Electricity Storage or Transmission?
Comparing Social Welfare between Electricity Arbitrages

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1. Introduction

The variable nature of solar power generation leads to substantial fluctuations in electricity supply and price instability that impose a challenge for power generators to project their profits. To mitigate this issue, two forms of electricity arbitrage—storage and transmission— have been employed to adjust the surplus electricity. The former enables inter-temporal arbitrage of electricity within a region by storing surplus electricity and discharging it during low solar hours, while the latter realizes inter-regional arbitrage by transmitting surplus electricity to other regions. This study investigates these two forms of arbitrages for the surplus of solar power in Kyushu area, Japan, where the solar power curtailment has been frequently conducted. We quantify the social benefits (private and external benefits) of two forms of arbitrages and derive an implication for the socially and environmentally preferable electricity arbitrage.

2. Methodology and Main findings

In our analysis, we first estimate electricity demand function and develop electricity supply function, and then quantify the social benefits based on these functions. Using monthly panel data of nine regions in Japan from FY2016 to FY2021, we estimate the electricity demand functions and the price elasticity of electricity demand in high solar hour and low solar hour. We employ the average fuel price as an instrumental variable to mitigate an endogeneity concern. The estimated price elasticity of electricity demand in high and low solar hour is –0.230 and –0.148, respectively. It implies that electricity demand is more elastic in high solar hour than low solar hour. We then construct a stepwise electricity supply function based on the average hourly supply and the marginal cost of each power source. Figure 1 shows the changes of supply functions before and after each arbitrage. By avoiding the surplus solar power to be curtailed, the arbitrages shift the supply curves to the rightward. We then quantify the social benefits of the current operation of storage and inter-regional transmission in Kyushu area

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(985 MWh and 1936 MWh, respectively). Estimated social benefits are summarized in Table 1. Both the storage and transmission increase the producer surplus. Moreover, they bring large positive external benefits. It can be attributed to the fact that both arbitrages substitute oil-fired power generation, which has a high external marginal cost in terms of CO_2 emission. We conclude that both storage and transmission improve social welfare. In addition, we found that transmission also improves the consumer surplus.

Figure 1: The changes of demand and supply curves

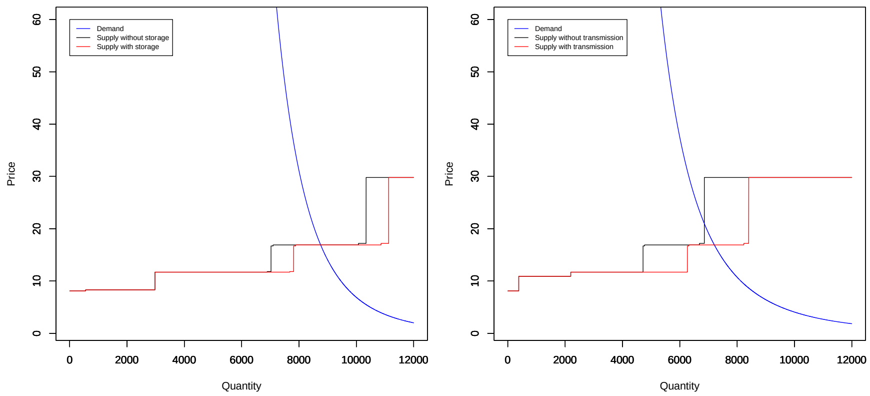

Table 1: The social benefits of storage and transmission (JPY)

	Consumer surplus	Producer surplus	External benefit
Storage（985 MWh）	0	4,097,600	8,431,600
Transmission（1936 MWh）	685,710	6,044,700	10,988,900

3. Conclusions

This study compared the storage and transmission in terms of the impact of their current operation on social welfare. As the first step, we estimated price elasticity of electricity demand in high and low solar hour. Estimated demand was more elastic in high solar hour (–0.230) than low solar hour (–0.148). Moreover, we found that both storage and transmission improve the social welfare. Arbitrages help reduce the curtailment of renewable energy and substitute oil-fired generation. They would provide higher benefits in the future, where both the fossil fuel price and the carbon price is expected to rise.