GREEN CERTIFICATE PRICE UNCERTAINTY AND RENEWABLE ENERGY INVESTMENT: EVIDENCE FROM AN INTEGRATION BETWEEN SOLAR AND NON-SOLAR RENEWABLE ENERGY CERTIFICATE (REC) MARKETS IN KOREA

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Overview

A stable income flow from renewable energy certificate (REC) sales is crucial for ongoing business in renewable energy companies. This paper examines the relationship between REC price uncertainty and renewable energy investment. Using a REC market data in Korea, I find that a high level of uncertainty about REC prices discourages renewable energy investment. Given that the decision to invest in renewable projects is highly irreversible, it is optimal to postpone new renewable energy installations until REC price uncertainty is resolved. Solar photovoltaic (PV) is a prime example. Solar project developers significantly reduce new capacity investment in the periods with highly volatile REC prices, while they increase investment when the prices are expected to be stable. I further show that renewable energy firms require more debt and equity financing to proceed a project in the presence of severe uncertainty about REC revenues. This finding suggests that increased dependence on external financing contributes to deter investments in new capacity installations.

Methods

To capture the REC uncertainty influence on renewable energy investment, I exploit the exogenous variation in REC price volatility before and after the integration of solar and non-solar REC markets. Integration of the two REC markets significantly curtails REC price uncertainty. Before the integration, solar and non-solar RECs were traded separately in Korea.[1] Interestingly, supply and demand shocks have dominated the price movements in solar and non-solar REC markets, respectively. Especially in the solar REC market, oversupply of RECs induces large fluctuations in the prices. During the period of 2012-2014, many solar energy firms undertake new solar photovoltaic (PV) projects in response to the sharp decline in solar PV module prices. However, these active investments increase market concerns about the possibility of future solar REC sales since the government sets the total demand of solar RECs into a certain small level, namely a solar-carve out. In particular, the solar carve-out in 2013 was only 723 GWh (i.e., 723,000 RECs), and this demand level was not sufficient to satisfy the overall supply of solar RECs. Excessive supply problem in the solar REC market increases uncertainty about the feasibility of future REC transactions, and thereby resulting highly volatile solar REC prices.

In the non-solar REC market, however, demand shocks driven by fears about future REC supply shortfalls lead to large fluctuations in the prices. Aggregate supply of non-solar RECs was not sufficient to meet the relatively large amount of demand. Uncertainty about the availability of non-solar RECs might trigger highly unstable prices.

After the integration of the two REC markets, solar and non-solar RECs are traded in a single market with a single price. The integration facilitates trades between solar and non-solar RECs, and therefore it resolves supply and demand shocks in each market. In particular, excess supply of solar RECs alleviates the short supply problem of non-solar RECs. Consequently, a stable equilibrium of supply and demand in REC transactions reduces the uncertainty about REC prices. I use this finding and then perform a two stage least square (2SLS) estimation of the effects of REC price uncertainty on renewable energy investment. Specifically, the 2SLS identification strategy used in this paper is as follows:

(i) First stage: $\textit{REC price uncertainty}_{i,t}=\alpha^1+\beta^1\cdot\textit{Integration announcement}_t+\gamma^{1\prime}X_{i,t}+\delta_i+\zeta_{i,t}$

(ii) Second stage: $\textit{Renewable energy investment}_{i,t+12}=\alpha+\beta\cdot\textit{REC price uncertainty}_{i,t}^{*}+\gamma^{\prime}X_{i,t}+\delta_i+\varepsilon_{i,t}$

i and *t* represent the sector and month, respectively. Solar, wind, biomass, and small hydro sectors are included. The sample period covers from January 2012 to February 2017. *Integration announcement* is an indicator variable

[1] The Korean government sets a solar carve-out, a regulation that utilities should meet a specified amount of electricity only with solar RECs. The solar carve-out and solar REC market were initially designed to compensate relatively high costs of solar PV system compared to other RETs.

that equals 1 if the Korean government has announced the integration of solar and non-solar REC markets by month *t*. *REC price uncertainty* is the rolling standard deviation of REC prices over the past six months preceding the month *t*. *Renewable energy investment* is either installed renewable capacity or renewable electricity generation. *X* is a set of control variables. δ is an industry fixed effect that aborbs technology-specific characteristics.

Results

Figure 1 shows renewable capacity installations at varying levels of REC price volatility. Samples with low REC price volatility (high REC price volatility) indicate the periods when the price volatility lies below the 30th percentile (above the 70th percentile). Subsequent renewable energy installation (MW) is calculated as a sum of newly installed capacity over 12 months after the REC price volatility is observed. While the subsequent installation level is 145.54 MW in the periods with low REC price volatility, newly installed capacity in the periods with high REC volatility is only 77.22 MW. The difference is 68.32 MW and significant at the 1% level.

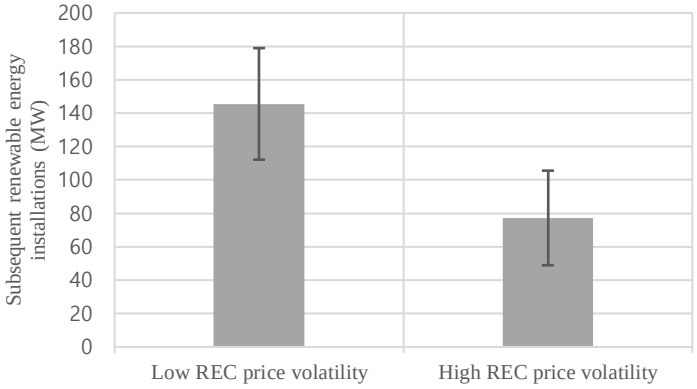

Figure 1 REC price volatility and subsequent renewable energy installations

Table 1 shows the 2SLS estimation results examining the relationship between REC price volatility and renewable energy investment. The significantly negative coefficient of *REC price volatility* indicates that high uncertainty about REC prices provides incentives for decreasing new capacity installations. In contrast, when low REC price volatility is observed and the prices are expected to be stable in the future, renewable project developers increase new capacity installations.

Table 1 REC price volatility and renewable energy investment

	Installed capacity$_{i,t+12}$	Electricity generation$_{i,t+12}$
	(1)	(2)
REC price volatility$_{i,t}$	-5.940***	-0.512***
	(0.000)	(0.000)
GDP growth$_t$	72.982	-5.011
	(0.139)	(0.604)
RPS mandates$_t$	3.524***	0.359***
	(0.000)	(0.000)
Dependence on REC revenue$_{i,t}$	-6.106	-0.253
	(0.149)	(0.667)
Growth of new capacity installations$_{i,t}$	-0.004	-0.001
	(0.696)	(0.246)
Industry fixed effect	Yes	Yes
Observations	189	189
Robust regression-based Hausman test	18.10**	3.603
	(0.013)	(0.131)

Table 2 reports the subsample studies. Interestingly, the effect of REC price uncertainty on renewable capacity installations is pronounced in solar sectors. Since solar projects are typically small-scale projects, they are highly sensitive to REC price uncertainties.

Table 2 Subsample studies

	Installed capacity$_{i,t+12}$			
	(1)	(2)	(3)	(4)
Sector	Solar	Wind	Biomass	Small hydro
REC price volatility$_{i,t}$	-26.885***	-8.866***	0.005	-0.281***
	(0.000)	(0.000)	(0.230)	(0.000)
Control variables	Yes	Yes	Yes	Yes
Observations	48	47	47	47
Robust regression-based Hausman test	18.45**	24.02***	0.747	9.942**
	(0.013)	(0.008)	(0.436)	(0.034)

Conclusions

This paper examines whether higher uncertainty about REC prices affects investment decisions in renewable energy. Major finding of this paper is that in the presence of highly volatile REC prices, renewable project developers decrease new capacity investment. In contrast, when the uncertainty is resolved and REC prices are expected to be stable in the future, renewable energy firms increase investments in new projects.

Findings in this paper suggest that promoting renewable energy requires a well-functioning REC market that provides stable REC prices and low uncertainty on trades. Renewable project developers feel comfortable investing in new renewable capacity under the well-functioning REC market. This finding has an important implication for policy makers in emerging markets, who newly design the RPS or have recently introduced the RPS.