
Presentation by Greg Upton

Gregory Upton Jr.
Center for Energy Studies
Louisiana State University

Sanya Carley
School of Public and Environmental Affairs
Indiana University
Over the past three decades, countries across the world have implemented policies to promote the growth of renewable energy generation (RE). We focus on two policies:

- **Feed-in-tariffs (FITs)** - provides a RE source a long-term guarantee to purchase electricity at a fixed price. (e.g. 30 EURO cents/kWh for 15 years).
- **Renewable portfolio standards (RPSs)** - a requirement to produce or procure a percentage of retail sales or generation from RE by a set year (e.g. 20 percent Re by 2020).
This paper tests for the impact of FITs and RPSs on four outcomes of interest:

- Renewable energy generation
- Emissions
- Aggregate price levels
- Electricity demand
We might expect three potential channels through which a country might comply with an RPS:

- RPS $\Rightarrow \uparrow$ RE in country (likely most obvious)
- RPS $\Rightarrow$ purchase RECs from other countries $\Rightarrow$ no change RE within country
- RPS $\Rightarrow \downarrow$ fossil fuel generation OR $\downarrow$ electricity demand
  - Depends on whether the RPS is based on a share of generation or demand.
Hypotheses

RPS

RPSs might lead to decreases in emissions through three channels.

- **RPS** \(\Rightarrow\) ↑ renewable generation \(\Rightarrow\) ↓ emissions
- **RPS** \(\Rightarrow\) ↑ electricity price \(\Rightarrow\) ↓ electricity demand \(\Rightarrow\) ↓ emissions
- **RPS** \(\Rightarrow\) import fossil generation \(\Rightarrow\) ↓ emissions within country
  - Through this channel, the country might decrease emissions within the country, but not necessarily decrease its carbon footprint.
The impacts of FITs on markets is somewhat more straightforward:

- **FIT** $\Rightarrow \uparrow$ RE in country (likely most obvious) $\Rightarrow$ substitute away from fossil generation $\Rightarrow \downarrow$ emissions
  - But also potentially offsetting effect!
  - **FIT** $\Rightarrow \uparrow$ RE in country $\Rightarrow$ heat rate loss in fossil generation $\Rightarrow \uparrow$ emissions
- **FIT** $\Rightarrow \uparrow$ electricity price $\Rightarrow \downarrow$ electricity demand $\Rightarrow \downarrow$ emissions
Empirical Specification

DD Specification

Equation (1) illustrates the commonly used DD estimation strategy that will be used to test for the impact of FIT and RPSs on country electricity markets.

\[ Y_{ct} = \alpha + \delta(S_{REP} \times REP_{ct}) + \gamma_1 D_c + \gamma_2 D_t + \varepsilon_{ct} \]  

(1)

- Where \( Y_{ct} \) is the outcome of interest in country \( c \) in year \( t \).
- \( S_{REP} \) is an indicator variable corresponding to the countries treated with the respective policy and is zero for the control countries.
- \( REP_{ct} \) is an indicator variable that indicates the time periods after the REP was implemented for a particular country.
- \( D_c \) and \( D_t \) are country and year fixed effects that are included in all regressions.
But we are concerned about non-random adoption.

- Country becomes concerned with climate change ⇒ FIT or RPS
- But simultaneously, the country invests in EE, allows regulators to approve more expensive RE, consumers change behavior, etc.

Therefore, we will try and mitigate some of this concern through using synthetic control groups. Comparisons of SC results and baseline results might provide insight into the potential importance of selection bias.
Empirical Specification

Synthetic Controls

In order to create a synthetic control, choose \( W^* \) that minimizes the following:

\[
\sqrt{(X_1 - X_0 W)'V(X_1 - X_0 W)}
\]  

(2)

- \( X_1 \) is a vector of pre-intervention characteristics for the exposed regions (or treatment group).
- \( X_0 \) is a vector of pre-intervention characteristics of the non-exposed regions (or control group).
- \( W \) is a \((J \times 1)\) vector or positive weights that sum to one.
- \( V \) is some \((k \times k)\) symmetric and positive semidefinite matrix.
  - We choose \( V \) such that the mean squared prediction error of the outcome variable is minimized for the pre intervention periods (see Abadie and Gardeazabel (2003) Appendix for Details).

In this context, we create a synthetic country that is most similar along: GDP, population, share urban, and ICRG Corruption index.
All Renewable Energy - Percent of Production
Comparison of FIT and Control Countries

Year

Percent of Production
60% 50% 40% 30% 20%

FIT
Baseline Controls
SC
Non-Hydro Renewable Energy - Percent of Production

Comparison of FIT and Control Countries

Percent of Production

Year

FIT
Baseline Controls
SC
Non-Hydro Renewable Energy Generation

Comparison of FIT and Control Countries

- Baseline Controls
- FIT
- SC

kWh/Person

Year

All Renewable Energy - Percent of Production
Comparison of RPS and Control Countries

- RPS
- Baseline Controls
- SC

Year:
- 1990
- 1995
- 2000
- 2005
- 2010

Percent of Production:
- 60%
- 50%
- 40%
- 30%
- 20%
Non-Hydro Renewable Energy - Percent of Production

Comparison of RPS and Control Countries

Percent of Production

Year

RPS
Baseline Controls
SC
Non-Hydro Renewable Energy Generation

Comparison of RPS and Control Countries

Baseline Controls
RPS
SC

kWh/Person

Year

0 200 400 600 800 1000
CO2 Emissions
Comparison of FIT and Control Countries

FIT
Baseline Controls
SC
CO2 Emissions
Comparison of RPS and Control Countries

kt/CO2/Person


RPS
Baseline Controls
SC
Greenhouse Gas Emissions
Comparison of RPS and Control Countries

kt/CO2/Person

year


RPS
Baseline Controls
SC
Comparison of FIT and Control Countries

Price Level

FIT
Baseline Controls
SC

Year

1990
1995
2000
2005
2010
Comparison of RPS and Control Countries

Price Level

Year

RPS
Baseline Controls
SC
Electricity Consumption Per Person
Comparison of FIT and Control Countries

- FIT
- Baseline Controls
- SC

kWh per Capita

year


FIT and RPS  November 14, 2017
### Table 3: Impact of FIT

<table>
<thead>
<tr>
<th></th>
<th>Renewable Energy Generation</th>
<th>Emissions</th>
<th>Prices</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All RE Share</td>
<td>Non-Hydro RE Share</td>
<td>Ln(Non-Hydro Re/Pop)</td>
<td>ln(GHG/Pop)</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td><strong>Treatment Effect</strong></td>
<td>2.460***</td>
<td>2.460***</td>
<td>0.156</td>
<td>-0.0192</td>
</tr>
<tr>
<td></td>
<td>(0.898)</td>
<td>(0.898)</td>
<td>(0.710)</td>
<td>(0.0521)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>2,044</td>
<td>2,044</td>
<td>2,044</td>
<td>2,044</td>
</tr>
</tbody>
</table>

**Baseline Differences in Differences**

**Synthetic Control Specification**

<table>
<thead>
<tr>
<th></th>
<th>Renewable Energy Generation</th>
<th>Emissions</th>
<th>Prices</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All RE Share</td>
<td>Non-Hydro RE Share</td>
<td>Ln(Non-Hydro Re/Pop)</td>
<td>ln(GHG/Pop)</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td><strong>Treatment Effect</strong></td>
<td>2.333**</td>
<td>0.569</td>
<td>0.800***</td>
<td>0.108**</td>
</tr>
<tr>
<td></td>
<td>(1.094)</td>
<td>(0.766)</td>
<td>(0.194)</td>
<td>(0.0436)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>1,056</td>
<td>1,056</td>
<td>1,056</td>
<td>1,056</td>
</tr>
</tbody>
</table>

**Placebo Test**

<table>
<thead>
<tr>
<th></th>
<th>Renewable Energy Generation</th>
<th>Emissions</th>
<th>Prices</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All RE Share</td>
<td>Non-Hydro RE Share</td>
<td>Ln(Non-Hydro Re/Pop)</td>
<td>ln(GHG/Pop)</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td><strong>Treatment Effect</strong></td>
<td>0.582</td>
<td>0.101</td>
<td>0.0352</td>
<td>-0.00765</td>
</tr>
<tr>
<td></td>
<td>(1.681)</td>
<td>(0.548)</td>
<td>(0.146)</td>
<td>(0.0151)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>2,288</td>
<td>2,288</td>
<td>2,288</td>
<td>2,288</td>
</tr>
</tbody>
</table>

Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Standard errors clustered at country level. Country and year fixed effects include in all regressions. Baseline differences-in-differences specification uses all countries with neither policy adopted as control group. Synthetic control specification utilizes synthetic countries as controls. GHG emissions in kt/CO2 equivalent per million people. CO2 emissions also in kt per million people.
### Table 4: Impact of RPS

<table>
<thead>
<tr>
<th></th>
<th>Renewable Energy Generation</th>
<th>Emissions</th>
<th>Prices</th>
<th>Demand</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All RE Share</td>
<td>Non-Hydro RE Share</td>
<td>Ln(Non-Hydro Re/Pop)</td>
<td>ln(GHG/Pop)</td>
<td>Ln(CO2/Pop)</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>Baseline Differences in Differences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Effect</td>
<td>3.392*</td>
<td>2.124</td>
<td>0.917</td>
<td>-0.0192</td>
<td>-0.108**</td>
</tr>
<tr>
<td>(1.954)</td>
<td>(1.279)</td>
<td>(0.932)</td>
<td>(0.0521)</td>
<td>(0.0446)</td>
<td>(0.0276)</td>
</tr>
<tr>
<td>Observations</td>
<td>2.044</td>
<td>2.044</td>
<td>2.044</td>
<td>2.044</td>
<td>2.044</td>
</tr>
<tr>
<td>Synthetic Control Specification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Effect</td>
<td>2.882*</td>
<td>0.724</td>
<td>0.893***</td>
<td>0.0717</td>
<td>-0.0121</td>
</tr>
<tr>
<td>(1.484)</td>
<td>(1.142)</td>
<td>(0.196)</td>
<td>(0.0490)</td>
<td>(0.0434)</td>
<td>(0.0282)</td>
</tr>
<tr>
<td>Observations</td>
<td>792</td>
<td>792</td>
<td>792</td>
<td>792</td>
<td>792</td>
</tr>
<tr>
<td>Placebo Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Effect</td>
<td>1.833</td>
<td>0.259</td>
<td>0.110</td>
<td>0.0131</td>
<td>0.00158</td>
</tr>
<tr>
<td>(1.533)</td>
<td>(0.572)</td>
<td>(0.108)</td>
<td>(0.0675)</td>
<td>(0.0366)</td>
<td>(0.0183)</td>
</tr>
<tr>
<td>Observations</td>
<td>3.080</td>
<td>3.080</td>
<td>3.080</td>
<td>3.080</td>
<td>3.080</td>
</tr>
</tbody>
</table>

Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Standard errors clustered at country level. Country and year fixed effects include in all regressions. Baseline differences-in-differences specification uses all countries with neither policy adopted as control group. Synthetic control specification utilizes synthetic countries as controls. GHG emissions in kt/CO2 equivalent per million people. CO2 emissions also in kt per million people.
Conclusions

- We find evidence that RE has increased in both RPS and FIT countries relative to SCs.
- Point estimates for RPSs are larger than FITs.
- We find no evidence of emissions reduction associated with either policy.
- We do not find evidence that either policy is associated with aggregate price level increases.
- FIT countries have seen increases in electricity consumption per capita relative to SCs, while RPS countries have not.
The End

Thank You!