# RENEWABLE ENERGY DEPLOYMENT AND ENERGY STORAGE: EMPIRICAL EVIDENCE

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## Overview

Renewable energy can reduce pollution in cities by providing renewable electricity, heating, cooling and transportation. The main disadvantage of renewable energy deployment, is that once it reached a high share in electricity generation, the intermittency caused by renewable energy sources makes balancing of the energy system challenging. This study answers the question "What is the impact of renewable energy on energy storage?" Empirical literature studying deployment of renewable energy is abundant, however empirical literature studying the energy storage deployment is highly limited due to data availability. Using panel data from 28 OECD countries over the period 1990-2014 this paper provides an empirical evidence on the role of renewable energy deployment and low carbon technologies policy on energy storage investment. The results of fixed effects estimation provide an empirical evidence that countries with greater share of renewable energy promote energy storage. Drawing from the empirical results and experience from Singapore, this paper provides evidence-based policy recommendations on integration of energy storage with renewable energy. The results will be useful for policy-makers from countries with a growing share of renewable energy in total electricity, by providing lessons from countries which experienced problems with high share of renewable energy and started to promote energy storage alongside with renewable energy.

## Methods

Data on storage and intermittent energy are collected from four sources, i.e. International Energy Agency Energy Technology RD&D Statistics, International Energy Agency Renewables Information Statistics, International Energy Agency World Energy Statistics and Balances, International Energy Agency / International Renewable Energy Agency Global Renewable Energy Policies and Measures Database. All variables are across 28 countries over the period 1990-2014.

Several tests are performed to identify the suitable model for estimation. Fixed effects are identified using the Hausman test. The null-hypothesis of difference in coefficients is not systematic (random effects) in the Hausman test is rejected ($\chi^2(3) = 10.19^{***}$), in a favour of fixed effects model (**Error! Reference source not found.**). We failed to reject the null that the coefficients for all years are jointly equal to zero, therefore no time fixed effects are needed in this case ($F(24, 557) = 0.88$ with $Prob > F = 0.6276$). The presence of heteroscedasticity is identified using Modified Wald test which tests for group wise heteroscedasticity in fixed effect regression model. The null hypothesis of homoscedasticity is rejected ($\chi^2(29) = 2.1\text{e} + 05^{***}$) in favour of alternative hypothesis of heteroscedasticity. The presence of heteroscedasticity is corrected using robust standard errors. The absence of serial correlation is identified using Wooldridge test for autocorrelation in panel data. The null hypothesis of no first-order autocorrelation cannot be rejected ($F(1,28) = 1.02$ with $Prob > F = 0.32$).

Using the results of the above tests, fixed effects with robust standard errors is used as the most suitable model.

$$storage = \beta_0 + \beta_1 capacity_{it-1} + \beta_2 production_{it-1} + \beta_3 policy_{it} + u_i + \varepsilon_{it},$$

where storage is a share of expenditure on RD&D of energy storage technologies in total expenditure on RD&D of energy, capacity is a share of energy capacity of intermittent energy sources in total capacity of renewable energy, production is a share of electricity generation from intermittent energy sources in total electricity generation from all energy sources, including renewable and non-renewable and policy is a binary variable, which equals one from the year when policy to promote energy storage was introduced and zero before.

## Results

Using data from 28 countries over the period 1990-2014 this paper provides an empirical evidence on the role of energy storage in renewable energy deployment. The impact of renewable energy generation on energy storage is presented in Table 1 column 2 “Fixed effect with robust standard errors”. The results of estimation using other methods fixed effect, random effect and OLS are also presented for comparison. The preliminary results of panel data estimation provide an empirical evidence renewable energy generation promoted energy storage. This could be explained by the challenges caused by intermitted energy sources. Countries with greater renewable energy share will deploy more energy storage in order to overcome challenges associated with intermittent energy sources.

Table 1 Results

| Variables | Fixed effect robust s.e. | Fixed effect | Random effect | OLS |
|---|---|---|---|---|
| Production | 0.26* | 0.26* | 0.14 | 0.11 |
| | (0.14) | (0.15) | (0.12) | (0.12) |
| Capacity | -0.02 | -0.02 | 0.04* | 0.04* |
| | (0.05) | (0.04) | (0.02) | (0.02) |
| Policy | 0.01 | 0.01 | -0.01 | -0.01** |
| | (0.01) | (0.01) | (0.01) | (0.01) |
| Constant | 0.04*** | 0.04*** | 0.04*** | 0.04*** |
| | (0.01) | (0.01) | (0.01) | (0.01) |
| Observations | 613 | 613 | 613 | 613 |
| R-squared within | 0.01 | 0.01 | 0.00 | |
| R-squared between | 0.14 | 0.14 | 0.19 | |
| R-squared overall | 0.00 | 0.00 | 0.02 | 0.02 |
| F-test (Wald $\chi^2$) | 2.16* | 2.16* | 9.25** | 5.67*** |
| Number of panels | 29 | 29 | 29 | |

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

## Conclusions

We provide an empirical evidence that a greater share of renewable energy generation associated with a greater investment in RD&D of energy storage technologies.

## References

International Energy Agency (IEA) and International Renewable Energy Agency IRENA (2017) Joint Policies and Measures database for Global Renewable Energy, Paris

International Energy Agency IEA (2017) World Energy Statistics and Balances Extended, Paris