159% found in the non-NPF municipalities.

These simple comparisons between NPF and non-NPF municipalities in the 1970s and 2000 provide two implications. First, selection based on socio-economic factors should be an important consideration in choosing the location of NPFs, and this endogenous selection may be problematic when it comes to identifying the effects of NPF establishment. Second, the implications of the above comparison do not contradict the conceptual framework in Section 2: NPF establishment seems to affect per capita income positively through a direct labor demand shock in construction and other relevant industries, and this direct impact then has certain indirect effects on other industries such as the service industry. I will revisit this mechanism in Section 4.

3.4. Trends and simple DID

In this subsection, I provide time-trend graphs and simple difference-in-difference (DID) estimates in order to consider what can be learned from a simple DID framework. First, Fig. 3 shows the time trends of per capita taxable income in the eight NPF municipalities with solid lines and the counterpart trend of control municipalities with dashed lines. The control municipalities

[14] The municipality list of my dataset is arranged based on 1998.4.1. I do not use the data for after 2002 because a huge municipality amalgamation (the so called Heisei Amalgamation) took place in the 2000s and the number of municipalities decreased from 3232 (1999.3.31) to 1730 (2010.3.31). I also excluded all the 55 municipalities that experienced amalgamation between 1973.4.1 and 2002.3.31 from the sample.

[15] In any case, panel data on local GDP are not available at the municipality level.

[16] Kariwa village is not a coastal municipality but very close to the sea and provides the land for the Kashiwazaki–Kariwa nuclear power plant, which is located across Kashiwazaki and Kariwa.

[17] The Densely Inhabited Districts population ratio is an index of urbanization and is calculated as the ratio of population in Densely Inhabited Districts to total population. See online Appendix A for further details.

[18] The industrial classification here follows the Japan Standard Industrial Classification. The primary sector consists of agriculture, forestry, fisheries and mining. The secondary sector includes construction and manufacturing. The remaining industries such as wholesale trade, retailing, finance, insurance, transportation, communication, other services, and public service belong to the tertiary sector.

[19] "Other services" include various tertiary industries that are *not* categorized either as wholesale, retail, finance, insurance, transportation, communication, electricity, gas, heat supply, water business, real estate, or public service.

[20] See footnote 8 for a brief description of the LAT grants.

Table 2
Descriptive statistics in the 1970s and 2000.

Variable	NPF municipalities							Non-NPF coastal municipalities							
	1970s			2000			(1) Growth rate (70s-00)	1970s			2000			(2) Growth rate (70s-00)	Diff (1) – (2)
	N	Mean	Std. Dev.	*N*	Mean	Std. Dev.		*N*	Mean	Std. Dev.	*N*	Mean	Std. Dev.		
Per capita taxable income (Thousand yen)	8	507.77	125.35	8	1162.09	139.34	128.9%	887	556.55	260.18	895	1061.83	290.58	90.8%	38.1%
Demographic variables															
Population	8	19,438	25,000	8	19,923	28,106	2.5%	895	46,202	168,284	895	52,676	196,161	14.0%	−11.5%
Densely Inhabited Districts population ratio	8	0.0994	0.1842	8	0.1167	0.2161	17.4%	895	0.1893	0.2714	895	0.2180	0.3097	15.2%	2.2%
Population ratio (Age 0–15)	8	0.2715	0.0528	8	0.1477	0.0197	−45.6%	895	0.2644	0.0451	895	0.1457	0.0236	−44.9%	−0.7%
Population ratio (Age 16–64)	8	0.6361	0.0423	8	0.6167	0.0461	−3.1%	895	0.6412	0.0495	895	0.6127	0.0517	−4.4%	1.4%
Population ratio (Age 65–)	8	0.0924	0.0270	8	0.2356	0.0576	155.0%	895	0.0944	0.0273	895	0.2416	0.0640	155.8%	−0.9%
Growth rate (Population, Age 0–15, 10 years)	8	−0.3912	0.1575	8	−0.2427	0.0721	–	845	−0.2633	0.3436	895	−0.2509	0.1219	–	–
Growth rate (Population, Age 16–64, 10 years)	8	−0.0735	0.2097	8	−0.0649	0.1551	–	848	0.0191	0.2118	895	−0.0874	0.1215	–	–
Growth rate (Population, Age 65–, 10 years)	8	0.1819	0.0908	8	0.3385	0.1452	–	845	0.2703	0.4340	895	0.3647	0.1406	–	–
Basic industrial structure															
Employment ratio to population	8	0.4973	0.0579	8	0.5093	0.0467	2.4%	895	0.4932	0.0553	895	0.4890	0.0461	−0.8%	3.3%
Sectoral ratio (Primary)	8	0.4475	0.1685	8	0.0974	0.0385	−78.2%	895	0.3756	0.1930	895	0.1591	0.1188	−57.6%	−20.6%
Sectoral ratio (Secondary)	8	0.2766	0.1243	8	0.3774	0.0713	36.4%	895	0.2551	0.1320	895	0.2899	0.0865	13.6%	22.8%
Sectoral ratio (Tertiary)	8	0.2758	0.1142	8	0.5252	0.0802	90.4%	895	0.3693	0.1247	895	0.5511	0.1096	49.2%	41.2%
Growth rate (Employment, Primary, 10 years)	8	−0.2857	0.1643	8	−0.3942	0.0647	–	848	−0.3175	0.1177	895	−0.2844	0.1882	–	–
Growth rate (Employment, Secondary, 10 years)	8	0.1443	0.4544	8	0.0118	0.5440	–	847	0.4362	0.6841	895	−0.0718	0.1751	–	–
Growth rate (Employment, Tertiary, 10 years)	8	0.1308	0.4110	8	0.1550	0.2039	–	848	0.3224	0.2898	895	0.0873	0.1281	–	–
Detailed industrial structure															
Sectoral ratio (Fishery)	8	0.0866	0.1253	8	0.0391	0.0589	−54.8%	895	0.0714	0.1137	895	0.0470	0.0749	−34.2%	−20.6%
Sectoral ratio (Mining)	8	0.0076	0.0096	8	0.0019	0.0012	−75.3%	895	0.0081	0.0396	895	0.0026	0.0120	−67.3%	−8.0%
Sectoral ratio (Construction)	8	0.0930	0.0874	8	0.1915	0.0776	105.8%	895	0.0817	0.0444	895	0.1248	0.0423	52.8%	53.0%
Sectoral ratio (Manufacturing)	8	0.1760	0.1068	8	0.1841	0.0948	4.6%	895	0.1654	0.1277	895	0.1624	0.0898	−1.8%	6.4%
Sectoral ratio (Wholesale/Retail)	8	0.1103	0.0354	8	0.1376	0.0299	24.7%	895	0.1313	0.0539	895	0.1754	0.0482	33.6%	−8.9%
Sectoral ratio (Other services)	8	0.1044	0.0367	8	0.2598	0.0535	148.9%	895	0.1313	0.0531	895	0.2492	0.0570	89.8%	59.2%
Fiscal variables (Thousand yen)															
Tax revenue per capita	8	38.52	12.86	8	478.18	282.42	1141.4%	895	38.83	27.55	895	100.92	57.07	159.9%	981.4%
Fiscal equalization grants (LAT)	8	84.26	45.71	8	7.82	18.49	−90.7%	895	74.94	62.91	895	227.72	197.87	203.9%	−294.6%
Central grants per capita	8	47.94	29.62	8	117.39	155.37	144.9%	895	46.96	51.23	895	59.21	173.20	26.1%	118.8%
Expenditure per capita	8	262.58	120.47	8	1040.03	1052.29	296.1%	895	244.25	143.83	895	632.73	539.42	159.0%	137.0%
Construction per capita	8	86.35	41.54	8	257.28	315.56	198.0%	895	84.51	75.43	895	173.06	226.73	104.8%	93.2%

Notes: See online Appendix A for the definitions and data sources of all the variables. Statistics in the 1970s are different due to data availability: per capita taxable income is based on 1972 data, demographic variables and industrial structure on 1970 data, fiscal variables except central grants on 1975 data, and central grants on 1977 data. The other 14 NPF municipalities, which are not listed in Table 2, are excluded from the sample. The neighboring municipalities of these excluded NPF municipalities are also eliminated from the sample. One exception is Yokohama town in Aomori prefecture. This town is a neighboring municipality of both Rokkasho (a treated NPF municipality in this study) and Higashidori and is kept in the sample as a neighboring municipality of Rokkasho. Miyake village in Tokyo prefecture is also dropped because of residents' evacuation from their island in 2000 due to a volcanic eruption. Finally, coastal special districts (called ku) in Tokyo are also not included in the sample.

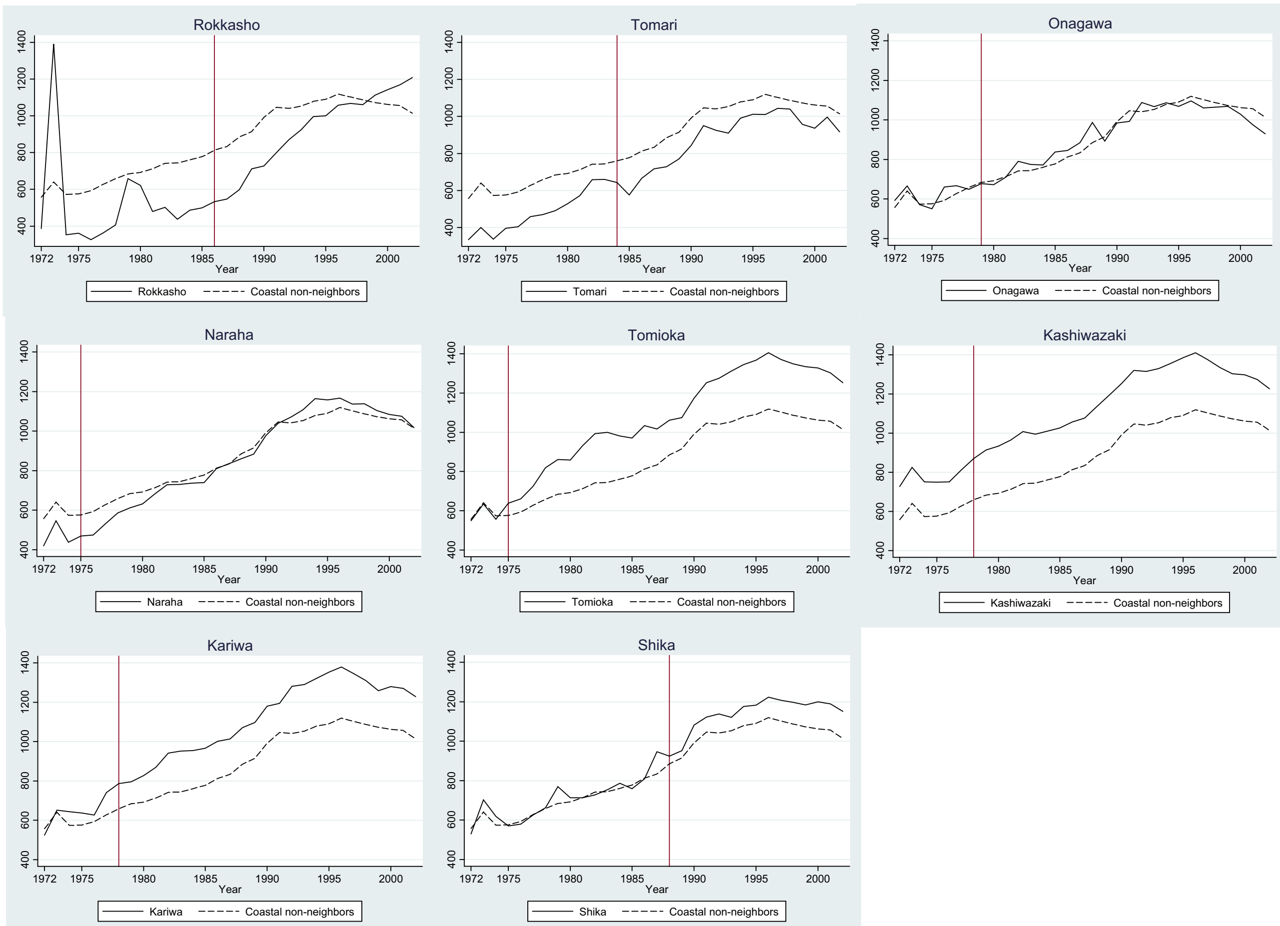

Fig. 3. Per capita taxable income in NPF municipalities (thousand yen). Notes: Solid lines represent per capita taxable income in the 8 NPF municipalities. The dashed lines in all the graphs represent the same average per capita taxable income in coastal non-neighbors. A vertical line in each graph indicates the intervention year, which is presented in Table 1.

consist of the coastal local bodies which do not have NPFs and also do not border on the NPF municipalities (called "coastal non-neighbors").[21] I exclude the coastal neighboring municipalities of the NPF municipalities from the control group because these municipalities are expected to gain some benefits from NPF establishment such as employment, subsidies, and other indirect effects.

The comparison of the two trends in the eight graphs indicates that (I) the income trends in Rokkasho, Tomioka, and Kariwa are clearly shifted upward compared with the income trend in the coastal non-neighbors, implying that NFP establishment seems to positively affect per capita income in these municipalities,[22] (II) the trends in Naraha and Shika also show modest upward shifts after intervention, (III) the trend in Tomari is hard to interpret because the pre-intervention trend is apparently different from the coastal non-neighbors, and (IV) Onagawa and Kashiwazaki have similar trends to the coastal non-neighbors after intervention, suggesting no NPF impact.

Second, to clarify the graphical implications mentioned above, I implement OLS estimation with the following simple DID model:

$$Y_{it} = \gamma_i + \pi_t + \alpha D_{it} + \varepsilon_{it}, \tag{1}$$

where Y_{it} is per capita taxable income in municipality i in period t, γ_i is municipality fixed effects, π_t is a common time effect, ε_{it} is an error term, and D_{it} is a dummy variable that takes a value of one for NPF municipalities in and after the intervention years and zero otherwise. I use the same data as in Fig. 3 to obtain DID estimates for the eight location events respectively by setting only one NPF municipality as a treated group and excluding the other NPF municipalities from the sample.[23] The results are shown in Table 3. DID estimates for respective NPF establishment are compatible with the implications from Fig. 3. For example, DID estimates for Rokkasho, Tomioka, and Kariwa are larger than estimates for the others. In sum, DID estimates are mostly positive and suggest that the NPF location could have some positive "effect" on NPF municipalities.

4. Estimation

4.1. Empirical strategy

Although the graphical analysis and the simple DID estimation provide useful information about what happened to the income levels of NPF municipalities, reliable causal interpreta-

[21] Here I do not restrict control municipalities to municipalities geographically proximate to each NPF municipality as I do in the SC estimation, but instead use a single control group, so that the average income trend of the all control municipalities can be used as a common reference trend.

[22] Income fluctuation in Rokkasho before the 1980s is huge, but in the first half of the1980s Rokkasho has more or less a similar income trend to that of coastal non-neighbor municipalities.

[23] In Appendix I, I provide a more standard DID estimation where all 8 NPF municipalities are included in a treated group. In addition, in order to see whether NPF location has a spillover effect on neighboring areas, I also implement a DID analysis with which 18 coastal neighboring municipalities are used as a treated group.

Table 3
DID estimates of the impact of NPF establishment on per capita income.

Treated municipalities	(1) Rokkasho	(2) Tomari	(3) Onagawa	(4) Naraha	(5) Tomioka	(6) Kashiwazaki	(7) Kariwa	(8) Shika
DID estimate	164.67***	61.5***	−17.18	115.02***	222.43***	82.07***	157.36***	78.94***
	(38.30)	(17.10)	(14.67)	(15.51)	(12.19)	(6.18)	(20.90)	(12.61)
Adjusted R-squared	0.9166	0.9169	0.9168	0.9168	0.9169	0.9169	0.9169	0.9168
Observations	19,305	27,161	27,161	27,161	27,161	27,161	27,161	27,161
No. of municipalities	878	878	878	878	878	878	878	878
No. of the treated municipalities	1	1	1	1	1	1	1	1
Sample period	1981–2002	1972–2002	1972–2002	1972–2002	1972–2002	1972–2002	1972–2002	1972–2002

Notes: Heteroskedasticity-robust standard errors are in parentheses. The unit is 1000 yen (around 10 dollars). In column (1), observations before 1981 are excluded for Rokkasho because per capita taxable income in Rokkasho during this period fluctuates considerably.
*** Significance at the 1% level.

Table 4
Settings used in the synthetic control method.

Outcome variable	• Real per capita taxable income (1972–2002, deflated by CPI 2005)
Treated municipality	• 8 municipalities with NPFs
Intervention year	For Rokkasho (See also the notes of Table 1.) • Year when land reclamation for the first NPF started For Tomari, Onagawa, Naraha, Kashiwazaki, Shika • Year when the first NPF construction started For Naraha (see also the notes of Table 1) • Year when the first NPF construction started in Tomioka For Kariwa (see also the notes of Table 1) • Year when the first NPF construction started in Kasiwazaki
Donor pool (the set of control units)	• Coastal municipalities within the same region • Excludes neighboring municipalities and other NPF-located municipalities
Predictors (averages over the pre-intervention period)	• Real per capita taxable income (deflated by CPI 2005) • Employment ratio to population • Densely Inhabited Districts population ratio • Population ratios (age 16–64, age 65 and over) • Sectoral ratios of employment (primary, tertiary) • Detailed sectoral ratios of employment (fishery, mining, construction, manufacture, wholesale and retail, other services) • Growth rates of population ratios and basic sectoral ratios (from 10 years ago)

tion is difficult because the common trend assumption might not be plausible since NPF assignment is not random but somewhat endogenously determined by various factors such as geographic and socio-economic environments, which should be correlated with income trends. Although Fig. 3 shows that the common trend assumption is not entirely implausible, it would be better to explicitly control for possible differential trends.

In this paper, instead of refining the DID approach, I use the Synthetic Control (SC) method developed by Abadie and Gardeazabal (2003) and Abadie et al. (2010). The SC method is a data-driven procedure that is suitable for comparative case studies that focus on the impact of a particular event or intervention.

Intuitively speaking, the SC method constructs a "counterfactual" synthetic control unit (hereafter SC unit) by weighing control-group municipalities such that the weighted average of outcomes and relevant covariates in the pre-intervention period will be close to their counterparts in the treated unit. Because the SC method is able to focus on each NPF municipality individually, heterogeneity of NPF impact can also be addressed. Another advantage of the SC method is that post-estimation comparisons of covariates between a treated unit and a SC unit can easily be implemented in order to examine how the relevant covariates of the treated unit have diverged from the corresponding covariates of the counterfactual SC unit. This will be useful in understanding the sources of effect heterogeneity.

4.2. Identification

Define α_{it} as the effect of an NPF location on municipality i at year t. Let D_{it} be a treatment indicator which satisfies

$$D_{it} = \begin{cases} 1 & \text{if NPF are located in municipality } i \text{ in year } t, \\ 0 & \text{otherwise.} \end{cases}$$

Then an observed outcome variable Y_{it}, per capita taxable income for municipality i at year t, is

$$Y_{it} = Y_{it}^N + \alpha_{it} D_{it}, \tag{2}$$

where Y_{it}^N is a "counterfactual" outcome that would be realized if there were no intervention by NPF establishment. Let's focus on one NPF municipality as a "treated" unit and assume that only municipality $i = 1$ is exposed to NPF establishment after year $t = T_o$. Then $D_{it} = 1$ if $i = 1$ and $t > T_o$ and $D_{it} = 0$ otherwise.

The objective is to estimate α_{1t} after $t = T_o$, that is,

$$\alpha_{1t} = Y_{1t} - Y_{1t}^N, \quad \text{for } t > T_o. \tag{3}$$

Because Y_{1t} is observed, only Y_{1t}^N needs to be estimated to obtain α_{1t}. Abadie and Gardeazabal (2003) and Abadie et al. (2010) define a "synthetic control unit" as a weighted average of the control units in the donor pool, and use these weights to construct Y_{1t}^N. That is, a synthetic control can be represented by a $(J \times 1)$ vector of weights $\boldsymbol{W} = (w_2, \ldots, w_{J+1})'$ for municipalities $j = 2, \ldots, J+1$,

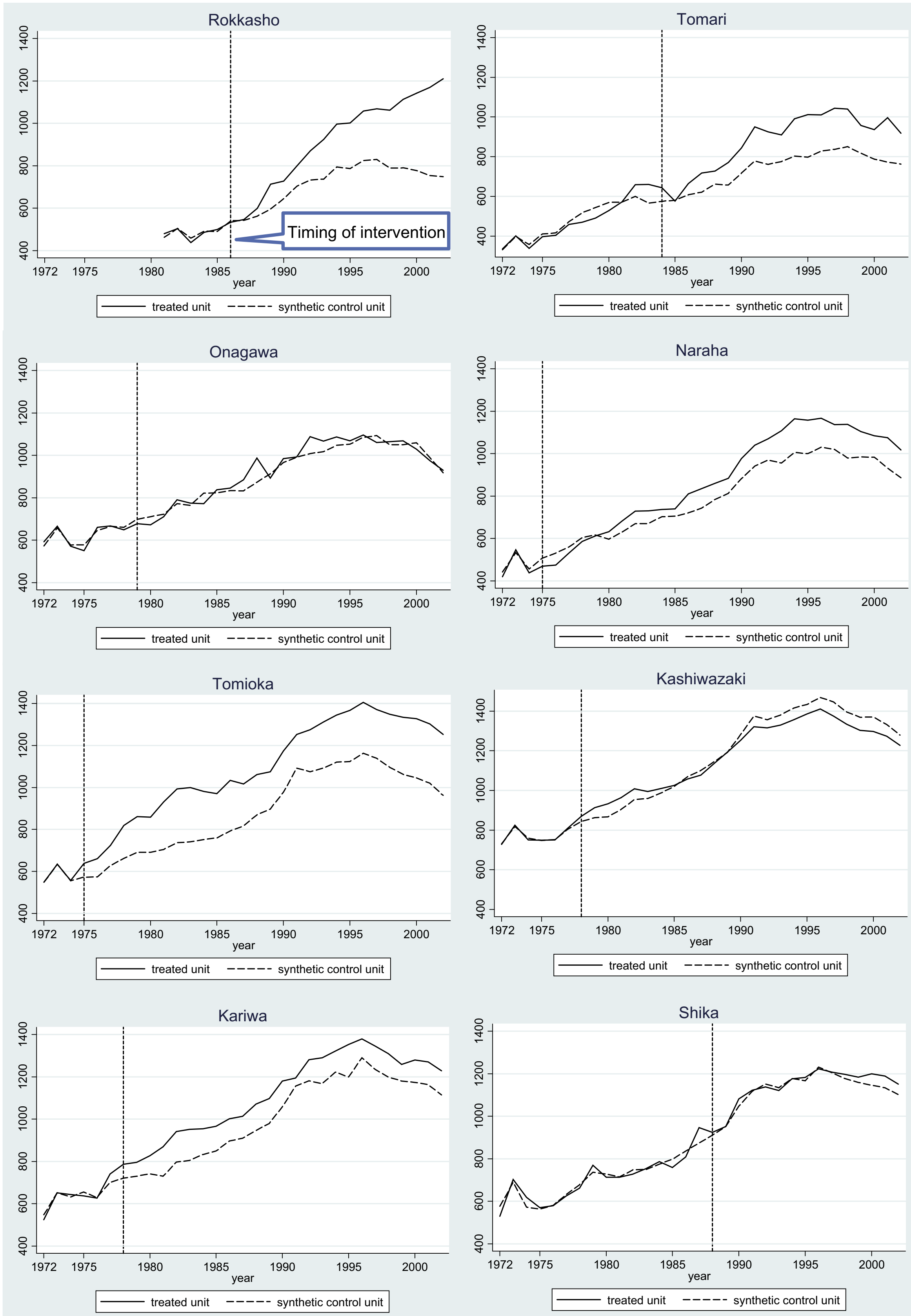

Fig. 4. Per capita taxable income: treated municipalities and synthetic control units. Notes: In Rokkasho, the pre-intervention period is limited to from 1981 because per capita taxable income in Rokkasho fluctuates in the 1970s. In Tomari, one municipality, Atsuma town, is excluded from the donor pool due to extreme outliers for its per capita taxable income in 1972 and 1973.

Table 5
Summary of results in the SC method.

Municipality	Average		Maximum		In 2002	
	Gap	Percent	Gap	Percent	Gap	Percent
Rokkasho	198.83	26.19	461.34	61.67	461.34	61.67
Tomari	138.90	18.21	223.81	28.98	154.35	20.23
Onagawa	10.79	1.07	114.08	13.06	10.65	1.16
Naraha	75.82	8.22	158.51	16.16	132.14	14.92
Tomioka	208.42	23.63	290.74	34.91	290.74	30.22
Kashiwazaki	−17.87	−0.83	66.20	7.64	−52.76	−4.12
Kariwa	107.44	11.06	153.63	19.10	113.78	10.21
Shika	15.72	1.42	54.22	4.78	48.49	4.40
Average	92.26	11.12	190.32	23.29	144.84	17.34
Average (without Rokkasho)	77.03	8.97	151.60	17.80	99.63	11.00

Notes: "Gap" is "Per capita taxable income in a treated unit − Per capita income in a synthetic control unit" and the unit is 1000 yen (around 10 dollars). "Percent" is calculated by dividing "Gap" by per capita taxable income in the synthetic control and then multiplying this value by 100. "Average" is averaged over the post-intervention period. "Maximum" is a maximum gap or percent in the post-intervention period.

which satisfy $0 \leqslant w_j \leqslant 1$ and $w_2 + \cdots + w_{J+1} = 1$. Using a vector of some optimal weights $\boldsymbol{W}^* = (w_2^*, \ldots, w_{J+1}^*)'$, Y_{1t}^N is estimated as the weighted average of Y_{jt}. Then α_{1t} is estimated as follows:

$$\hat{\alpha}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt}. \tag{4}$$

A vector of optimal weights $\boldsymbol{W}^*$ is selected so that $\boldsymbol{W}$ minimizes the difference between the pre-intervention characteristics (called *predictors*) of the treated unit and the weighted average of predictors for the control units in the donor pool. For a more detailed account of this see Abadie and Gardeazabal (2003) and Abadie et al. (2010).

Assuming a linear factor model that allows time-varying unobserved confounding effects, Abadie et al. (2010) show that the estimator of the SC method is unbiased if the treated unit and the synthetic control unit are matched in observed covariates and a long set of outcome variables in pre-intervention periods. One caveat regarding the application of the SC method to my research is that outcome variables for relatively few pre-intervention years are available in a few of the case studies included in this paper. In these cases, the quality of pre-intervention fits for earlier periods cannot be examined and has to be assumed. Nevertheless, this assumption is not very restrictive because the short duration of pre-intervention periods does not necessarily reduce the ability to find optimal weights $\boldsymbol{W}^*$ and it is at least possible to check pre-intervention fits in both outcome variables and pre-determined covariates.

4.3. Placebo tests

Because conventional large sample inference is not readily available for the SC method, I conduct the placebo test that is suggested by Abadie et al. (2010) and further discussed in Abadie et al. (2014). I also introduce two simple extensions of the original test.

First, in the original placebo test, the same SC method is applied to every control municipality in an original donor pool one by one, instead of a NPF municipality. That is, the treatment status is assigned to one control unit as if this control unit had experienced NPF establishment in the intervention year. This procedure is then repeated for all of the control units in the original donor pool. In each trial, the remaining donor-pool municipalities are used as a new donor pool and the NPF municipality is excluded from the sample. Placebo effects are calculated as gaps between the outcome values of a placebo unit and its synthetic control.

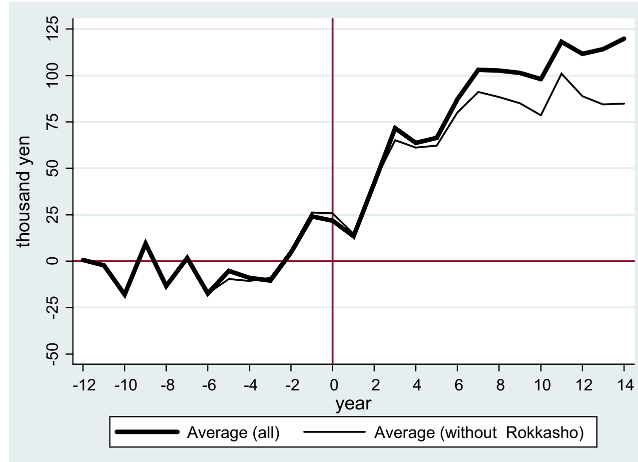

Fig. 5. Trend of average per capita income gap with the SC method. Notes: Income gaps are averaged across the 8 NFP-located municipalities between the normalized year −3 and 14. Average gaps in normalized years before −3 are based on a smaller number of income gaps because only Tomari and Shika have a pre-intervention period of 12 years or more. Nonetheless the average gaps are shown during this period because average gaps in the pre-intervention period are supposed to be close to zero with the SC methods in all the cases. Average gaps after year 14 are not shown because the number of income gaps that can be used for calculating an average is decreasing.

After obtaining all placebo estimates, the time trends of estimated treatment effects and placebo effects are graphically compared. The former should not be extreme compared with the latter under the null hypothesis of no intervention effect. In other words, if the treatment effects for a NPF municipality are larger than most placebo effects, the treatment effects may be considered plausible. This idea is akin to Fisher's exact test or classical randomization inference, but an essential difference is that the actual treatment assignment is not randomized in most application of the SC method. Thus the interpretation of this placebo test is rather informal but at least intuitively informative.

Second, although the original placebo test provides useful information about the likelihood of estimated treatment effects under the null hypothesis, plausible p-values are not readily available in general due to the limited number of placebo units in one case study and the existence of unit-specific transitory shocks that should be mean zero but are not averaged out in the estimator of the SC method. In order to complement these insufficiencies, the second placebo test investigates whether there is reason to believe that each intervention has a significant impact *on average*, exploiting all case studies.

More precisely, the second test is based on the placebo test developed by Abadie et al. (2010), but I further average estimated treated effects and placebo effects across years in order to reduce noise from unit-specific transitory shocks. Then the sizes of *average* treatment effects are tested by the distribution of *average* placebo effects for all placebo units in all case studies, where the total number of average placebo effects are increased by summing placebo trials in different case studies. The practical implementation of this is described in online Appendix B.

Finally, the third placebo test examines the question of whether the average of average treatment effects across different case studies, what I call the *overall* average treatment effect, is plausibly different from zero.[24] In other words, I test whether the overall average

[24] The wording here could be a little bit confusing. I use the term "*average* treatment effect" as an *average* of treatment effects across years in one treated municipality. On the other hand, the term "*overall* average treatment effect" is defined as the *average* of "average treatment effects" across treated municipalities in different case studies.

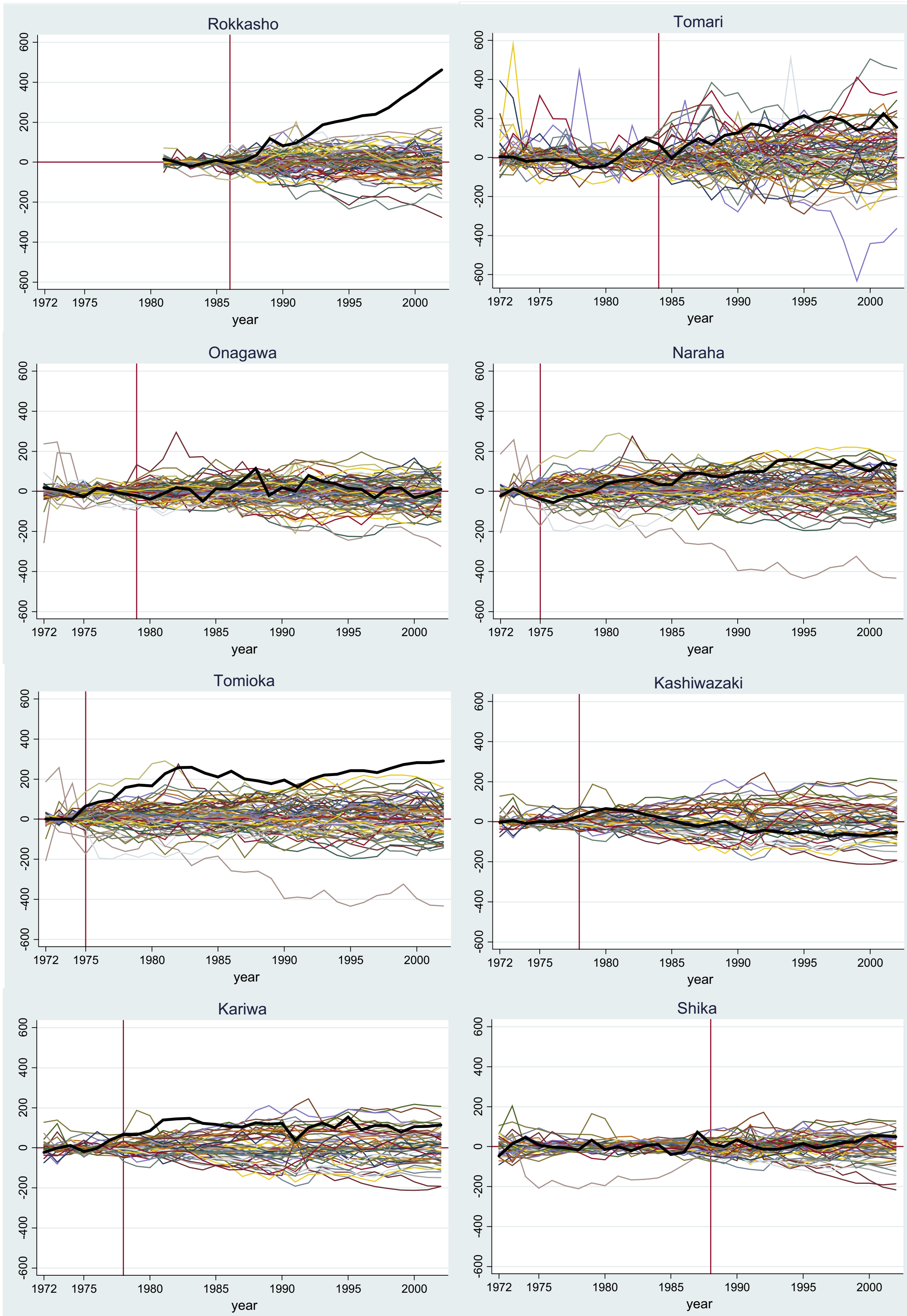

Fig. 6. Per capita taxable income gaps for the treated municipalities and placebo municipalities. Notes: Bold lines are per capita taxable income gaps for treated municipalities. The other lines are gaps for the placebo municipalities. Placebo gaps in Naraha and Kashiwazaki are identical to those in Tomioka and Kariwa respectively, because donor pools and intervention timings are the same. Placebo gaps for Sarufutsu village (a well-known "rich" municipality with a successful scallop industry) in the case of Tomari are all excluded due to their extreme values both in pre- and post-intervention periods. Placebo gaps for Notojima town cannot be estimated in the cases of Kashiwazaki and Kariwa due to an optimization failure.

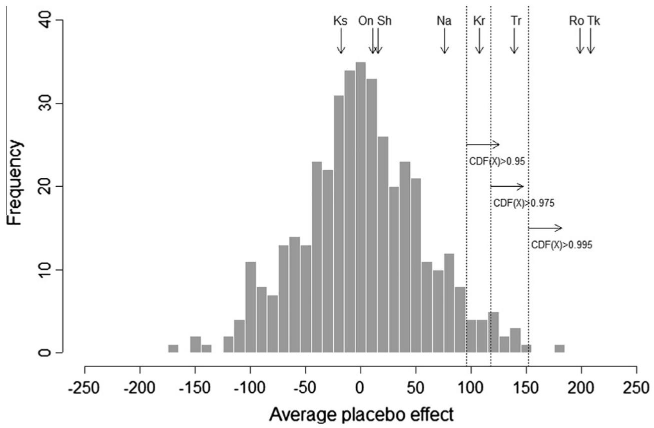

Fig. 7. Histogram of average placebo effects ($N = 407$). Notes: Arrows on the upper side indicate the magnitude of average treatment effects in 8 NPF municipalities: from the left-hand side, Ks = Kashiwazaki, On = Onagawa, Sh = Shika, Na = Naraha, Tr = Tomari, Kr = Kariwa, Tk = Tomioka and Ro = Rokkasho. The values of average treatment effects are presented in the first column of Table 5. CDF(X) is the empirical cumulative distribution function of average placebo effects. Because the placebo municipalities in the case studies of Naraha and Kashiwazaki are identical to those in the studies of Tomioka and Kariwa, I can use only 6 sets of placebo effects out of 8 case studies. As in Fig. 6, I exclude an average placebo effect for Sarufutsu village in the case of Tomari due to its extreme value.

treatment effect is sufficiently large in comparison to the distribution of corresponding placebo estimates that are calculated with randomly chosen placebo units. The actual implementation of this test is also described in online Appendix B. When the number of case studies is relatively large, the resampling method described in online Appendix B can generate a sufficiently large amount of overall average placebo effects.

This approach is similar to a placebo test with the SC method proposed by Cavallo et al. (2013). One difference is that, while Cavallo et al. (2013) test the confidence about the magnitude of average treatment effects across different case studies on an annual basis, I examine a *single* overall average treatment effect in order to determine "whether the magnitude of intervention effects as a whole is plausibly different from zero".

4.4. Settings used in the SC method

I apply the SC method to estimate the effects of NPF location on per-capita taxable income in eight NPF municipalities.[25] Various settings in the SC method in this paper are summarized in Table 4 and described as follows.

First, the timing of intervention $t = T_o + 1$ is defined as in Table 1. Second, I restrict a donor pool to municipalities that are geographically similar to NPF municipalities in order to set up a more plausible "comparable" donor pool.[26] To begin with, the donor pool is geographically limited to the municipalities that belong to the same regional category, which in general consist of several contiguous prefectures.[27] Then, as in the previous DID analysis, I use only coastal municipalities for the donor pool and exclude other NPF municipalities and the neighboring municipalities which border on the NPF municipalities.

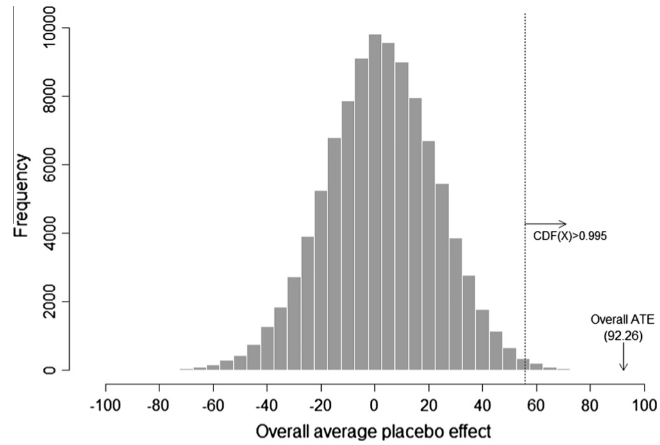

Fig. 8. Histogram of overall average placebo effects ($M = 100{,}000$). Notes: CDF(X) is the empirical cumulative distribution function of overall average placebo effects.

Third, for observed predictors, I use the outcome variable and 18 demographic variables in the pre-intervention periods: per capita taxable income, employment ratio to population, Densely Inhabited Districts population ratio, basic sectoral ratios of employment (primary and tertiary), detailed sectoral ratios (fishery, mining, construction, manufacture, wholesale and retail, and other services), and population ratios (age 16–64, age 65 and over), growth rates of employment over ten years (primary, secondary, and tertiary sectors), and finally, growth rates of population over ten years (age 0–15, age 16–64, and age 65 and over).[28] The summary statistics of these variables in the 1970s and 2000 are already listed in Table 2.

The ratio of employment (the number of people working) to population is a variable that indicates the level of local employment before NPF establishment. The densely Inhabited Districts population ratio should reflect municipalities' urbanization and production capacity. Basic and detailed sectoral ratios are used in order to capture both fundamental and subtle industrial structures of NPF municipalities before NPF location. It would be better if I could also use per capita private and public capitals in the pre-intervention period as predictors but they are not available. Nonetheless, regressions of per capita taxable income Y on these 18 demographic covariates with a pooled OLS model and fixed-effect model show that adjusted R-squared are around 0.8, so my covariates can predict per capita taxable income well.[29]

Finally, I also implement a SC method that does not exclude coastal neighboring municipalities from the original donor pools because the analysis in Appendix I implies that coastal neighboring municipalities may not be affected by NPF establishment. In addition, their geographical proximity to NPF municipalities could contribute to the construction of better synthetic controls.

5. Results

5.1. Estimation results

To begin with, in order to see how similar a treated unit and a synthetic unit are before intervention, per capita taxable income and covariates in the pre-intervention period are compared

[25] In the estimation, I use the `synth, nested` command in Stata, which has been developed by Jens Hainmueller, Alberto Abadie, and Alexis Diamond.

[26] Abadie et al. (2010) suggest that a donor pool may be restricted to regions with similar characteristics to the region exposed to the intervention of interest.

[27] Tomari is in the Hokkaido region. Rokkasho, Onagawa, Naraha, and Tomioka belong to the Tohoku region, Kashiwazaki, Kariwa and Shika are included in the Hokuriku region. Kashiwazaki and Kariwa in Niigata prefecture are sometimes categorized in the Tohoku region, but I include them in Hokuriku due to geographical proximity.

[28] Growth rate of X over ten years is expressed as $(X_t - X_{t-10})/X_{t-10}$.

[29] In these regressions, I use demographic covariates in both pre-intervention and post-intervention periods. That is, I use the data in 1975, 1980, 1985, 1990, 1995, and 2000 because all demographic variables are based on Census data, which is collected every fifth year. As in the DID estimation in Section 3, I use only the data of coastal municipalities and exclude the other 14 NPF municipalities and their neighbors. The estimation results can be provided upon request.

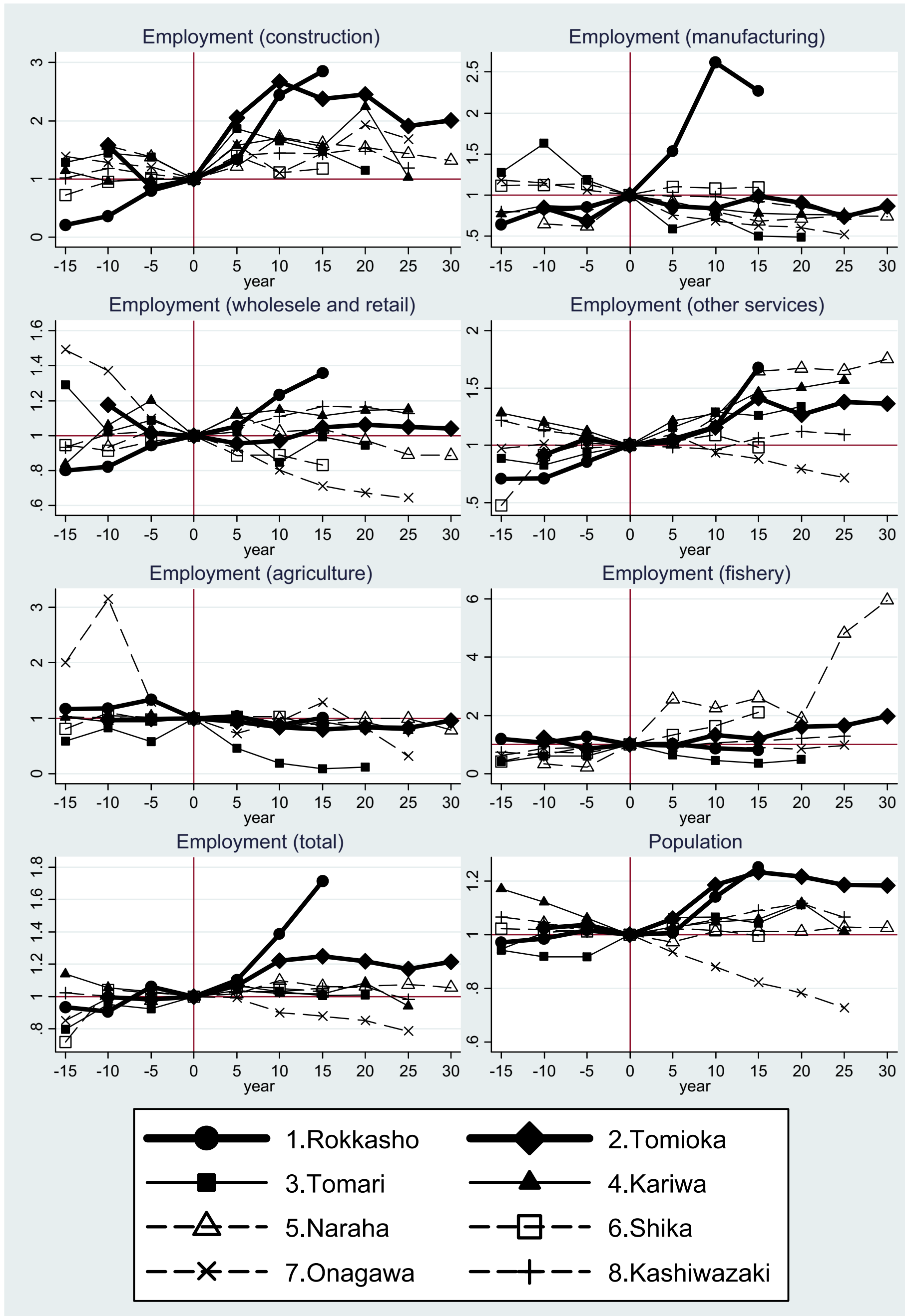

Fig. 9. The comparisons of employment and population in the treated units to those in their SC units. Notes: Employment ratios are first calculated as the numbers of people working in individual industries in NPF municipalities divided by the corresponding number in their SC units. These ratios are then standardized to 1 just before NPF establishment. Because the data (Census) is available every 5 years, the reference year for each NPF municipality is the pre-intervention year that is nearest to the year of intervention. For example, if the year of intervention is 1984, the reference year will be 1980.

between the treated unit and the synthetic unit. Fig. 4 graphically shows that the levels and trends of per capita taxable income are similar before intervention between the treated and the synthetic control in all of the cases. Predictor balances in the pre-intervention period in online Appendix C also indicate that the values of most pre-determined covariates of the synthetic units are close to those of the treated units. These results suggest that the identifying assumptions of the SC method are more or less satisfied and the treated and synthetic units are reasonably comparable in the post-intervention period.[30]

Second, when it comes to the impact of NPF location, Fig. 4 shows that per capita taxable income in Rokkasho, Tomari, Naraha, Tomioka, and Kariwa diverge upward from their synthetic counterparts after NPF location. Estimated effects (income gaps between the treated and synthetic units) in the 1990s and 2000s are often more than 200,000 yen in Rokkasho and Tomioka and around 100,000–200,000 yen in Tomari, Naraha and Kariwa. On the other hand, no noticeable positive divergence is observable in Onagawa, Kashiwazaki, and Shika.

Table 5 provides some summary statistics about outcome gaps between the treated units and the synthetic units.[31] According to

[30] Weights on donor-pool municipalities in synthetic units are also presented in online Appendix D.

[31] More detailed outcome statistics can be provided by the author on request.

this table, the gaps in Rokkasho indicates that per capita taxable income in Rokkasho is 26.2% higher than in the synthetic unit on average and 61.7% higher in 2002. Tomioka's income is also 23.6% higher on average and 30.2% higher in 2002. On the other hand, the gaps in Onagawa, Kashiwazaki and Shika are all small (on average 1.1%, −0.8%, and 1.4% respectively). These average gaps with the SC method have a more or less similar tendency to the DID estimation results in Table 3, but the values of the estimates differ significantly in most cases. Since similarity between the treated and the control in pre-intervention period is more plausible in the SC method than in the simple DID estimation, it can be argued that the estimates in the SC method are less biased.

In Table 5, I also present the averages of outcome gaps. First, the per capita taxable income level in all 8 NPF municipalities is 11.1% higher on average than in their counterparts in the synthetic control units after NPF establishment. Second, when I exclude Rokkasho from averaging and focus on the effect of nuclear power plant establishment, the average income level in the treated units is still around 9% higher than the average income level in the synthetic controls.

Finally, Fig. 5 presents the trend of the average per capita income gap between the treated units and the synthetic control units, based on the normalized years in which the intervention year is set as zero. The bold line represents the average income gap in all 8 NPF municipalities and the thin line indicates the average income gap in 7 municipalities without Rokkasho. According to this graph, the average income gap between the NPF municipalities and the synthetic controls diverge from around zero a few years after the NPF location and then continue to increase.

In online Appendix E and F, I also provide additional two empirical results. First, in online Appendix E, I present SC estimation results with another donor-pool setting where I add coastal neighbors to the original donor pools. These estimation results do not differ significantly from the baseline results above, particularly in the case of NPF municipalities which show larger effects in the baseline analysis.

Second, in online Appendix F, taking an approach similar to that of Greenstone et al. (2010), I compare the trends of taxable income in NPF municipalities and nearby municipalities which had been the candidates for NPF establishment but ended up not being selected to receive a NPF establishment. This investigation also reinforces my findings obtained using the SC method.

5.2. Placebo results

In Fig. 6, the results of placebo tests are shown. They suggest that an effect of NPF location seems particularly plausible in Rokkasho and Tomioka because their income gaps become clearly larger than almost all of the placebo gaps a few years after the intervention. The validity of estimated effects on Tomari, Naraha, and Kariwa are weaker in the sense that some placebo effects are larger than the treatment effects, but nevertheless the treatment effects are larger than most of the placebo effects. When it comes to Onagawa, Kashiwazaki and Shika, it is hard to distinguish the estimated outcome gaps from the placebo gaps.

Next, the result of the second test is graphically presented in Fig. 7. First of all, the distribution of average placebo effects (averaged over the years of each placebo trial) is more or less bell-shaped with a peak around zero, indicating that "placebos" do not cause systematic impacts on control units. When it comes to the magnitude of average treatment effects, Fig. 7 shows that the estimated average effects in Tomioka (Tk) and Rokkasho (Ro) are larger than 99.5% of placebo effects (CDF > 0.995) and the average effects in Tomari (Tr) and Kariwa (Kr) are larger than 97.5% and 95% of the average placebo effects respectively (CDF > 0.975 and CDF > 0.95). These thresholds are analogous to the 1%, 5%, and 10% significance levels in conventional two-sided tests. On the other hand, the average effects in the other NPF municipalities (Naraha, Shika, Onagawa, and Kashiwazaki) are smaller than 5% of the average placebo effects, so I have no confidence about the non-zero effect of NPF establishmen on local income levels for these municipalities.

Finally, the result of the third test is graphically presented in Fig. 8. It shows that the overall average treatment effect (averaged over years and then over placebo trials), is far larger than the threshold line at CDF = 99.5%, which is obtained by the distribution of overall average placebo effects. It is therefore quite unlikely that the magnitude of this overall average treatment effect is generated by random errors.

Both Figs. 7 and 8 imply that it is very rare to accidentally obtain the set of average treatment effects or the overall average treatment effect from the placebo distributions. Thus, it can be concluded that NPF establishment has some noticeable effects on local per capita taxable income levels while the size of the effects is quite heterogeneous.

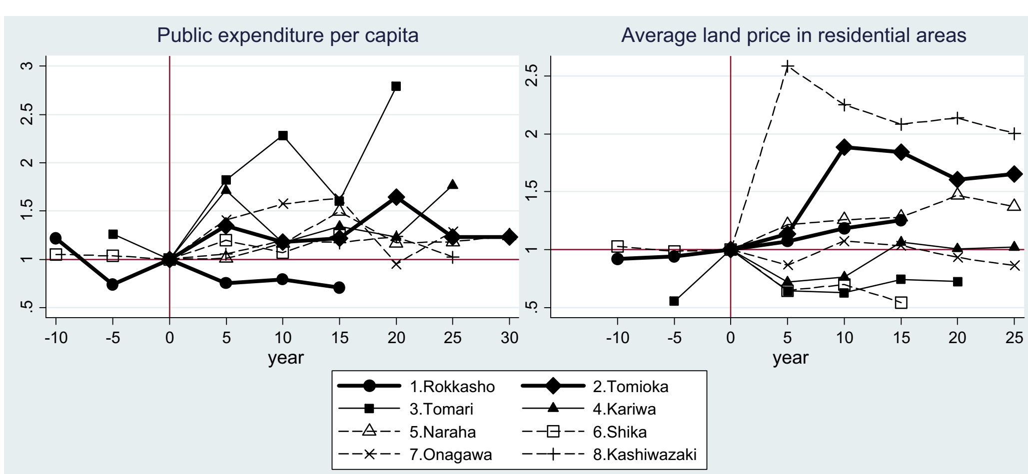

Fig. 10. Comparisons of expenditure and land price in treated units to those in SC units. Notes: On the calculation of ratios and the setting of reference years see the note on Fig. 9. Public expenditure data are from *Local Government Finance Settlement* and average land price data in residential areas is from *Public Notice of Land Prices* (Chika Koji). Data from every five years is used. Because my original public expenditure data starts from 1975 and the intervention year for Naraha and Tomioka is 1975, I independently collected public expenditure data from 1970 for Naraha, Tomioka, and their synthetic units in order to build data in their reference year. In addition, because land price data are available only from 1975, no pre-intervention year data are available for Naraha and Tomioka. I therefore have to use 1975, the intervention year, as the reference year for these municipalities. The reference years of the other NPF municipalities are after 1975 and therefore they have at least one pre-intervention year that can be used as a reference year.

5.3. Effect heterogeneity and employment change

It seems there are quite heterogeneous NPF effects on local per capita income while the average effect is strongly positive. In this subsection I examine the sources of this effect heterogeneity by relying on the conceptual framework in Section 2 and post-estimation comparisons between the NPF municipalities and their SC units, taking advantage of the availability of explicit counterfactual units in the SC method.

Fig. 9 presents the comparisons of employment and population in the eight treated units to those in their SC units. These ratios are standardized to 1 in pre-intervention reference years (year = 0).[32] Graphs in this figure show how the numbers of people working in different industries in NPF municipalities have changed relative to their SC units before and after NPF establishment. In these graphs, the eight NPF municipalities are categorized into the three groups based on the sizes of the SC estimates of NPF effects on per capita income: municipalities with large effects (1.Rokkasho and 2.Tomioka, thick solid lines), municipalities with modest effects (3.Tomari and 4.Kariwa, solid lines) and municipalities with no effects (5.Naraha, 6.Shika, 7.Onagawa, and 8.Kashiwazaki, dashed lines).

I refrain from straightforward causal interpretation based on Fig. 9 because some pre-intervention trends observed in these employment ratios suggest that the treated units and the synthetic control units have differential trends in employment during the pre-intervention period. Nonetheless the graphs provide several important implications.

First, construction employment in all NPF municipalities increased in comparison with their SC units after NPF establishment, and the magnitude of this increase was particularly sizable for 1.Rokkasho and 2.Tomioka (thick solid lines) and 3.Tomari and 4.Kariwa (solid lines) follows and to a lesser extent. This indicates that the direct labor demand shock of NPF establishment on construction employment is directly related to the increases in local income levels. The marked increase in construction employment in 1.Rokkasho may be explained by the fact that several nuclear fuel cycle facilities, not a nuclear power plant, are located in this small village. When it comes to 2.Tomioka, the number of people working in the construction industry was twice as large as the number in neighboring 5.Naraha after NPF establishment, indicating that the direct labor demand shock caused by Fukushima Daini (II) nuclear plant was more influential in Tomioka than in Naraha.

Second, manufacturing employment significantly increased only in 1.Rokkasho, where nuclear fuel cycle facilities were located. This increase was presumably caused by both the direct and indirect impact of the establishment of nuclear fuel cycle facilities. As is mentioned in footnote 13, more than 80 companies have moved to or have been established in Rokkasho since NPF establishment. Industry agglomeration related to the nuclear fuel cycle industry presumably also contributed to the increase in the number of jobs in the manufacturing sector. On the other hand, manufacturing employment decreased in most of the other NPF municipalities, implying that the establishment of nuclear power plants may have no indirect positive effect or may even have a negative effect on the tradable manufacturing industry. This result is compatible with the theoretical prediction regarding the tradable sector stated in Section 2.

Third, employment in nontradable industries such as wholesale/retail and other services increased in comparison with the SC units after NPF establishment for most, but not all, NPF municipalities. In particular, the relative increases in employment in other services in 1.Rokkasho, 2.Tomioka, 3.Tomari, and 4.Kariwa were higher than the increases in 6.Shika, 7.Onagawa, and 8.Kashiwazaki. This result indicates that indirect effects on the service sectors may be larger for municipalities in which direct labor demand shocks on construction employment (and manufacturing employment for 1.Rokkasho) are larger.

Fourth, there was a tendency toward a relative decrease in agriculture employment and a relative increase in fishery employment. The former can be understood as a shift of labor into higher-wage employment such as construction and services. The latter may be related to economic compensation to the fishery industry after NPF establishment, but in any case the absolute number of fishery employees is in most cases small and sometimes negligible.[33]

Finally, relative increases in total employment and population compared with the synthetic units are observed in most NPF municipalities and in particular 1.Rokkasho and 2.Tomioka.

Considering the magnitude of the SC estimates and the clear increase in employment in the secondary and service sectors compared with SC units in 1.Rokkasho and 2.Tomioka, it is plausible to conclude that the sizable direct labor demand shocks on the secondary sector (construction and/or manufacturing) caused by NPF establishment in these municipalities have increased local employment and wages in this sector and have had indirect effects on local nontradable service industries. When it comes to 1.Rokkasho, the manufacturing industry could have also been affected by agglomeration in the nuclear fuel cycle industry. As a whole, NPF establishment has caused higher local employment and higher local wages, resulting in higher per capita income levels. It is also likely that there is a similar mechanism operating through the smaller direct labor demand shocks caused by NPF establishment in 3.Tomari and 4.Kariwa. On the other hand, labor demand shocks caused by NPF establishment in 5.Naraha, 6.Shika, 7.Onagawa, and 8.Kashiwazaki have had more modest impacts on employment in the construction and nontradable service industries than in the other four NPF municipalities, resulting in no significant impact on local income levels.

5.4. Public expenditure and land price

There may be some speculation that increases in public revenue and expenditure caused by NPF establishment, not a labor demand shock, are the primary sources of increases in local income levels in some NPF municipalities. As discussed in the section on this study's conceptual framework and descriptive statistics, NPF establishment seems to raise public expenditure via intergovernmental transfers and local tax revenues.

The graph on the left side of Fig. 10 however, suggests that increases in public expenditure may not have been a primary factor in the increases in per capita income. In this graph, the relative increase in public expenditure compared with a SC unit is even negative for 1.Rokkasho and is also not particularly high for 2.Tomioka. This implies that public expenditure may not have contributed significantly to the increase in per capita income found in Rokkasho and Tomioka, the two locations that have been the most significantly affected by NPF establishment according to SC estimation. See also online Appendix G that provides the corresponding graphs of other fiscal variables such as revenue per capita, local tax revenue per capita, and fiscal-equalization grants per capita.

Finally, my conceptual framework also predicts that NPF establishment may cause increases in local housing costs and may hurt employment in both tradable and nontradable industries. The graph on the right side of Fig. 10 shows that average land prices

[32] Because the data (Census) is available every 5 years, the reference year for each NPF municipality is the pre-intervention year that is nearest to the year of intervention.

[33] Relative increases in fishery employment are explicitly observed in Naraha, Tomioka, and Shika and the number of workers in the fishery sector changed from 3 in 1970 to 11 in 2000 in Naraha, from 19 to 17 in Tomioka, and from 52 to 104 in Shika.

in residential areas in 1.Rokkasho, 2.Tomioka, 5.Naraha, and 8.Kashiwazaki have increased relative to their SC units since NPF establishment.[34] For example, the increase in average residential land prices in 8.Kashikazaki is much larger than that of the SC unit, and there is a possibility that the resulting higher local costs may have partially offset the positive effect of NPF establishment on per capita income in this municipality.

6. Conclusion

This paper has examined how NPF establishment has influenced local income levels with eight quantitative case studies. Estimation and inference with the SC method clarifies that while the NPF effects on per capita taxable income levels are highly heterogeneous, the effects seem to be significantly different from zero in at least 4 out of 8 cases and also on average. The size of impact is often economically meaningful and in some cases huge: a 11.1% increase on average, a 61.7% increase in Rokkasho in 2002, and a 30.2% increase in Tomioka in 2002. On the other hand, several NPF municipalities have received weak or negligible effects from NPF establishment.

When it comes to the causal mechanism of the NPF effects, my post-estimation comparisons between the NPF municipalities and their SC units clarify that the difference in the size of the initial labor demand shocks and subsequent indirect employment effects on nontradable service sectors may have affected the increase in per capita income levels. In particular, Rokkasho and Tomioka, where the effects of NPF establishment on per capita income were most significant, experienced marked increases in employment in construction, manufacturing (in Rokkasho), wholesale and retail (in Rokkasho), and other services when compared to their SC units.

This paper's findings contribute to the evaluation of NPF-related local development and development policies. To begin with, NPF establishment has had a clear positive impact on local income levels in several municipalities. In this sense, NPF establishment may work as a place-based policy for increasing local income growth, while development may come to rely heavily on the NPFs. In particular, Rokkasho and Tomioka have experienced marked income growth and have joined the richest groups in their prefectures after NPF establishment.[35] On the other hand, negligible or weak effects in some municipalities and the unpredictable risks of NPFs make it hard to assert that this possible local income growth always outweighs the cost of NPF establishment in the long run.[36]

I conclude the paper with some comments on the potential and limitations of the research methods adopted in this study. By using the SC method, I was able to take into account the diversity present in the eight cases of NPF establishment by examining individual NPF effects. I was also able to investigate the possible causal mechanism of the NPF effects on per capita income levels through post-estimation comparisons between the NPF municipalities and their SC units. The approach adopted in this study can be characterized as particularly useful when researchers and policy makers want to examine the impact of individual cases rather than a single average impact or when the number of cases is small and the estimation of an average effect could be difficult or potentially misleading.

At the same time, from the standpoint of a more detailed case study which exclusively focuses on one case with much richer quantitative and qualitative information, the data-driven procedure of the SC method with relatively restricted sets of pre-determined covariates may be perceived as a crude research design. I would nonetheless argue that the data-driven procedure of the SC method provides transparent results that are comparable across different cases and easily reexamined by other researchers. More extensive qualitative and quantitative case studies focusing on individual NPF sites would complement, not replace, the findings of this study.

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Appendix I. Additional DID estimates for the NPF and their neighbors

This appendix complements Section 3.4 in the main text and investigate how per capita taxable income changes *on average* after the intervention for 8 NPF municipalities and their 18 neighboring municipalities.

First, two average income gaps are provided in Fig. A with a normalized horizontal axis in which the intervention year is set as zero. In this graph, the bold line presents the average of income gaps between the NPF municipalities and the coastal non-neighbors and the thin line indicates the average of income gaps between

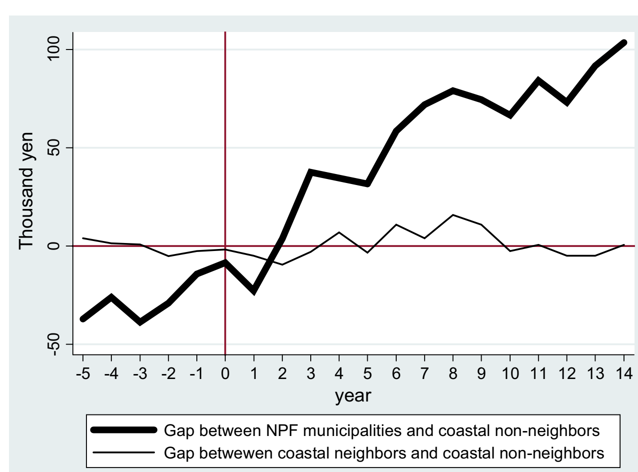

Fig. A. Gaps in average per capita taxable income. Notes: Income gaps are averaged across the 8 NFP municipalities between the normalized year −3 and 14. In normalized year −5 and −4, two NPF municipalities (Naraha and Tomioka in Fukushima prefecture) and two coastal neighbors (Iwaki and Hirono in Fukushima prefecture) are dropped from these averages because these municipalities have only three pre-intervention years (1972, 1973 and 1974). Average gaps in normalized years before −5 and after 14 are not shown because the number of income gaps that can be used for calculating an average is decreasing.

[34] Other average land prices cannot be used for analysis due to the lack of data.

[35] Futaba and Okuma in Fukushima prefecture, which I could not investigate in this paper, were also two of the richest municipalities in Fukushima prefecture in the 2000s.

[36] Davis (2012) provides a broader perspective on the future of the nuclear power industry.

Table A
Additional DID estimates of the impact of NPF establishment on per capita income

Treated municipalities	(1) 8 NPF municipalities	(2) Coastal neighbors
DID estimate	93.01	−0.86
Robust S.E.	(10.16)***	(6.29)
Clustered S.E.	(22.16)***	(19.22)
Adj. R-squared	0.9170	0.9169
Observations	27369.00	27,688
No. of clusters (municipalities)	885	895
No. of the treated municipalities	8	18
Sample period	1972–2002	1972–2002

Notes: "Clustered S.E." is the cluster-robust standard errors that are clustered by municipality. The unit is 1000 yen. Observations before 1981 are excluded for Rokkasho because per capita taxable incomes in Rokkasho during this period fluctuate considerably. In column (2), The 18 coastal neighbors of 8 NPF municipalities are set as the treated group and the timings of treatment are defined as the neighboring NPF municipalities' intervention years. The 18 coastal neighbors are excluded from the sample in Column (1) and the 8 NPF municipalities are excluded from the sample in Column (2).
*** Significance at the 1% level.

the coastal neighbors[37] and the coastal non-neighbors. This normalized graph has straightforward implications.[38] When it comes to the NPF municipalities, the average per capita income gap is negative and has a slight upward trend during the pre-intervention period, but it shows a steeper upward trend after intervention and turns positive three years after NPF establishment. On the other hand, the average gap of the coastal neighbors is more or less around zero and indicates no upward or downward trend either before or after NPF establishment. This suggests that an NPF establishment has a positive impact on the NPF municipalities whereas no spillover effect on coastal neighbors is observed.

Second, Table A provides a DID estimate for all 8 NPF location events in Column (1) and a DID estimate for 18 coastal neighboring municipalities in Column (2). The same DID model with Eq. (1) in the main text is used for estimation. The results show that an estimated average "effect" on the 8 NPF municipalities is around 93 thousand yen (930 dollars if 100 yen = 1 dollar) per year. On the other hand, the average "effect" on coastal neighboring municipalities is almost zero.

Appendix II. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jue.2014.10.005.

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[37] Coastal neighbors consist of the 18 seaside municipalities that border on the 8 NPF municipalities.
[38] The average income gaps in this graph are calculated as follows. First, annual per capita income gaps in an NPF municipality are calculated by subtracting the average per capita income of the coastal non-neighbors from the per capita income of a NPF municipality year by year (the annual gaps between the solid line and the dashed line for each graph in Fig. 3). Then I average these gaps across the eight NPF municipalities based on normalized years. The same procedures are applied when I calculate average gaps between the coastal neighbors and the coastal non-neighbors and, in this case, the intervention year of a coastal neighbor is set as the intervention year of the municipality on which this coastal neighbor borders.

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