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# The Non-operating Solar Projects: Examining the Impact of the Feed-in Tariff Amendment in Japan

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## Abstract

The non-operating solar power projects refers to a large gap between the operating and approved solar capacity in Japan. The country amended the feed-in tariff (FIT) law in 2017 to address this issue. This empirical study investigates the impact of the amended FIT policy on non-operating solar projects using municipality-level panel data from 2014 to 2019. We find that the amended policy improved the relationship between the approved capacity and operating capacity of solar power projects. The impacts are heterogeneous across different sizes of solar power projects: they are more substantial in large- and mega-scale solar power than in small-scale projects. To explore the determinants of non-operation, we also apply a cross-sectional analysis to identify municipal characteristics related to non-operating capacity. We find that the coefficient for the terrain slope is negative in the operating capacity model and positive in the non-operating capacity model. As a steep land surface leads to higher construction and maintenance costs, the results indicate that non-operating projects are located in municipalities with higher construction costs.

Keywords: Solar power; Feed-in tariff; Japan; Non-operation; Panel data analysis

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# 1 Introduction

Renewable power generation in Japan is expected to increase further because of its importance in reducing GHG emissions and attaining energy self-sufficiency after the Fukushima Daiichi accident in 2011. The Japanese government revised the Basic Energy Plan in July 2018; the plan emphasizes the need for renewable energy as a major power source (METI, 2018b). However, as of 2018, the share of renewable energy in electric power generation in Japan was 16.9% (9.2% if hydroelectric power is excluded) (METI, 2020), which seems low compared to that in major developed countries. Japan launched the feed-in tariff (FIT) scheme in 2012 as a policy measure to promote the deployment of renewable energy. FIT has helped increase renewable power generation, particularly in solar cells, although it encountered several challenges. The biggest challenge is the non-operating solar power projects: a large gap between the operating and approved solar capacity. The country amended the feed-in tariff (FIT) law in 2017 to address this issue by revising requirements to obtain project approval.

This study empirically investigates the impact of amended FIT policies on the operation of solar power. We estimate the relationship between operating capacity and approved capacity before and after the amendment using municipality-level data of solar power capacity in Japan from 2014 to 2019. To investigate the heterogeneous effect on solar projects among different scales, we distinguish the projects according to their capacity to explore whether the policy impact differs according to project size. In addition, the study examines the characteristics of municipalities that locate non-operating solar projects.

Many studies have evaluated policy instruments to support renewable energy. Jenner et al. (2013) assess the effectiveness of FIT policies in promoting renewable energy in 26 European Union countries from 1992 to 2008. They create an indicator for policy strength that represents the return on investment provided by FIT and find that for a 10% increase in return on investment, countries will install 3.8% more solar capacity and 2.8% more onshore wind capacity. Polzin et al. (2015) investigate the influence of different measures on subsequent investments into renewable energy capacity by institutional investors in OECD countries from 2003 to 2011. They find that FIT is more effective than subsidies for less-mature technologies such as solar. Renewable portfolio standards and emission trading systems seem to be more effective for mature

technologies such as wind. [Böhringer et al. \(2017\)](#) examines the impact of the German FIT on the innovation of renewable energy technologies from 1990 to 2014. The results imply a positive effect of FIT on inducing innovation. However, the inducement effect of prior FITs with moderate subsidy rates is not significantly different from that of later FITs with much higher prices. [Muhammad-Sukki et al. \(2014\)](#) investigate the impact of Japanese FIT schemes on residential and non-residential solar power using financial analysis. They indicate that FIT rates generate a good profit, a moderate annual return on investment, and an acceptable payback period, suggesting that this would potentially attract more interest in installing solar photovoltaic (PV) systems.

This study also relates to previous studies that examine the factors affecting the growth of solar PV capacity. [Zhang et al. \(2011\)](#) use prefecture-level data from 1996 to 2006 to analyze the factors affecting the diffusion of residential solar PV systems in Japan. They find that the regional government's policies help promote PV system adoption. Installation costs have a significant negative effect, whereas housing investment and environmental awareness have positive impacts. [Tanaka et al. \(2017\)](#) examine the factors determining purchasing decision time for residential solar PV using survey data in 2012 in Japan. The results show that FIT accelerates the decision-making process while subsidy schemes do not contribute to reducing the decision-making time, leading to the purchase of a PV system. FIT offers long-term benefits to PV system users by allowing them to sell surplus electricity back to the grid, contrary to subsidies that provide financial assistance only initially at the time of investment. Conversely, information obtained from other users lengthens the decision-making process regarding purchasing a PV system, since consumers who sought information or who communicated with existing users were more cautious in their purchasing decisions. Using county-level data from 2005 to 2013 in the northeastern United States, [Crago and Chernyakhovskiy \(2017\)](#) investigated the impact of policy incentives on the commercial solar power capacity. They find that rebates, sales exemptions, and renewable portfolio standards have statistically significant and positive effects. Factors that directly affect financial viability and returns on investment, such as solar insolation and installation cost, have the most impact on capacity growth in the commercial solar PV market.

This study differs from the existing literature by focusing on the non-operating capacity of solar power projects. We examine whether the amended FIT policy alleviates the gap between the operating and ap-

proved solar capacity. Few studies have mentioned the existence of non-operating solar power. For instance, Kuramochi (2015) reviews policy measures on energy and climate change implemented in Japan and points out a large gap between the installed capacity and the approved capacity, particularly for non-residential facilities. However, no quantitative analysis was conducted in this policy review. To the best of our knowledge, our study is the first to empirically investigate the issue of non-operating solar projects by examining the effect of FIT amendments. Furthermore, in contrast to studies focusing on drivers of growth in solar PV installed capacity (Zhang et al. (2011); Crago and Chernyakhovskiy (2017); Crago and Koegler (2018)), we examine municipal characteristics that tend to locate non-operating facilities and explore the characteristics before and after the amendment of the FIT scheme.

The remainder of this paper is organized as follows. Section 2 provides an overview of Japan’s FIT policy and the issue of non-operating solar projects while Section 3 introduces the revisions made by the amended FIT scheme. Section 4 presents the regression model and describes the dataset used in the analysis, while Section 5 discusses the empirical results. Finally, Section 6 presents the conclusions.

## 2 Feed-in Tariff Policy in Japan

To increase the share of renewable energy in the energy mix,<sup>1</sup> Japan launched a national FIT scheme based on the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities in July 2012. Under FIT, renewable energy producers—solar PV, wind power, small hydro, geothermal, and biomass, are required to submit documents to obtain FIT approval<sup>2</sup> from the Japanese government. Electric utilities<sup>3</sup> are obliged to purchase electricity generated from renewable energy sources at a fixed price (tariff) for a specific period. Electricity generated from renewable energy sources shall be transmitted to the power grid of the electric utility and distributed to end-users. All electricity customers

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<sup>1</sup> Japan implemented a renewable portfolio standard program from 2003 to 2011, but its impact on renewable power development was small.

<sup>2</sup> FIT approval refers to the application of an existing or proposed renewable energy power facility confirmed and certified by the Ministry of Economy, Trade, and Industry.

<sup>3</sup> Ten regional electric utility companies are Hokkaido, Tohoku, Tokyo, Hokuriku, Chubu, Kansai, Chugoku, Shikoku, Kyushu, and Okinawa.

then pay a surcharge for renewable energy proportional to their usage to cover the expense of purchasing renewable power (METI, 2012).

Table 1 presents the purchase price under FIT from 2012 to 2016. The Japanese government adopted a nationwide but source- and size-specific price scheme. A unified FIT scheme would reduce unfavorable renewable capacity allocations, foster market competition, and reduce electricity costs, but would not benefit some high-cost renewables. In contrast, setting differentiable purchase prices would encourage investment by ensuring profit margins, but it also could risk increasing the economic burden on electricity consumers (Li et al., 2019). Hence, the Ministry of Economy, Trade, and Industry (METI) sets the purchase price differentiated by the category of renewable energy sources and the size of the power generation facilities. The FIT payments are also adjusted for new projects to address changes in electricity supply and generation cost over time. The purchase prices for electricity generated by solar power have continued to fall year by year while prices for other renewable sources remained stable.

The FIT scheme guarantees a fixed price (tariff) for a designated period, thereby enhancing certainty and stability for FIT-eligible renewable electricity producers. The approved capacity of renewable energy has been growing rapidly (it was 88,773 MW by the end of December 2016) (Ito, 2015). However, the operating capacity among them was only 33,659 MW, which indicates that more than 62% of solar projects were not in operation, regardless of the FIT approval. This problem of “non-operation” was even more serious in non-residential solar power ( $\geq 10$  kW) projects because most of the non-operating capacities fall under this category.

The economic reason behind a large number of non-operating solar projects is that the purchase price is determined when the METI approves the facility. Therefore, earlier approval means a higher tariff and higher revenue from selling electricity. For instance, by receiving the FIT approval in 2012, the electricity producer of non-residential solar power can sell the electricity at 43.2 Japanese yen per kWh, which is 35% higher than the purchase price for solar power approved in 2014. Meanwhile, the price of a typical 10-kW solar PV system decreased from 430,000 in 2012 to 346,000 JPY/kW in 2014 (METI, 2018a), which means that by delaying installation of solar PV, one can enjoy a lower equipment cost. Moreover, there was no explicit regulation on the deadline for approved projects to connect to the electricity grid and start their operation.

Thus, the scheme provides solar power developers an incentive to obtain FIT approval as early as possible and to delay the operation to maximize profits. In 2014, METI investigated the status of installations of non-residential facilities approved during 2012. A total of 3 GW capacity of the approved facilities had either not secured land or ordered the purchase of a solar PV system or did not respond to the inquiry (Kuramochi, 2015).

Many FIT-approved projects should have been generating electricity already. The existence of non-operating projects means that a substantial amount of potential electricity from renewable resources is not available despite the rapid expansion of approved capacity, thus suggesting that the original FIT scheme is not effective in promoting renewable electricity. Furthermore, even if these non-operating projects might start to operate and generate electricity long after the FIT approval, they have the privilege to sell electricity with higher FIT prices. The higher purchase price would then be transferred to future consumers on their electricity bills.



Table 1. Purchase price under Japan's FIT scheme (JPY/kWh), 2012 - 2016

Energy source	Category	2012	2013	2014	2015	2016	Duration (year)
Solar PV	<10 kW	42	38	37	35	33	10
	$\geq 10$ kW	43.2	37.8	32	27	24	20
Wind	<20 kW	59.4	57.75	55	55	55	20
	$\geq 20$ kW	23.76	23.1	22	22	22	20
Geothermal	<15,000 kW	43.2	42	40	40	40	15
	$\geq 15,000$ kW	28.08	27.3	26	26	26	15
Hydro	<200 kW	36.72	35.7	34	34	34	20
	200 kW~1000 kw	31.32	30.45	29	29	29	20
	1000 kW~3000 kW	25.92	25.2	24	24	24	20
Biomass	Manure biogas	42.12	40.95	39	39	39	20
	Forest residues	34.56	33.6	32	32	32	20
	Primary mill residues	25.92	25.2	24	24	24	20
	General waste	18.36	17.85	17	17	17	20
	Recycled wood	14.04	13.65	13	13	13	20

Source: METI (2012-2016), [Dong and Shimada \(2017\)](#)

Note: Duration means the period for purchasing electricity generated by each power source.

### 3 Amended FIT Policy in Japan

To address non-operating solar projects, the Japanese government has promulgated the amendment to the FIT Act on June 2, 2016. The amendments came into force on April 1, 2017, and made three main revisions to the existing rules. First, renewable power producers must conclude grid connection agreements before the approval of FIT. Concerning existing FIT-approved projects, a deadline for connection agreements is set to ensure the continued validity of the applicable purchase price and purchase period after April 2017. Projects approved on or before June 30, 2016, are required to make a grid connection agreement by March 31, 2017, while projects approved between July 1, 2016, and March 31, 2017, are required to do so within 9 months of the approval ([METI, 2017](#)). The projects lose eligibility of FIT if the deadline is missed. Second,

METI has replaced a facility certification system for FIT applications with a business-plan-based certification system. Renewable energy developers must submit a detailed business plan, including the commencement date for operation and the description of the interconnection arrangement to maintain a valid FIT approval. Third, a bidding system for FIT approval is introduced to reduce the applicable purchase price to promote competition among developers. A reverse auction system is introduced for the FIT price of  $\geq 2MW$  solar projects. The bidding process is managed by a nonprofit organization designated by the METI. In summary, the amended FIT policy tightens the requirements for FIT approval and introduces competition to determine FIT prices.

Figure 1 shows the total approved capacity and operating capacity of solar power during 2012-2019. According to METI (2017), 456,000 approved projects with a total capacity of 27.66 GW were expected to lose their FIT approval validity after the amendment. A sharp decline is observed in the cumulative capacity of approved projects from 2016 to 2017. The previous FIT policy only required information concerning facility location and the PV system specifications for approval. In contrast, the amended FIT introduced a stricter requirement on the commencement of operation, such as grid connection agreements and information on the commencement date in 2017, thus increasing the operating capacity. The figure shows the gap between operating capacity and approved capacity decreased after 2017, suggesting that the amended FIT policy mitigated the issue of non-operating projects.

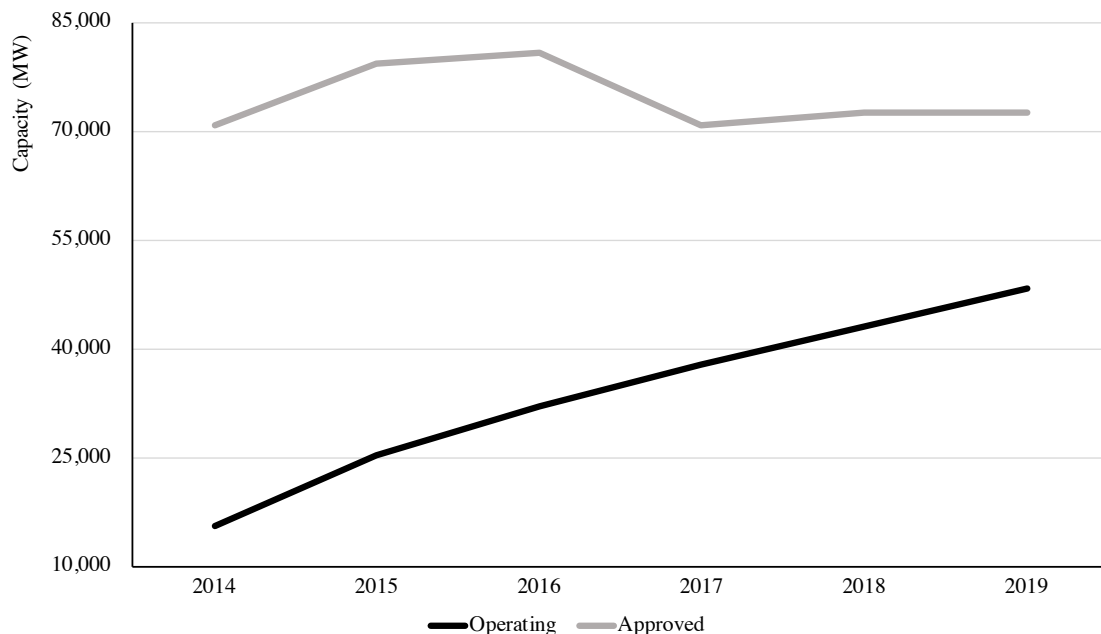


Figure 1: Time trend of FIT approved capacity and operating capacity

## 4 Empirical Strategy and Data

### 4.1 Model Specification

Our empirical analysis investigates the impact of the amended FIT policies on the operation of new solar power facilities<sup>4</sup> approved by FIT. We estimate the impact by examining the relationship between operating capacity and approved capacity before and after the amendment. We hypothesize that the linear relationship between operating and FIT approved capacity changed after the amendment.

Figure 2 illustrates this hypothesis. The 45-degree dashed-line implies that the operating capacity equals the approved capacity. However, in reality, because neither deadline for commencing operation nor grid connection agreements were required when approving new facilities under the previous FIT policy, the operating capacity is much lower than the approved capacity. This is shown by the flatter line in the figure. The amended FIT affects this relationship by imposing stricter requirements. Thus, the slope becomes steeper than before. This change in slope reflects the impact of the FIT amendment.

<sup>4</sup> In this context, new solar power facilities refer to facilities deployed after the implementation of the FIT policy.

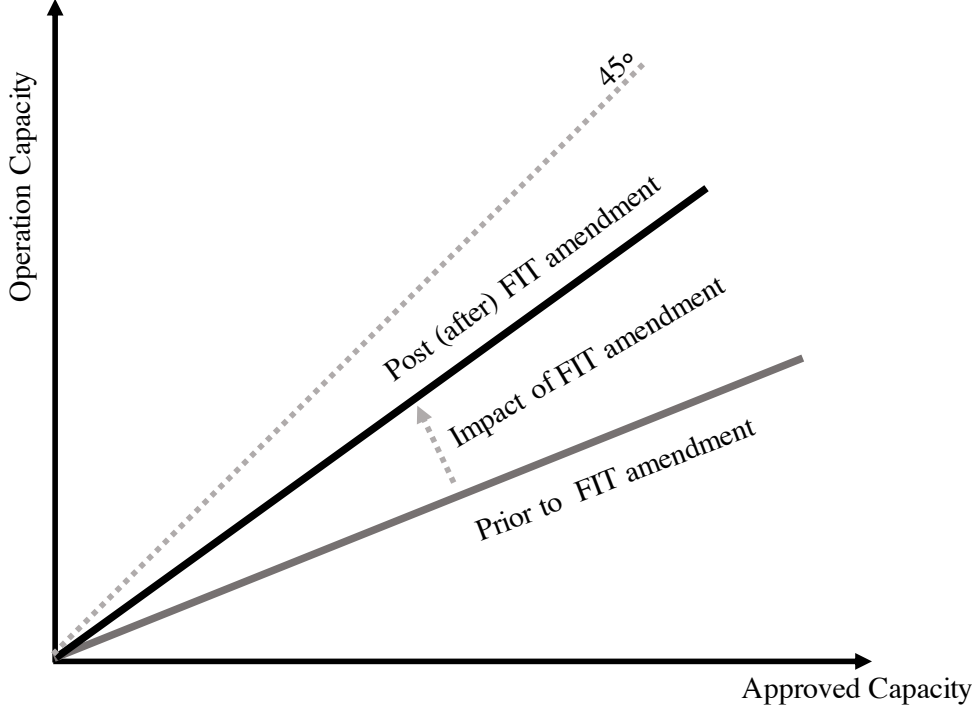


Figure 2: Hypothesis on the effect of amended FIT

A linear fixed effects regression is adopted to estimate the effect of the amended FIT. The general specification can be written as follows:

$$Y_{it} = \beta_1 A_{it} + \beta_2 A_{it} \times Post + \beta_3 E_{it} + \lambda_t + \theta_i + \epsilon_{it}$$

where  $Y_{it}$  indicates the installed capacity of operating solar facilities with FIT approval in municipality  $i$  by the end of year  $t$ .  $A_{it}$  is the FIT approved capacity of new solar power facilities in municipality  $i$  by the end of year  $t$ , which has not necessarily started its operation. The interaction term  $A_{it} \times Post$  denotes the approved capacity after enforcement of the amended FIT. Time-varying and municipality-varying economic conditions are captured by  $E$ .  $\lambda_t$  is the vector of the year dummy capturing the year fixed effects. It controls for unobserved factors that change over time and are constant across municipalities.  $\theta_i$  denotes the municipality fixed effects estimator, which accounts for time-invariant municipality characteristics.  $\epsilon_{it}$  is the error term. The operating capacity in this study only refers to the capacity of active solar power facilities approved by FIT. In other words, it should not be larger than the approved PV capacity. Thus, the constant term is removed in the ordinary least squares (OLS) model.

In addition, a cross-sectional model is used to explore the determinants of the non-operating capacity of solar power across municipalities. This model focuses on municipality heterogeneity by including municipality-specific variables in regressions. We run cross-sectional regression in 2014 and 2019, respectively, to investigate changes over time. Regression using operating capacity as the dependent variable was also performed as a benchmark. The specifications of our estimation model are as follows:

$$Y_i = \alpha + \beta_1 M_i + \beta_2 E_i + \beta_3 L_i + \beta_4 D_i + \beta_5 P_i + \epsilon_i.$$

where  $Y_i$  denotes the operating or non-operating capacity of solar power facilities that have received FIT approval in municipality  $i$  by year 2014 or 2019. Explanatory variables include meteorological factors such as solar radiation ( $M_i$ ), an economic condition ( $E_i$ ), land availability ( $L_i$ ), electricity grid access ( $D_i$ ), and a geographic factor ( $P_i$ ) for developing solar power projects. We use the terrain slope of the land as an important geographic variable. Hilly areas with steep slopes tend to suffer from natural disasters, such as landslides, more than flat areas. It also leads to higher construction costs and risks of a project, leading to a higher number of non-operating projects.  $\epsilon_i$  denotes the disturbance term.

To explore the heterogeneity of the effect among solar power with different sizes, we decompose solar facilities according to their capacity. The solar power less than 10 kW capacity is defined as small-scale (residential) solar PV facilities. When the capacity is larger than 10 kW and less than 2 MW, we define it as large-scale commercial solar power. Projects larger than or equal to 2 MW capacity are sorted into the category of mega commercial solar.

## 4.2 Data

We construct a panel dataset of 1,741 municipalities from 2014 to 2019. A sub-dataset for 2014 and 2019 is also used in our cross-sectional analysis. Table 2 and Table 3 present the descriptions and summary statistics of the variables used in the empirical analysis.

Data on solar power capacity have been aggregated at the municipality level. The data were obtained from the website of the Agency for Natural Resources and Energy (ANRE) of Japan.<sup>5</sup> The agency collects capacity information from the application documents submitted by renewable energy project developers for

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<sup>5</sup> The website for information disclosure of FIT in Japanese. Available at <https://www.fit-portal.go.jp/PublicInfoSummary>.

FIT approval. As shown in Table 3, the average FIT approved capacity is 42.8 MW, while the average operating capacity is approximately 19.3 MW. This indicates that, on average, at the municipality-level, only 45% of the solar power capacity approved by FIT is in operation. Figure 3 depicts scatter plots between the operating and approved capacity of large-scale solar power. This graphically suggests that the correlation between operating and approved capacity improved after 2017 in support of our hypothesis on the effect of the amended FIT.

Data on new housing construction are used as a proxy for economic conditions. They were collected from the Survey on Construction Statistics of the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT). Data on the area of arable land and abandoned farmland as a measure for land availability were obtained from the Statistical Survey on Crops of the Ministry of Agriculture, Forestry and Fisheries (MAFF). Data on solar insolation are from the New Energy and Industrial Technology Development Organization (NEDO). Insolation is a measure of solar radiation energy received on a given surface area at a given time. It is expressed as the average irradiance in kilowatt-hours per square meter per day ( $\text{kWh}/\text{m}^2/\text{day}$ ). Electricity grid access is related to the construction cost of the grid connection and affects solar power plants' operation. The distance from the municipal office to the nearest electricity grid is used as an index of access to the electricity grid and measured using Geographic Information System (GIS) software.

Table 2. Description of variables

Variable	Unit	Description
Operating Capacity	kW	Total installed capacity of new solar power facilities approved by FIT that have been in operation
Non-operating Capacity	kW	Capacity of solar power facilities approved by FIT but have not started operation
Approved Capacity	kW	FIT Approved capacity of new solar power facilities
House	house	Number of new construction starts of dwellings
Solar Insolation	kWh/m <sup>2</sup> /day	Solar radiation energy received
Arable Land	hectare	Area of arable land
Electricity Grid Access	km	Distance from the municipal office to the nearest electricity grid
Slope	degree	Steepness of the land surface

Table 3. Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Operating Capacity					
Solar	10,446	19,313	31,879	0	497,904
Small Solar	10,446	2,768	5,441	0	86,436
Large Solar	10,446	13,955	22,701	0	372,875
Mega Solar	10,446	2,591	10,656	0	185,980
Non-operating Capacity					
Solar	1,741	13,961	32,326	0	440,561
Small Solar	1,741	156	323	0	4,272
Large Solar	1,741	5,917	10,705	0	90,864
Mega Solar	1,741	32,981	53,763	0	504,376
Approved Capacity					
Solar	10,446	42,810	72,912	0	905,690
Small Solar	10,446	3,044	5,895	0	90,207
Large Solar	10,446	25,409	40,707	0	457,453
Mega Solar	10,446	14,358	43,784	0	676,420
House	10,446	430	1,590	0	38,199
Solar Insolation	1,741	3.5	0.2	3	4.5
Arable Land	1,741	2,526	3,679	0	63,300
Electricity Grid Access	1,741	1.406	2.904	0	49.393
Slope	1,741	0.359	0.2	0	0.773

Note: Solar represents total solar PV facilities.

Small solar means  $< 10kW$  solar power. Large solar means  $10kW \sim 2MW$ . Mega solar means  $\geq 2MW$ .



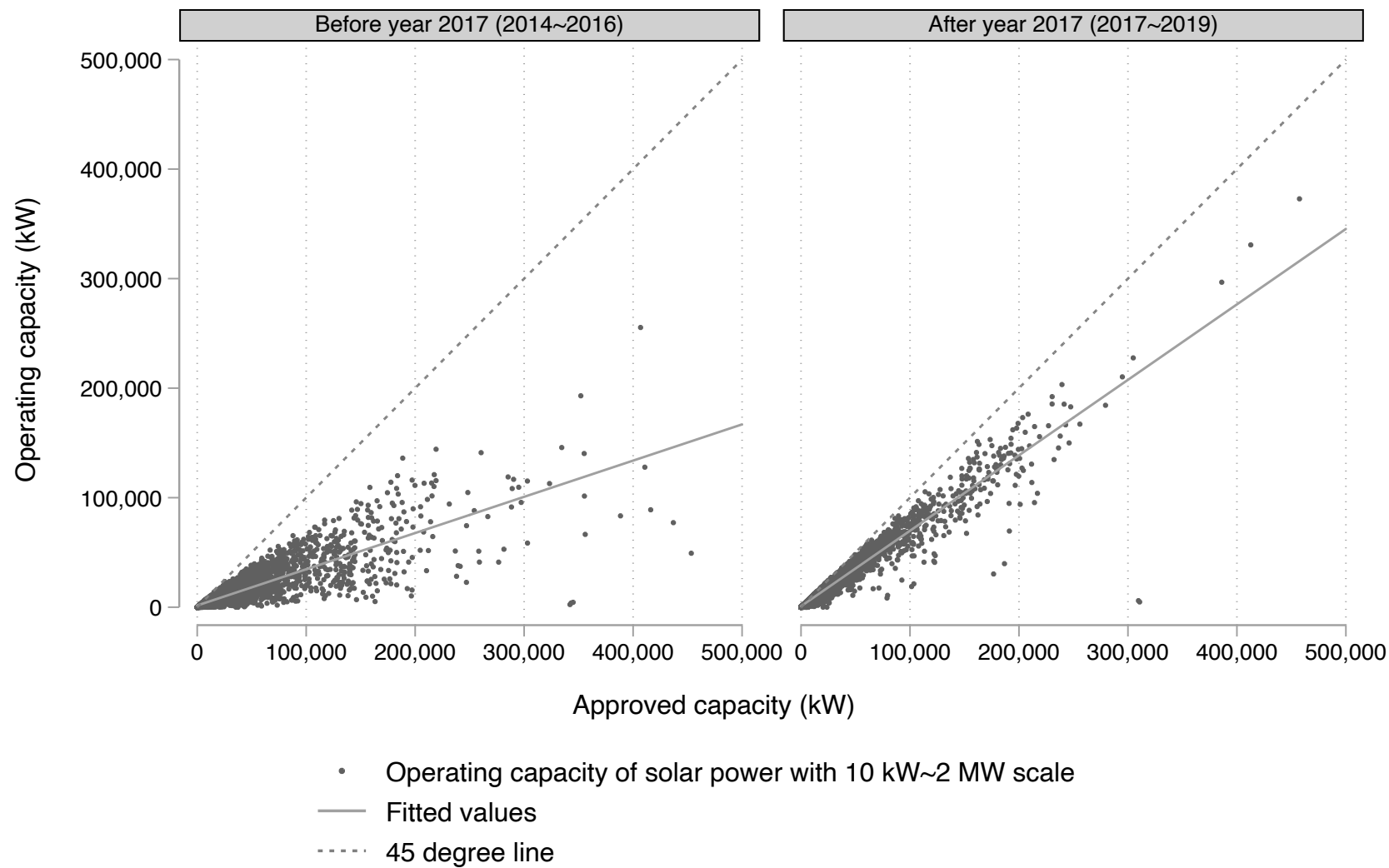


Figure 3: Scatter plots of operating and approved capacity (large-scale solar power)

## 5 Results and Discussion

### 5.1 The effect of FIT amendment

We estimate the effect of amended FIT on the gap between the approved and operating capacity of solar power using a linear regression model. We assign solar power to three categories: residential solar ( $< 10kW$ ), large commercial solar ( $\geq 10kW$  and  $< 2MW$ ), and mega solar ( $\geq 2MW$ ). The OLS model with time fixed effects was used as a baseline regression.

Table 4 presents the main regression results on the effect of the amended FIT. The interaction term between approved capacity and post captures the effect of the amended FIT on the gap between the approved and the operating capacity. In all the model specifications, coefficients for the interaction term are statistically significant and positive. The results suggest that the amendment of the FIT resulted in an increase in the operation of solar power projects. The estimated coefficient in column 1 indicates that, after the amended FIT, 1 kW of added approved capacity related to an additional 0.265 kW increase of operating solar PV capacity. When controlling for the municipality fixed effects in column 2, the estimated coefficient of interaction term decreases by 0.053.

The results from columns 3 to 8 demonstrate the heterogeneous effects across different sizes of solar power. The most substantial impact is found in large-scale solar radiation. In column 3, before the amendment, 1 kW of approved capacity was related to 0.320 kW of operating capacity. After the amendment, it is associated with 0.68 kW of operating capacity. The estimated coefficients decrease slightly when including the municipality fixed effects shown in column 4. In contrast, the change after the amendment is marginal for small-scale solar. As shown in column 4, the correlation between approved and operational capacity is 0.85, even before the amendment. The amendment added 0.104, a 10% increase in the relationship. The results in column 7 show that the amended FIT has a positive impact on mega solar power. The amendment of FIT reduced the gap between operation and approved capacity by an additional 0.129 kW with regard to 1 kW approval. These results suggest that the amendment was effective for commercial facilities rather than residential facilities.

Table 4. The effect of FIT amendment

	Solar		Small Solar		Large Solar		Mega Solar	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	FE	OLS	FE	OLS	FE	OLS	FE
Approved Capacity	0.186*** (0.019)	0.035 (0.028)	0.850*** (0.004)	0.887*** (0.006)	0.320*** (0.018)	0.148*** (0.032)	0.039*** (0.010)	-0.038*** (0.012)
Approved Capacity $\times$ Post	0.265*** (0.018)	0.212*** (0.017)	0.104*** (0.003)	0.092*** (0.003)	0.360*** (0.011)	0.298*** (0.013)	0.129*** (0.023)	0.111*** (0.022)
House	3.300*** (0.584)	-1.239*** (0.345)	-0.001 (0.006)	-0.022*** (0.006)	0.972*** (0.220)	-0.329** (0.162)	0.313** (0.145)	-0.225* (0.134)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,446	10,446	10,446	10,446	10,446	10,446	10,446	10,446
Adjusted $R^2$	0.770	0.614	0.999	0.998	0.920	0.769	0.286	0.216

Note: Constant terms are excluded in OLS regressions.

Robust standard errors in parentheses.

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

## 5.2 Locations of non-operating projects

In this subsection, we apply cross-sectional regressions to explore the municipality characteristics that locate non-operating projects. Table 5 reports the estimation results using cross-sectional data in 2014. We focus on large-scale solar projects because more than half (about 56%) of the non-operating capacity comes from such solar projects. The most contrasting results are found in the coefficient for terrain slope: it is

negative in the operating capacity model and positive in the non-operating capacity model. Because a steep land surface may lead to higher construction and maintenance costs, the results indicate that non-operating projects are located in municipalities with higher construction costs.

Estimated coefficients for other variables also suggest that the non-operating projects are located in municipalities with less attractive conditions for solar projects. Solar insolation has statistically significant and positive effects on operating and non-operating capacity, but the coefficient is lower in the non-operating capacity model. According to column 6, for every 1% increase in solar insolation, the non-operating capacity of large-scale projects is increased by 11%. This indicates that solar power project developers tend to choose municipalities with rich solar resources as their plants' locations to obtain FIT approval, but their response is lower than that of operating projects. The estimated coefficients of electricity grid access on non-operating capacity are negative and statistically significant. The response of the non-operating capacity to a 1% increase in distance to the grid is less sensitive than the operating capacity.

Table 6 presents regression results of the cross-sectional analysis in 2019. We found similar impacts of solar insolation, electricity grid access, and slope, while the differences between operating and non-operating capacity models are smaller compared to the results in Table 5. Because the FIT amendments reduced unreasonable non-operating projects, such as projects without a mature business plan and careful consideration on the practical operation, we can expect both the operating and non-operating projects to be located in similar municipalities after 2017.

To test the statistical difference of coefficients between the operating and non-operating regressions, we apply the Chow test. This test examines the equality of the regression coefficients between different samples. The null hypothesis is that the coefficients of the variables in one model are equal to those in another model (Chow, 1960). Tables 7 and 8 present the results of the Chow test. In general, the difference in coefficients between the operating and non-operating capacity models is less statistically significant in 2019 than in 2014. This implies that operating and non-operating projects are both located in more similar municipalities in 2019. Specifically, the coefficients for solar insolation were not statistically different between the operating and non-operating models in 2019. The non-operating solar locations were no more different from those of the operating solar projects, with regard to the richness of solar resources.

Table 5. Location of projects in 2014

	Solar		Small Solar		Large Solar		Mega Solar	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Operating Capacity	Non-Operating Capacity	Operating Capacity	Non-Operating Capacity	Operating Capacity	Non-Operating Capacity	Operating Capacity	Non-Operating Capacity
Solar Insolation	11.546*** (0.952)	10.278*** (1.047)	7.919*** (0.751)	8.597*** (0.646)	14.192*** (1.058)	11.673*** (1.023)	2.310*** (0.574)	10.885*** (1.046)
House	0.367*** (0.012)	0.315*** (0.016)	0.399*** (0.010)	0.384*** (0.010)	0.361*** (0.014)	0.311*** (0.015)	0.115*** (0.018)	0.314*** (0.016)
Arable Land	-0.017 (0.023)	0.033 (0.032)	-0.038** (0.016)	-0.014 (0.017)	-0.010 (0.029)	0.022 (0.032)	0.032 (0.024)	0.036 (0.033)
Electricity Grid Access	-0.271*** (0.047)	-0.164*** (0.064)	-0.221*** (0.037)	-0.170*** (0.034)	-0.275*** (0.052)	-0.163*** (0.061)	-0.020 (0.043)	-0.198*** (0.061)
Slope	-0.151*** (0.032)	0.201*** (0.042)	-0.213*** (0.026)	-0.190*** (0.026)	-0.142*** (0.037)	0.136*** (0.041)	0.083** (0.035)	0.114*** (0.039)
Constant	-7.900*** (1.212)	-5.184*** (1.349)	-4.986*** (0.945)	-7.539*** (0.814)	-11.676*** (1.368)	-7.306*** (1.331)	-2.905*** (0.706)	-5.725*** (1.366)
Observations	1741	1741	1741	1741	1741	1741	1741	1741
Adjusted $R^2$	0.447	0.226	0.564	0.577	0.402	0.256	0.041	0.251

Note: All variables are in log-form.

Robust standard errors in parentheses. \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 6. Location of projects in 2019

	Solar		Small Solar		Large Solar		Mega Solar	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Operating Capacity	Non-Operating Capacity	Operating Capacity	Non-Operating Capacity	Operating Capacity	Non-Operating Capacity	Operating Capacity	Non-Operating Capacity
Solar Insolation	8.852*** (0.934)	9.771*** (1.176)	6.762*** (0.763)	9.995*** (0.631)	10.963*** (1.028)	10.425*** (1.117)	1.821 (1.283)	9.678*** (1.057)
House	0.420*** (0.016)	0.425*** (0.023)	0.512*** (0.013)	0.516*** (0.013)	0.401*** (0.018)	0.400*** (0.022)	0.379*** (0.041)	0.383*** (0.018)
Arable Land	0.032 (0.023)	0.081** (0.034)	-0.019 (0.016)	-0.024 (0.017)	0.039 (0.028)	0.096*** (0.033)	0.096** (0.049)	0.047 (0.030)
Electricity Grid Access	-0.242*** (0.049)	-0.208*** (0.066)	-0.243*** (0.036)	-0.135*** (0.032)	-0.245*** (0.053)	-0.194*** (0.064)	-0.023 (0.083)	-0.246*** (0.057)
Slope	-0.045 (0.033)	0.227*** (0.049)	-0.182*** (0.026)	-0.137*** (0.030)	-0.045 (0.036)	0.147*** (0.049)	0.558*** (0.063)	0.046 (0.038)
Constant	-3.316*** (1.197)	-6.080*** (1.518)	-2.704*** (0.962)	-10.011*** (0.789)	-6.413*** (1.335)	-7.512*** (1.438)	-1.081 (1.624)	-4.244*** (1.379)
Observations	1741	1741	1741	1741	1741	1741	1741	1741
Adjusted $R^2$	0.354	0.222	0.561	0.606	0.304	0.326	0.088	0.065

Note: All variables are in log-form.

Robust standard errors in parentheses. \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 7. Chow test of location analysis in 2014

	Solar	Small Solar	Large Solar	Mega Solar
Solar Insolation	*	**	***	***
House	***	***	***	***
Arable Land	**	**	*	
Electricity Grid Access	***	**	***	**
Slope	***	*	***	

Note: The difference of coefficients between operating and non-operating regressions are tested.

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table 8. Chow test of location analysis in 2019

	Solar	Small Solar	Large Solar	Mega Solar
Solar Insolation		***		***
House				
Arable land	**		***	
Electricity grid access		***		***
Slope	***	**	***	***

Note: The difference of coefficients between operating and non-operating regressions are tested.

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

## 6 Conclusion and Policy Implications

This study has examined the impact of amended FIT policies on the gap between operating capacity and approved capacity of solar power. Our empirical results suggest that amendments to the FIT scheme reduced the gap and thus mitigated the problem of non-operating solar power projects. However, the impacts are heterogeneous across different facility sizes. In large and mega scales, the effects of the amended FIT are more substantial than in small ones. Furthermore, we apply cross-sectional analyses to explore the municipal characteristics that locate non-operating capacity. Regression results indicate that, in general, municipalities with steeper land have a more non-operating solar capacity. Using a chow test, we confirmed that operating and non-operating solar projects are located in municipalities with similar characteristics.

Our findings have several policy implications. First, there is a trade-off between attracting investment in renewable power and controlling the financial burden of FIT. Under the 2012 Japanese FIT scheme, generous procurement prices are provided to reduce the risks and uncertainty for the project developer. The high procurement price attracts substantial capital investment in solar power generation, while there is no explicit regulation on the deadline for approved projects to start operation. Project developers have an incentive to obtain FIT approval as soon as possible, even if the project is immature and even without careful consideration of the practical operation. Similarly, the decreasing price of the solar panel may tempt some project developers to maximize profits by intentionally delaying the installation. This leads to a large discrepancy between the approved and operating capacity of solar power projects. Second, the results of this study shed light on how the revisions of existing policies based on actual market situations could effectively support renewable energy. The previous FIT scheme offered a policy loophole for solar power project developers to undermine the program's effectiveness. The amendments in 2017 prescribe the deadline for the starting operation and the requirement on grid connection contracts with relevant utility companies when determining the FIT rates. In addition, a reverse auction system is introduced for the FIT price of solar projects that has a capacity larger than 2 MW. It encourages competition among project developers and signals the solar power market the commitment of the government to reduce the cost of the FIT scheme. These amendments are effective in addressing the issue of non-operating solar power projects.



The obtained results highlight the importance of a well-designed FIT scheme in supporting the sustainable development of renewable energy. In this regard, our finding is consistent with [Xia et al. \(2020\)](#), which explores wind-power curtailment issues under the Chinese FIT policy.

This study has some limitations. The data used in this study cannot distinguish how many non-operating projects are delayed intentionally or how many are yet to operate within a reasonable period. In practice, for instance, it takes an average of 1~1.5 years for solar power from FIT approval to start their operation ([Li et al., 2019](#)). Therefore, this study does not exactly capture the extent to which the amended FIT reduces the intentional delay of solar PV installation. In addition, in the location analysis, poor electricity grid access is measured by the distance from the municipal office to the nearest electricity grid. If detailed data such as voltage information<sup>6</sup> on the grid are available, the distance can represent the electricity grid access more accurately.

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<sup>6</sup> The voltage information on the grid can distinguish whether the grid line is, for instance, low voltage ( $\leq AC600V$ , or  $\leq DC750V$ ) or high voltage ( $> AC600V$  and  $\leq DC70,000V$  or  $> DC750V$  and  $\leq DC70,000V$ ) and help identify the availability of grid connections for solar size.

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