Regional redistribution effects of public support to renewable energy

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Introduction

Debate on decentralization of regional energy policies

- Hard to coordinate action against climate change even within countries when energy policies are decentralized (e.g. regional energy plans in Italy)
- Evidence: more coordination among regions and countries is needed (Sapio 2015, Gianfreda et al. 2016)
- Heterogeneity in locations and environmental preferences, so little reason for uniform support means (Lin 2016)
- Redistributive reasons, which if disrupted can foster opposition to RE support and votes to ”pro-carbon” parties in some regions

The *green energy budget*

The *green energy budget* in Italy

- Each user contributes based on energy consumption (A3 component in the energy bill)
- The budget is used by GSE (Gestore Servizi Energetici) to subsidize renewables

Aggregating among users in the same region (or zone), one can compute the *net contribution* of each region/zone to the green energy budget

North-South patterns

- Uniform support rules, yet regional differences in
  - Wind, solar, geothermal power potentials
  - Environmental preferences / attitudes
  - Per capita incomes
  - Industrial density ($\Rightarrow$ industrial vs. domestic users)

- A stylized North-South pattern

North High income and industrial density; low RE potential

$\Rightarrow$ Larger net contribution to the green energy budget?

South Low income and industrial density; high RE potential

Changes

- Recent changes
  - Sardinian cable since 2011, Sicilian cable since May 2016
  - From fixed feed-in tariffs and green certificates, to incentives linked with electricity market prices (MD 6 July 2012; MD 23 June 2016)
  - Reducing the progressivity of the A3 component (Energy Authority deliberation 582/2015/R/eel)
- Forthcoming (?) changes
  - Constitutional reform (referendum on Dec 4): centralized energy policies

Outline of the talk

1. A simple model for the *green energy budget*
2. How zonal net contributions to the green energy budget change after...
   a. Switch to electricity price-based incentives
   b. New interconnections
   c. [future research] Removing progressivity of contributions
   d. [future research] Centralization of regional energy policies

Modeling electricity demand and supply

- z: market zone
- D_z: zonal demand (short-run price-inelastic, exogenous)
- R_z: zonal renewables (short-run price-inelastic, exogenous)
- S_z: zonal supply s.t.

$$S_z = R_z + \sigma(p_z)$$

with $\sigma'(.) > 0$

Zonal prices

- If each market zone clears independently (i.e. no transmission capacity is available), $S_z = D_z$, hence

$$p_z = \sigma_z^{-1}(D_z - R_z) \equiv p_z(D_z - R_z)$$

- If zones are fully integrated, $S_n + S_s = D_n + D_s$, hence

$$p_z = p(D_n + D_s - R_n - R_s)$$

Green incentives

I_z: total incentives cashed in by renewable energy producers in zone z

- Fixed regime: fixed incentives π per unit of RE, hence

$$I_z = \pi R_z$$

- Market-based regime: $\max\{0, \underline{\pi} - p_z\}$ per unit of RE, hence

$$I_z = (\underline{pi} - p_z)R_z = (\underline{pi} - p_z(D_z - R_z))R_z$$

if $p_z < \underline{\pi}$

User financing of green incentives

Incentives financed by final (industrial and household) users through the so-called A3 component, whose zonal aggregate reads:

$$A3_z = \alpha_z(D_z)$$

with

- $\alpha_z(0) > 0$ (fixed part)
- $\alpha_z' > 0$

(ignoring green certificates, feed-in premia, and vintage stratification)

Net zonal contributions - with zonal separation

- Fixed regime:

$$A3_z - I_z = \alpha_z(D_z) - \pi R_z$$

  - Positive effect of demand, negative effect of RE $\Rightarrow$ Zones with higher energy use and less renewables contributed more

- Market-based regime:

$$A3_z - I_z = \alpha_z(D_z) - \max\{0, \underline{\pi} - p_z(D_z - R_z)\}R_z$$

  - Zones with higher demand: larger gross contribution, yet also receiving less incentives because of a higher zonal price.
  - Zones with higher RE: receiving more subsidies, and even more are implied by downward pressure on the zonal price (merit order effect).

Re-shuffling the deck of cards

Market-based regime; effects if $p_z < \underline{\pi}$

- Net zonal contribution decreasing with RE output:

$$\frac{\partial(A3_z - I_z)}{\partial R_z} = \underbrace{-(\underline{\pi} - p_z)}_{-} \underbrace{-p_z' R_z}_{-}$$

- Net zonal contribution increasing with demand:

$$\frac{\partial(A3_z - I_z)}{\partial D_z} = \underbrace{\alpha_z'}_{+} + \underbrace{p_z'}_{+} R_z$$

Net zonal contributions - with full integration

- Suppose North and South are fully integrated. Hence, electricity price in zone $z \in \{n, s\}$ is now

$$p = p(D_n + D_s - R_n - R_s)$$

and $p = p_n = p_s$ since there is no congestion.

- The formula for $A3_z$ is unchanged, but now

$$A3_z - I_z = \alpha_z(D_z) - \max\{0, \underline{\pi} - p\}R_z$$

i.e. net revenues for zone z depend on both its own and the neighbor's electricity demand and renewables generation.

Pecuniary externalities

A marginal increase in Southern renewables yields

$$\frac{\partial(A3_s - I_s)}{\partial R_s} = -(\underline{\pi} - p) - p' R_s < 0$$

as before, and a pecuniary externality:

$$\frac{\partial(A3_n - I_n)}{\partial R_s} = -p' R_n < 0$$

Notice:

$$-(\underline{\pi} - p) - p' R_s < -p' R_n$$

also because $R_s > R_n$

Relative burden shifting

- By generating more RE, zone *s* depresses the common electricity price, therefore widening the gap between the price and the minimum tariff
  - Increasing its own as well as its neighbor's incentive.
- Yet, the incentive received by zone *s* increases more because its RE output has grown.
  - And the gross zonal contributions $A3_s$, $A3_n$ are given
- Overall, the North ends up with a proportionally higher net contribution to the national green energy budget

Net zonal contributions - with congestion

- θ: probability of North-South congestion:

$$\theta = \theta(D_n, D_s, R_n, R_s)$$

- If renewables from the South relieve congestion ($\frac{\partial \theta}{\partial R_s} < 0$), the full integration result holds (relative burden shifting)
  - Example: Sicily (see results in Sapio 2015)
- If instead renewables from the South cause congestion ($\frac{\partial \theta}{\partial R_s} > 0$), the effect is ambiguous

Balanced budget and the unit cost of RE support

Suppose the A3 component is defined as $A3_{zt} = \alpha D_{zt}$. Which α would ensure a balanced green budget on a given time horizon T?

- Aggregate I_{zt} and $A3_{zt}$ across zones and periods and equate to 0:

$$\sum_{t=1}^{T}\sum_{z}(A3_{zt} - I_{zt}) =$$

$$= \alpha \sum_{t=1}^{T}\sum_{z} D_{zt} - \sum_{t=1}^{T}\sum_{z} \max\{0, \underline{\pi} - p_{zt}\}R_{zt} = 0$$

- Hence, the A3 parameter that guarantees a balanced green budget reads

$$\alpha^{*} = \frac{\sum_{t=1}^{T}\sum_{z} \max\{0, \underline{\pi} - p_{zt}\}R_{zt}}{\sum_{t=1}^{T}\sum_{z} D_{zt}}$$

A hidden cost of new interconnections?

- Keeping the green budget balanced, when RE increase in a zone, requires a higher α parameter:

$$\frac{\partial \alpha^*}{\partial R_{st}} = \frac{\underline{\pi} - p_{st} + \sum_z p'_{zt} R_{zt}}{\sum_{t=1}^{T} \sum_z D_{zt}} \geq 0$$

  for t such that $p_{zt} < \underline{\pi}$

- Does market integration magnify α^*?
  - Market integration is one factor weakening the merit order effect p'_{zt} (see e.g. Ketterer 2014)
  - Without market integration (zonal separation), the numerator would be only $\underline{\pi} - p_{st} + p'_{st} R_{st}$, but p'_{st} would be higher
  - Thus, not clear whether market integration is a hidden cost

Summary

1. In the market-based regime on RE incentives, new RE installations in a (separate) zone imply a lower net contribution for two reasons
   a. More RE units are generated, regardless of the zonal price (below the minimum tariff)
   b. The merit order effect widens the gap between the zonal market price and the minimum tariff
2. New interconnections allow for relative burden-shifting from Southern to Northern regions
   - Possible burden-shifting among Southern regions if renewables alleviate congestion (e.g. from Sicily)
3. Under market integration, a balanced green energy budget balanced may imply higher unit costs of support
   - Depending on whether integration mitigates the merit order effect, i.e. on the fossil fuel technology mix and prices