Competition and Regulation with Smart Grids

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Background - The authority mission

- The Italian Authority for Regulation of energy, networks and environment (ARERA) has included within its programming the promotion of Smart Grid (SG) investment with the intention to improve the service quality to users and to facilitate **the integration of renewable plants**.
- The authority emphasizes that the introduction of such investment is in the hands of the DSO (Distribution System Operator) that without a specific incentive scheme will always prefer traditional rather than smart investment.
- This is why the authority is thinking about introducing **"output based" incentive schemes**, where the DSO is rewarded based on some observable outputs such as: the power flow and the state of resources in the network, the nominal generated power distributed from non-programmable renewable resources within the primary substation where the SG investment was introduced, etc.

Research purposes

The paper is divided in two parts:

1. In the first part we proposed a stylized model where we represent an energy market and we aim at studying how a SG investment might affect the producers' optimal choices (with a focus on photovoltaic producers). At the same time we also test how the composition of the local market may affect the optimal investment in SG.
2. In the second part simulate our model using real data on photovoltaic producers and plants.

In both the theoretical and empirical study, our intention is to show which different effect may have traditional "input based" compared to "output based" incentive schemes

Definition

Energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand accordingly (European Commission).

SG investments are fundamental to allow operators to assess grid stability, advanced digital meters that give consumers better information and automatically report outages, relays that sense and recover from faults in the substation automatically, automated feeder switches that re-route power around problems, and batteries that store excess energy and make it available later to the grid to meet customer demand (U.S. department of energy).

In the paper we consider SG as investment able to reduce (demand) uncertainty that differ from traditional investment that aim at reducing the operating cost

The setting

We model the SG problem as a Stackelberg leader-follower oligopoly: the DSO moves first by determining the level of investment in smart grid; then, downstream firms react to DSO move by choosing whether to entry and the production capacity.

- The modelling of uncertainty:

$$\tilde{p_z} = a - b\tilde{Q_z}$$
$$\tilde{Q_z} = Q_z + \theta\epsilon$$
$$\tilde{p_z} = p_z - b\theta\epsilon$$

where θ represents the weight of the random shock in terms of market equilibrium conditions (i.e., price and quantity):

$$\theta = \sqrt{\frac{1}{1+I}}$$

The payoffs

- Payoff generic risk averse producer (certainty Equivalent of a CARA utility function):

$$E(u(\tilde{\pi}_i)) = p_z(fc_i n) - K - mc_i - \frac{r_i}{2} b^2 \theta^2 (fc_i)^2$$

where:

  - p_z is the zonal price;
  - f annual production capacity for 1 kW;
  - n represents the useful life of the plant;
  - c_i is the installed capacity;
  - K is the fixed cost, while c_i is the marginal cost;
  - r_i is the coefficient of risk aversion.

- Payoff risk neutral DSO:

$$\tilde{\Pi} = T - d\tilde{Q}_z - I$$

Theoretical Results

Proposition 1

The aggregate installed capacity by photovoltaic producers increases in the investment in smart grid, I.

Proposition 2

The higher the investment in smart grid chosen by the DSO, I^*, the higher the level of the equilibrium supply of electricity, C_z^{pho}, and the higher the number of firms entering the downstream market.

Proposition 3

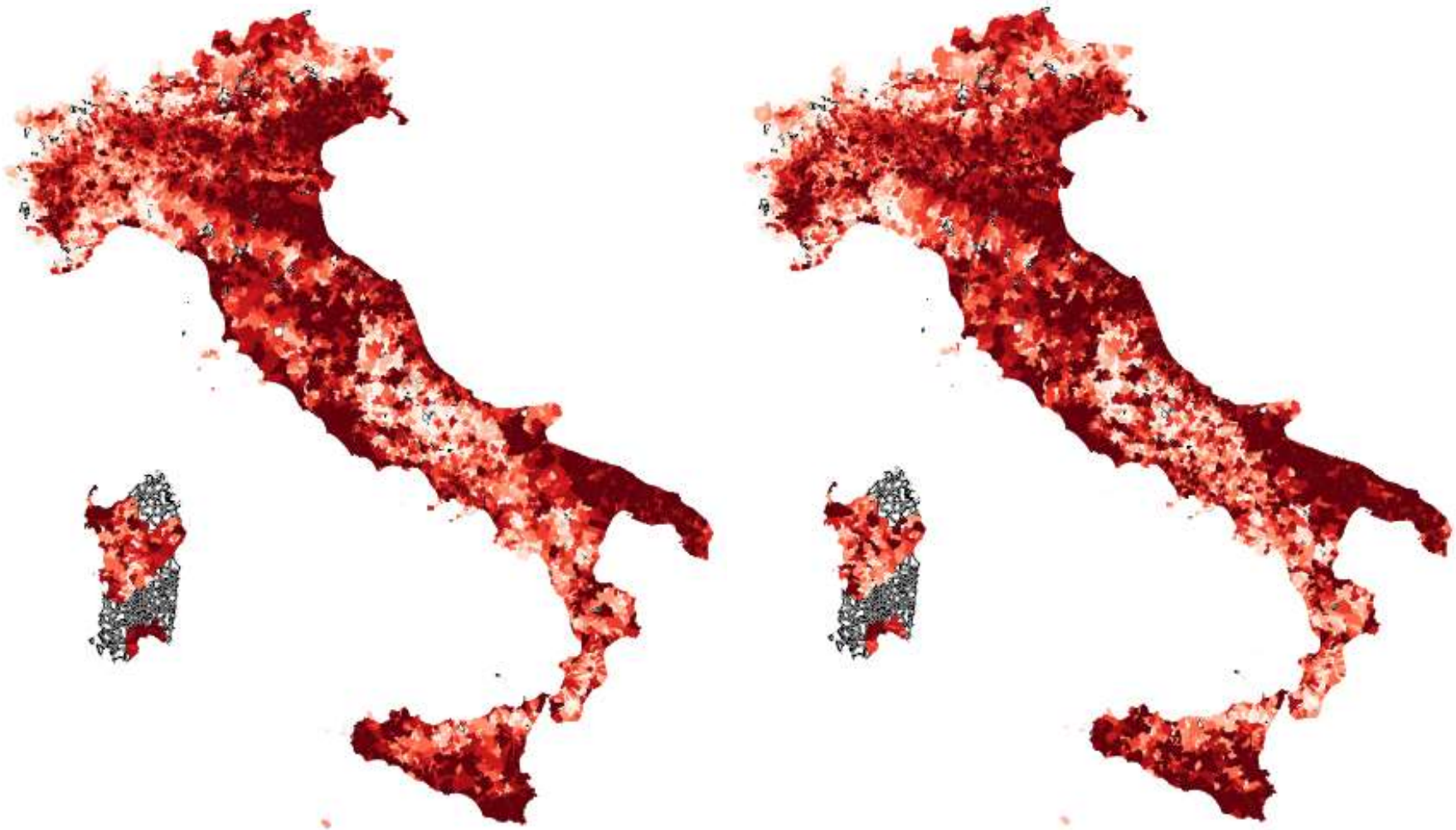
The level of smart grid investment that maximizes the total welfare is higher compared to the level of smart grid investment chosen by an independent DSO.

The data

- First, we have the population of photovoltaic plants installed in last 10 years (database Atlasole).
- Second, we have average prices SPOT market divided by zones (database GME) and the level of incentives received by each plant.
- For the marginal cost of the plant, we look at private case studies [1500 - 3500].
- the PVGIS database was used to assess the annual production capacity for 1 kW installed.
- Finally, we use ISTAT database to estimate the parameters of the demand function.

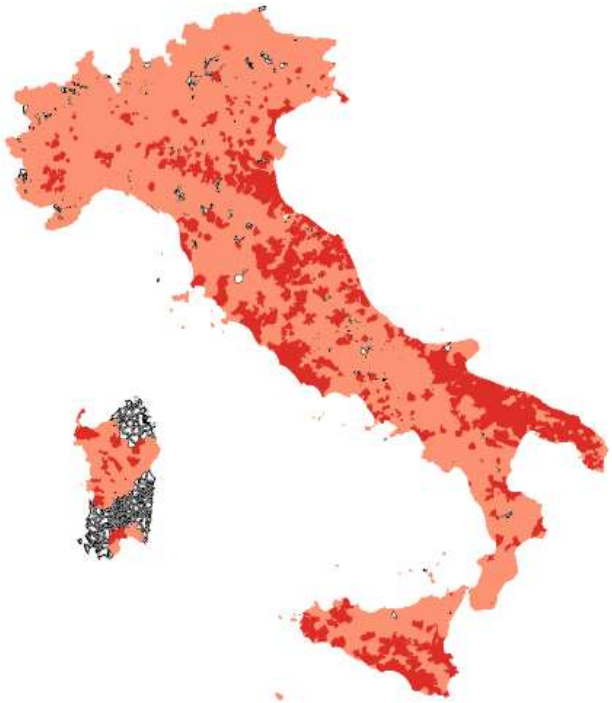
Without SG investment

Nb. of plants and Installed capacity



SG investment (First Best)

Simulated level of SG investment



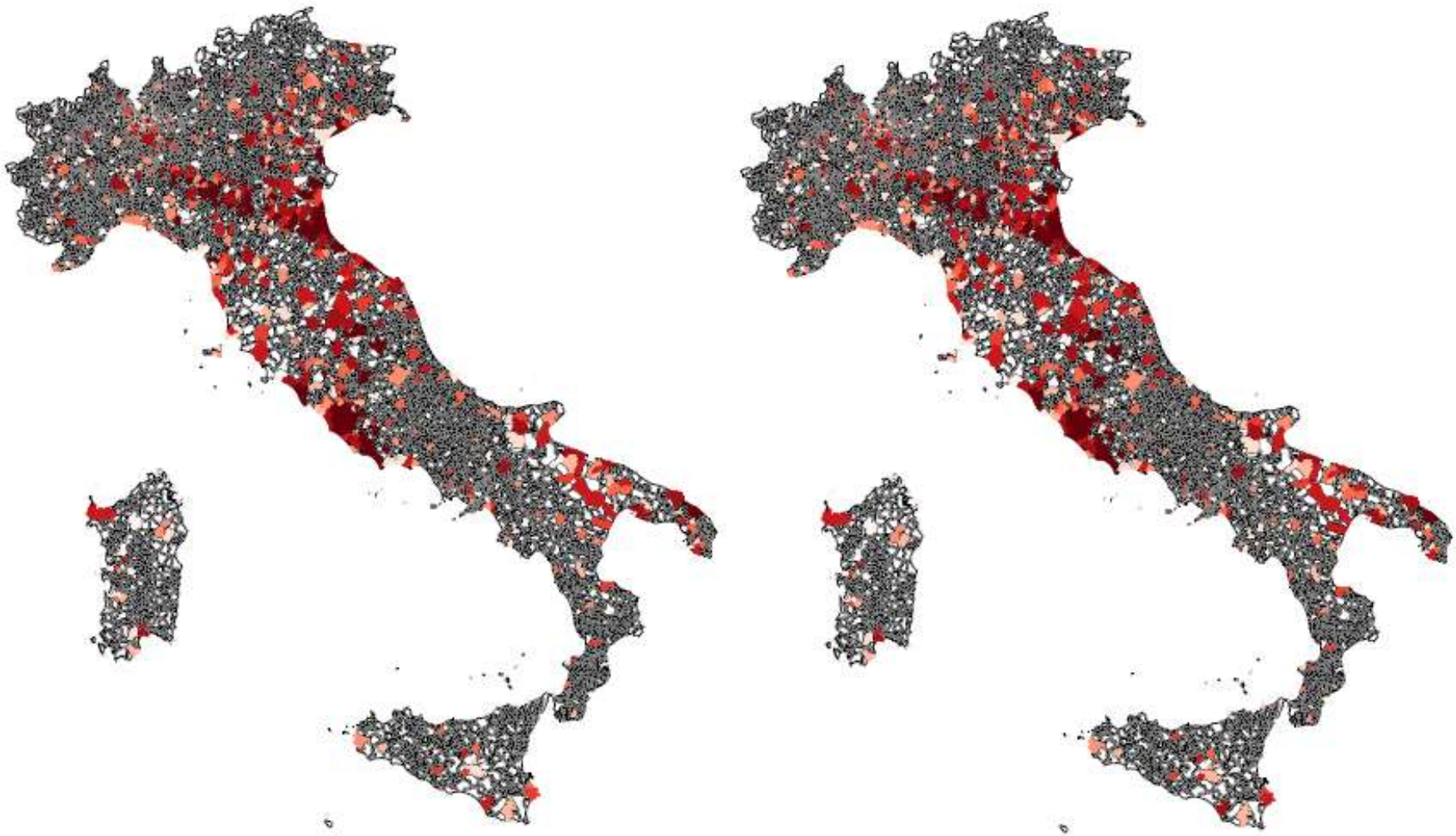
I: First Best

II: Input based regulation

III: Output based regulation

With SG investment

Nb. of new plants and Installed capacity



Conclusion

- In the paper we propose a theoretical setting and a simulation to show which can be determinants and effects of SG investment depending on local market characteristics.
- A first message of the paper is that effects of SG investment may vary a lot within territory and an optimal incentive scheme should consider these heterogeneous impacts.
- From the point of view of the regulator, we confirm that without the use of new output based incentive scheme, there are no reasons for the DSO to invest in SG.
- The final purpose of the paper is to propose different types of incentive scheme to study which one leads to final results that are closest to the First Best.

Future developments

- Improve the regulation paragraph.
- With the simulation analysis we would like to compare traditional investment to increase the capacity in the grid and then reduce operating cost with SG investment that decrease uncertainty. We would like to show different impacts of such investment within the Italian territory.
- Given that photovoltaic plants receive a large amount of subsidies in last years, we would like to compar different impacts of such incentives compared to SG investment.

Thank you

Thank you for your attention