# Can Renewable Energy Boost the Business Outcomes of Power Suppliers? An Empirical Study on Japan's Power Producer and Supplier

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## 1.Introduction

In Japan, the deregulation of the electricity market commenced in 2000, enabling the retail sale of electricity to large-scale consumers. This reform facilitated the market entry of specific-scale electricity providers, commonly referred to as Power Producers and Suppliers (PPS). Following the full liberalization of the electricity retail market in April 2016, the number of PPSs expanded rapidly – from 291 in April 2016 to 734 by September 2024 – many of which actively engage in electricity retailing (METI, 2024A).

A majority of PPSs do not possess their own large-scale generation facilities, thereby incurring relatively low fixed costs associated with power plant maintenance and labor. Approximately 80% of the electricity supplied by these new entrants is procured from incumbent utilities and the wholesale electricity market (METI, 2024B). Since late 2020, a tightening in the electricity supply – demand balance has triggered significant price volatility, resulting in severe cash flow pressures for PPSs. As a consequence, numerous PPSs have faced financial distress – manifested in bankruptcies, service suspensions, or delays in the commencement of full-scale operations despite formal registration (as of September 2024: 57 firms have exited the market, and 171 have transferred their business operations; METI, 2024A). The combination of intensified market competition and escalating electricity procurement costs has exerted substantial financial strain on the operational viability of PPSs.

To strengthen their market competitiveness, Power Producer and Suppliers (PPSs) have increasingly adopted electricity pricing strategies that are both more affordable and more diverse compared to those offered by traditional electric utilities. Concurrently, the role of PPSs in promoting regional economic circulation and fostering community-based energy systems has been extensively explored in recent scholarship (Nagaya et al., 2024; Goto, 2023; Tomoki, 2023; Shige, 2023). These studies consistently emphasize the strategic importance of renewable energy integration in enhancing the operational performance and long-term sustainability of Japan's PPS sector. Although the adoption of renewable energy is widely regarded as a key driver of competitive advantage for PPSs, its effect on firm-level profitability remains insufficiently investigated. To address this research gap, this study investigates the impact of renewable electricity generation on business performance indicators, with a particular focus on revenue and net profit after tax (NPAT) among PPSs.

## 2. Methodology and Data

We conducted an analysis using Random Forest (RF) and XGBoost combined with Double Machine Learning (DML) to examine the effects of renewable generation on the business outcomes of Japan's PPSs. First, we applied both RF and XGBoost to select the top 25% of variables by importance related to revenue and net profit after tax. These selected variables were then used as control variables in the DML framework to address the endogeneity of the treatment variable, renewable generation. The estimation model of DML is represented as follows:

$$Y_{it} = \alpha + \theta T_{it} + g(X_{it}) + \varepsilon_{it}$$
$$T_{it} = m(X_{it}) + \eta_{it}$$

where $Y_{it}$ is the dependent variable representing the business outcomes of $i$ in year $t$. $T_{it}$ de-

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notes the renewable generation of PPSs. $X_{it}$ includes variables potentially related to business outcomes, selected using RF and XGBoost. We use $g(X_{it})$ to predicts the business outcomes and $m(X_{it})$ to predict the renewable generation. The residual relationship between business outcomes and renewable generation, after removing the variation explained by $X_{it}$, provides a cleaner estimate of the true causal effect $\theta$ of renewable generation.

Renewable generation data were obtained from the website of the Agency for Natural Resources and Energy (ANRE, n.d.). Data on PPSs' business outcomes were sourced from Teikoku Databank (TBD, n.d.).

## 3. Results

Table 1 presents the estimated effects of renewable generation on the business outcomes of Japan's PPSs. Columns (1)–(3) report the effects of total renewable generation, solar generation, and wind generation on revenue, respectively. The statistically insignificant results suggest that renewable generation does not have a meaningful impact on the revenue of PPSs. In contrast, columns (4)–(6) indicate that renewable generation has a statistically significant and positive effect on net profit after tax. These findings imply that while renewable generation may not directly increase sales, it is associated with improved profitability. This could be attributed to lower marginal costs of renewable energy sources and financial incentives such as the Feed-in Tariff scheme.

Table 1: The effects of renewable generation on the business outcomes of Japan's PPS

| | Revenue | | | NPAT | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Type of renewable source | Total | Solar | Wind | Total | Solar | Wind |
| $T_{it}$ | -0.015 | -0.014 | 0.031 | 0.051** | 0.043** | 0.057** |
| | (0.028) | (0.025) | (0.066) | (0.022) | (0.025) | (0.024) |
| Constant | 10.32 | 10.37 | 10.22 | 1.095 | 1.353 | 1.089 |
| | (11.67) | (11.66) | (11.60) | (10.01) | (10.03) | (10.05) |
| Training set score | 0.83 | 0.83 | 0.83 | 0.86 | 0.86 | 0.86 |
| $N$ | 1,040 | 1,040 | 1,040 | 900 | 900 | 900 |
| $R^2$ | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 |

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Columns (1)–(3) show the effects of renewable generation on PPS's revenue, while columns (4)–(6) show the effects on PPS's net profit after tax. The robust option was used for all models. Year dummy variables were included in all columns. The training set score refers to the score from the first stage of the DML procedure. Using a log-log specification, the ATE coefficients represent the supply elasticity of renewable generation.

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