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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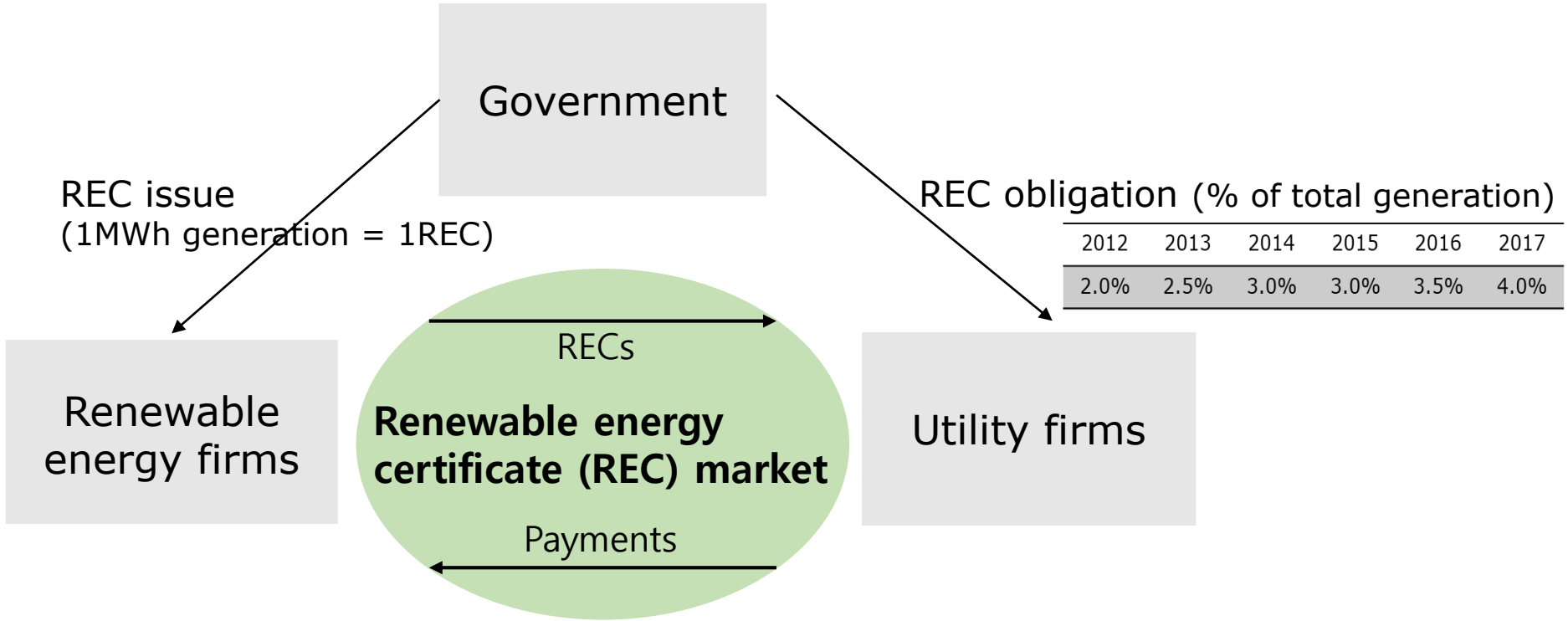
What is this paper about?

- Renewable Portfolio Standards (RPS) and Renewable Energy Certificate (REC) markets



What is this paper about?

- Concentrates on REC price fluctuation and its effect on renewable energy sector.

Period	Before an integration of two REC markets		After the integration
Market type	Solar REC market	Non-solar REC market	Integrated market
Market rule	RECs only from solar energy are traded.	RECs from other renewable energy are traded.	All types of RECs are traded together.
Features	Sensitive to supply and demand shock. **High REC price volatility**.		Less sensitive to supply and demand shock. **Low REC price volatility.**

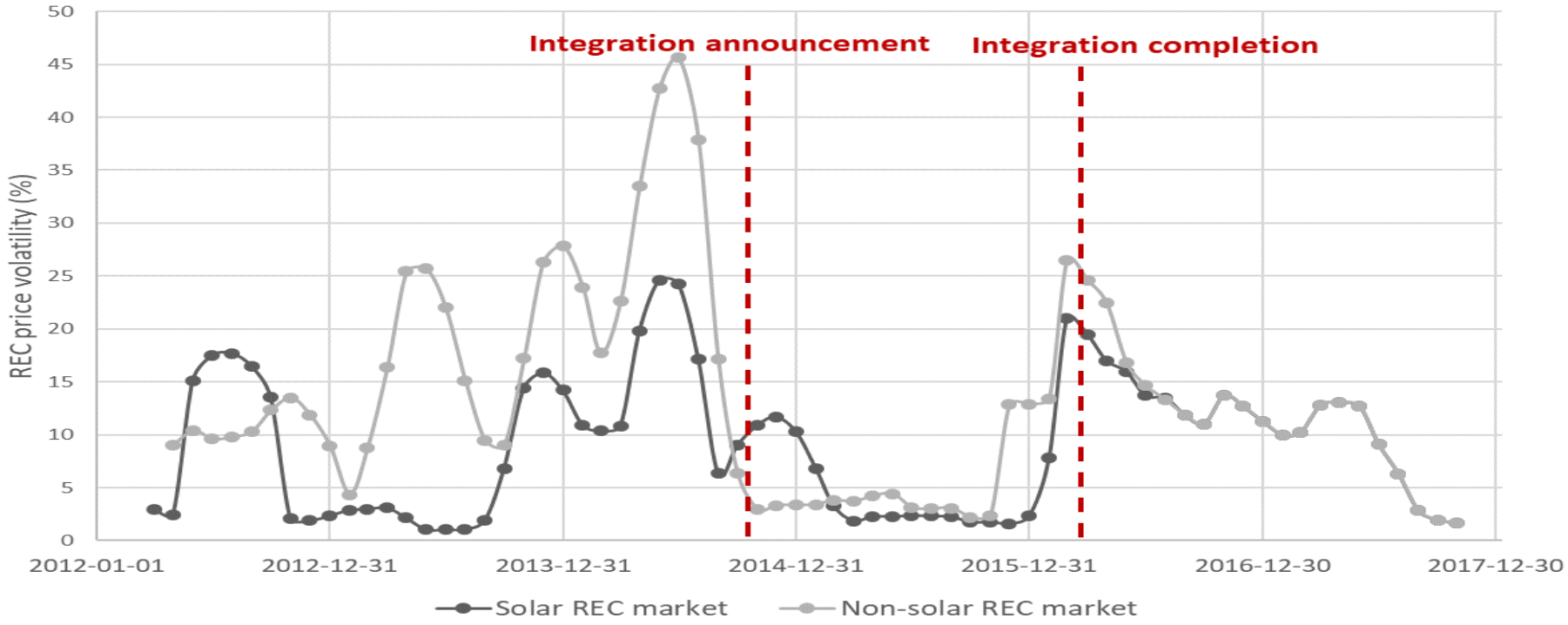


Figure 3A REC price volatility around the integration announcement between solar and non-solar REC markets

Research questions

- Does renewable energy firms decrease (increase) investments in capacity when REC prices are unstable (stable)?

- Does renewable energy firms require large amount of external financing to build a new plant when REC price uncertainty is high?

Preview of the results

- REC price volatility and renewable energy installations

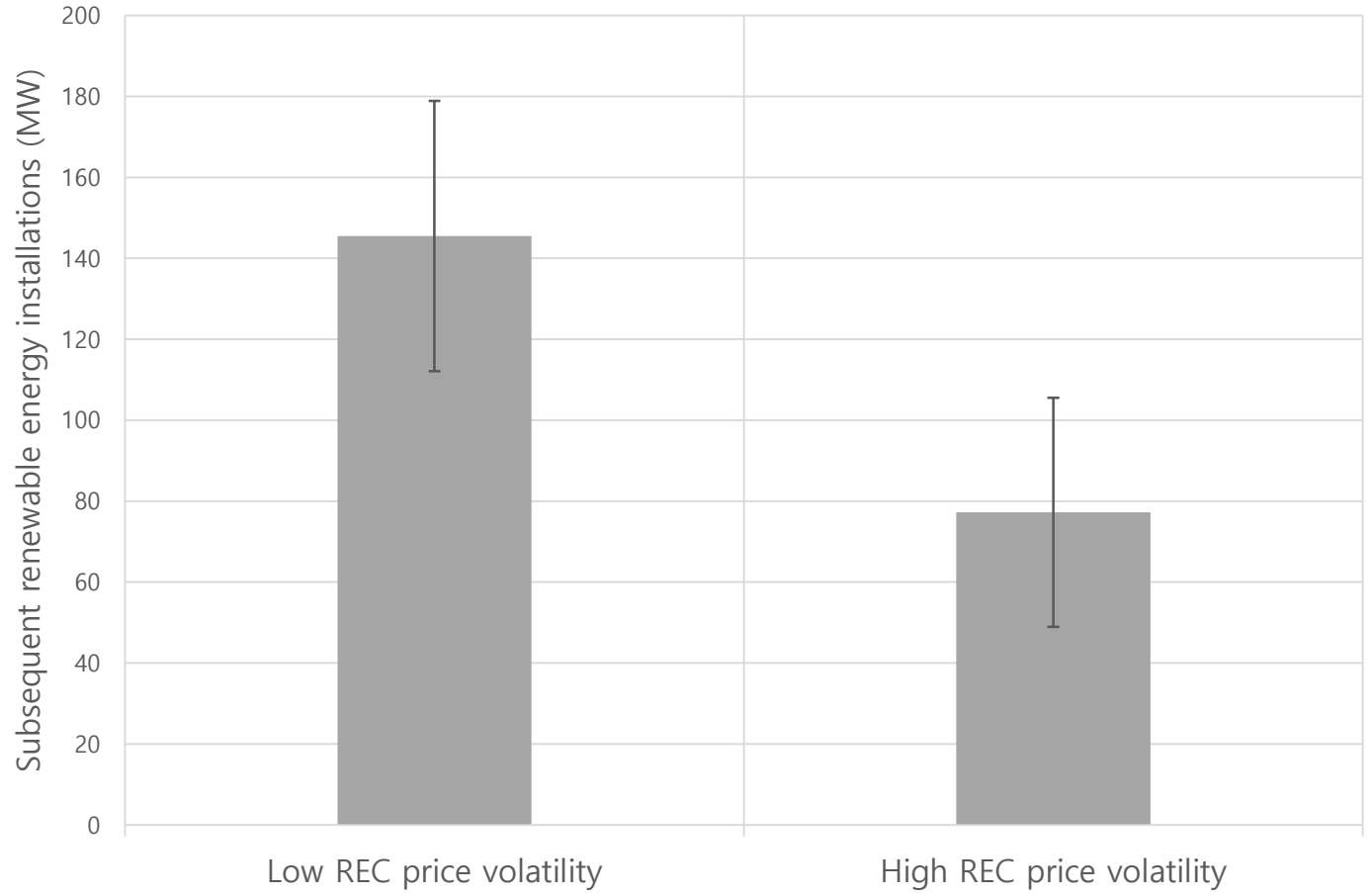


Figure 2 REC price volatility and subsequent 12-month renewable energy installations

Main findings

- Integration of solar and non-solar REC markets significantly reduces REC price volatility and facilitates trades.

- Renewable project developers decrease investment in the presence of high REC price uncertainty, while they increase investment when REC prices are expected to be stable.

- Under a severe uncertainty about REC prices, renewable energy firms require more debt and equity financing to proceed a project.

Data and methodology

A monthly panel dataset of 4 renewable industries –biomass, solar, wind, and small hydro – for the January 2012 – February 2017 period in Korea:

- Renewable energy investment:
  - Installed renewable capacity (MW), renewable electricity generation (GWh)
- REC price uncertainty
  - Rolling standard deviation of REC prices over the past 6 months / The average REC price
  - Rolling average of REC trading volume over the past 6 months
- Integration announcement
  - Dummy indicating whether the integration event has announced
- Dependence on external financing
  - The amount of debt and equity financing for the construction of new plant / Installed renewable capacity

Methodology:

- Two stage least square estimation (2SLS)
  - First stage: $REC\ price\ uncertainty_{i,t} = \alpha^1 + \beta^1 \cdot Integration\ announcement_t + \gamma^{1'} X_{i,t} + \delta_i + u_{i,t}$
  - Second stage: $Renewable\ energy\ investment_{i,t+12} = \alpha + \beta \cdot REC\ price\ uncertainty^*_{i,t} + \gamma' X_{i,t} + \delta_i + \varepsilon_{i,t}$

REC price volatility and renewable energy investment

Table 3 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)
OLS estimates: REC price volatility$_{i,t}$	-1.701	-0.089
	(0.432)	(0.724)

P-values are reported in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10% levels, respectively.

Heterogeneous effect of REC price volatility on renewable sectors

Table 4 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)
OLS estimates: REC price volatility$_{i,t}$	-6.644	-4.020*	0.002	-0.086**
	(0.357)	(0.060)	(0.480)	(0.043)

P-values are reported in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10% levels, respectively.

Potential channels: REC price volatility and dependence on external financing

Table 6 REC price uncertainty and dependence on external financing

	Dependence on external financing$_{i,t+12}$	
	(1)	(2)
REC price volatility$_{i,t}$	0.011***	
	(0.000)	
REC trading volume$_t$		-0.011***
		(0.009)
GDP growth$_t$	0.430***	0.180
	(0.001)	(0.320)
RPS mandates$_t$	-0.003***	-0.001
	(0.000)	(0.680)
Dependence on REC revenue$_{i,t}$	0.006	0.009
	(0.376)	(0.222)
Growth of new capacity installations$_{i,t}$	-0.000	0.000***
	(0.953)	(0.000)
Industry fixed effect	Yes	No
Observations	189	49
Robust regression-based Hausman test	0.347	5.840*
	(0.587)	(0.073)
OLS estimates: REC price volatility$_{i,t}$	0.013**	-0.003
and REC trading volume$_t$	(0.041)	(0.577)

P-values are reported in parentheses. ***, **, and * denote statistical significance at 1%, 5%, and 10% levels, respectively.

Concluding remarks

- This paper documents the relationship between REC price uncertainty and renewable energy investment.
- The success of the RPS policy is dependent on low uncertainty about REC prices. Promoting renewable energy requires a well-functioning REC market which provides stable REC prices.
- Solar projects are highly sensitive to the risks associated with REC prices.
- In the presence of uncertain REC prices, renewable energy firms need large amount of external capital in preparation for future risky revenues. This becomes a heavy burden for renewable energy firms.

Appendix: Summary statistics

Table 1 Summary statistics

Panel B	Before integration announcement (1)	After integration announcement (2)	Differences (2)-(1)
Installed capacity (MW)	331.857	599.536	267.679*** (0.000)
Electricity generation (GWh)	56.005	85.348	29.343*** (0.000)
Dependence on external financing ($/W)	1.073	0.841	-0.232 (0.216)
REC price volatility (% of average REC price)	13.824	9.205	-4.619 *** (0.004)
REC trading volume (in thousands)	26.337	63.310	36.973*** (0.000)
GDP growth (%)	0.718	0.697	-0.022 (0.733)
RPS mandates (%)	2.455	3.276	0.821*** (0.000)
Dependence on REC revenue (% of total revenue)	43.564	54.273	10.709*** (0.000)
Growth of new capacity installations (%)	67.607	97.206	29.599 (0.711)

Appendix

- REC trading volume around the integration of solar and non-solar REC markets

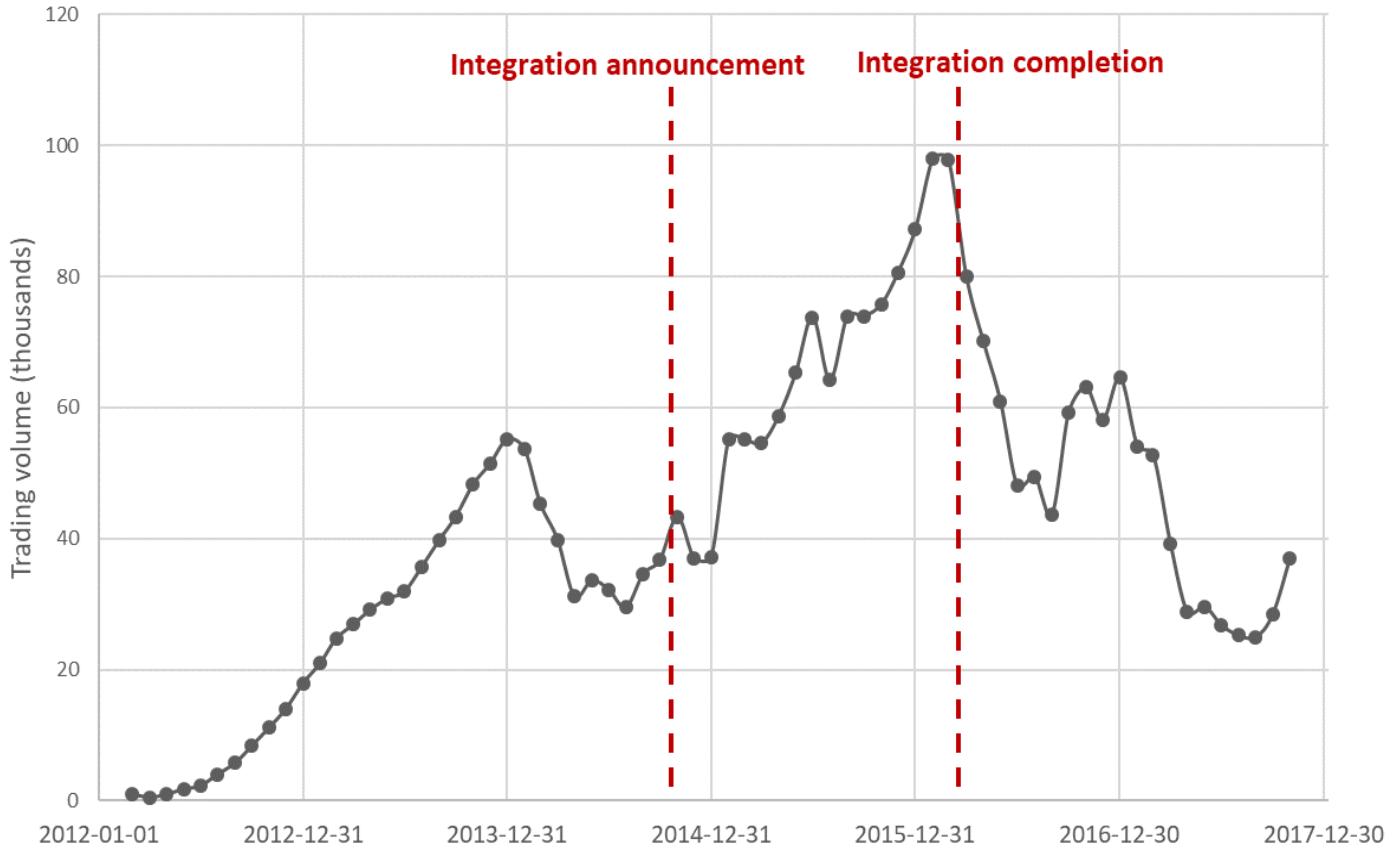


Figure 3B REC trading volume around the integration announcement between solar and non-solar REC markets

Appendix

- REC trading volume and renewable energy investment

Table 5 REC trading volume and renewable energy investment

	REC trading volume$_t$	Installed capacity$_{t+12}$	Electricity generation$_t$
	(1)	(2)	(3)
Model	First stage	Second stage	Second stage
Integration announcement$_t$	21.590***		
	(0.000)		
REC trading volume$_t$		20.570***	1.793***
		(0.000)	(0.000)
GDP growth$_t$	7.871	-100.205	-55.984**
	(0.442)	(0.512)	(0.022)
RPS mandates$_t$	0.210**	3.420**	0.437**
	(0.026)	(0.036)	(0.018)
Dependence on REC revenue$_{i,t}$	1.014*	-18.412***	-0.413
	(0.075)	(0.003)	(0.594)
Growth of new capacity installations$_{i,t}$	-0.000	0.077***	0.005
	(0.740)	(0.005)	(0.496)
Observations	49	49	49
F-statistic	201.878***	-	-
	(0.000)		
Robust regression-based Hausman test	-	12.67**	0.105
		(0.024)	(0.762)
OLS estimates: REC trading volume$_t$	-	14.415***	1.520**
		(0.005)	(0.016)