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IMPACTS OF PROSUMERS ON DSO INVESTMENTS: UPDATING TARIFF STRUCTURES

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BACKGROUND

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Climate change concerns lead to introduction of:

- Demand-side management programs to improve **energy efficiency** measures and reduce overall energy consumption;
- Policies imposing restrictions on carbon emissions, reinforcing the exploitation of **renewable energy resources** such as wind and solar;
- Policies promoting the settlement of **distributed generation** such as Article 14/7 2003/54/EC of the EU electricity directive.

Consequently

- Higher number of distributed generation resources;
- Traditional consumers converting to **prosumers.**

PROSUMERS' IMPACTS

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Benefits

- Prosumers are **environmental friendly** and **reduce carbon emission**.
- With low penetration level of prosumers the overall **electricity demand** and therefore the need for **excess capacity construction** decreases.

Challenges

- The growing number of distributed generation specially in form of prosumers, make the **regulators** face **new challenges** (Jenkins and Pérez-Arriaga, 2016).
- Regulators should provide **incentives** for utilities to invest in the network by setting up proper tariffs.
- They impose **extra costs on DSOs**: network reinforcement costs, connection costs, network management costs.
- DG **compensation methods** such as **net metering**, as well as **electricity tariffs**, set in presence of prosumers should be revised and modified respectively.

LITERATURE REVIEW

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Compensation systems

- 3 compensation mechanisms are currently used more than others: **feed-in tariffs, net metering** and **net purchase and sale.**
- Gautier et. al (2017), Brown and Sappington (2016, a&b), EPRS (2016), Brown and Sappington (2015) and Yamamoto (2012) study, compare and highlight the downfalls of these mechanisms.

Cost allocation in tariff design process

- Ortega et al. (2008) and Sotkiewicz and Vignolo (2007) focus on **cost causality principle** but do not consider the effect of **DG penetration** and the increasing number of prosumers.
- Brown and Sappington (2016, a&b) consider transmission, distribution and management costs **(TDMs).** Neither Brown and Sappington (2016, a&b) and Gautier et. al (2017) take into account costs associated with **energy losses.**

CLOSING THE GAP

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- Several studies such as Lampropoulos et al. (2010), Quezada et al. (2006) and Cao et al. (2007) examin and show that energy losses decrease with low DG penetration levels and increase with higher levels of DG penetration (Figure 1).
- The existing literature on **compensation mechanisms** and **tariff design** do not consider cost of energy losses imposed on DSOs by higher levels of DGs and prosumers.
- Related **investments** required to reduce these effects, are not considered comprehensively in the existing literature.
- Impact of these costs on grid users' decisions and DSO's investment plans, specially under **net metering** system, should be studied.
- The effect of including these costs as a part of the grid tariff on the **prosumption rate** should be analysed.

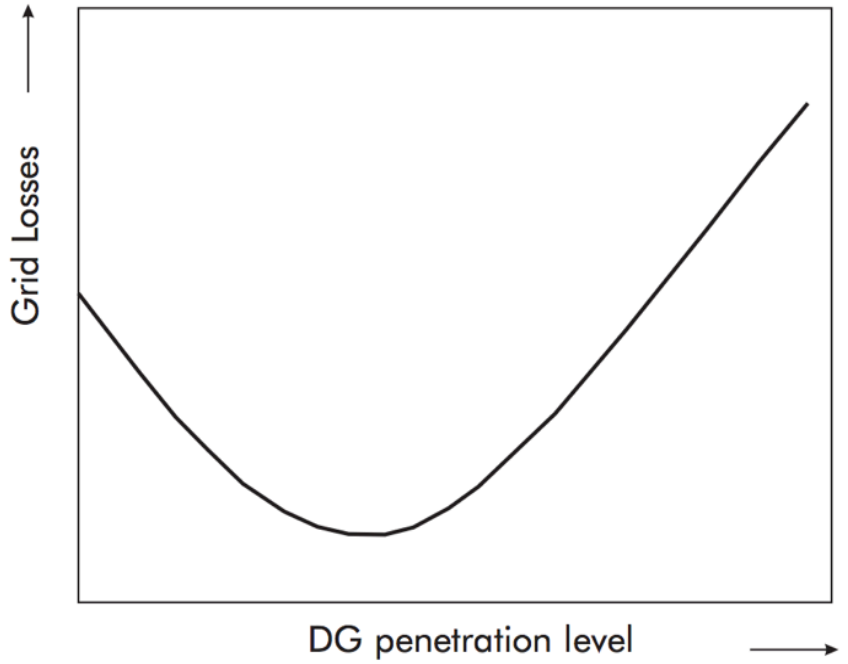

Figure 1- Grid losses related to the penetration of DG, European Copper Institute (2006)

METHODOLOGY

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- **Costs:** Identifying costs caused and incurred by various parts of the grid (consumers, prosumers, utilities).
- **Functions:** Setting up utility and profit functions of each grid user.
- **Players' Strategy:** Following a game theoretic model to identify each player's strategy under diverse scenarios.
- **Regulatory Action:** Analyzing the regulator's social welfare maximizing action.

MODEL (1/3)

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We followed a model used by Gautier et. al (2017) to define profit function of the utilities and utility functions of the consumers and prosumers under net metering scheme. Figure 2 demonstrates their suggested model of potential exchanges in the grid.

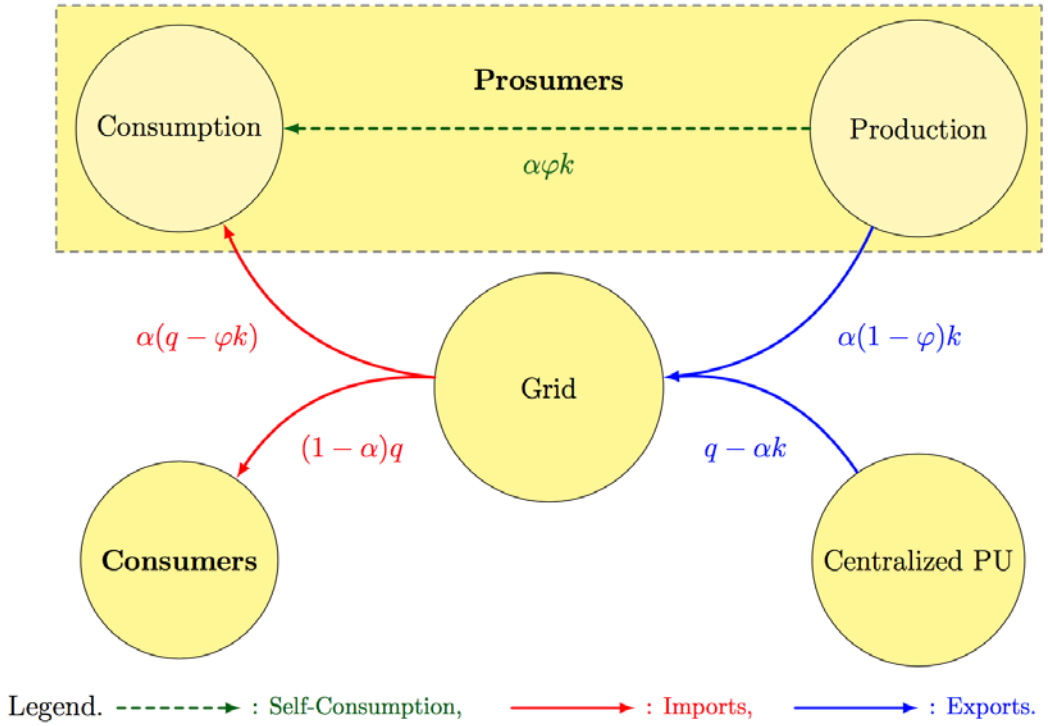

Figure 2- The exchanges between consumers, prosumers and utilities (Gautier et. al,2017).

MODEL (2/3)

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1. In our model, we considered the costs associated with increasing network losses due to higher levels of prosumers.
2. These costs can be considered as the required **future network investments** by utilities to reduce energy losses.
   - $\boldsymbol{I(k, \alpha)}$ depends on the installed DG capacity (k) and number of consumers becoming DG owners or prosumers (α).
3. Regulator's **welfare maximization problem** is as following:

$$Max \sum_{i=0}^{N} Ui \quad \textit{subject to } \Pi_{DSO} \geq 0$$

where Ui is the consumers' utility from consuming electricity and Π_{DSO} is the DSO's profit.

MODEL (3/3)

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- The **game theoretic model** used to identify the optimal strategies of the players (DSO, prosumers, consumers) is illustrated as Figure 3.
- To solve this game, a **backward induction method** is used. Starting from the last set of subgames, we analyse the optimal decisions of each of the players according to their corresponding payoffs.
- In the last stage of the game, the regulator evaluates the corresponding social welfare outputs and decides how to compensate the DSO for its investments.

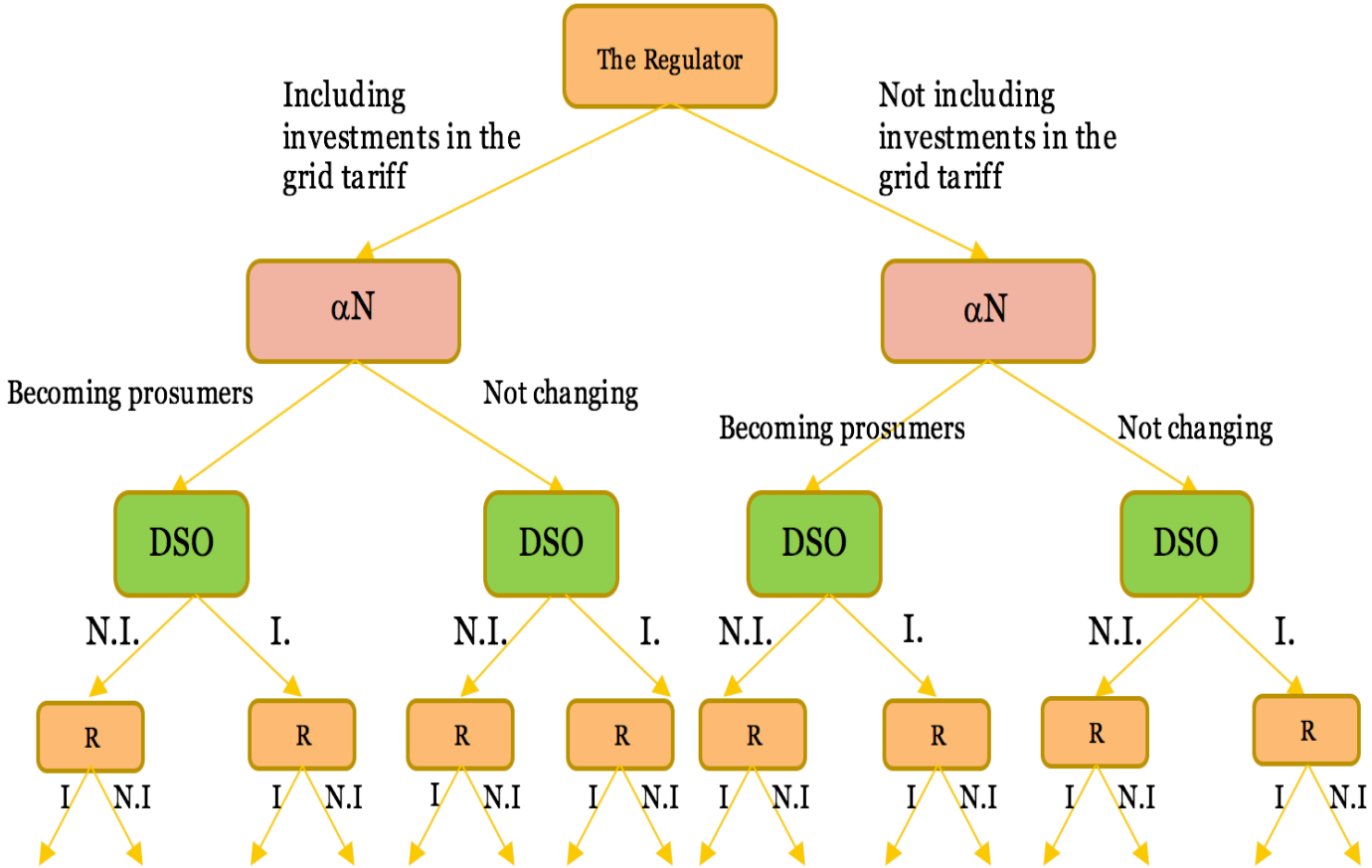

Figure 3- Repeated game

RESULTS

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- DSOs always choose not to invest in the grid to avoid **loss of revenue.**
- If DSOs invest in the network, the **grid tariff** should increase to cover these investments.
  - If the grid tariff increases, the DSO will fall further into the **death spiral effect** under **net metering** system (higher grid tariff, higher number of prosumers, lower revenues for DSO).
- It is not socially optimal to include network losses as DSOs' distribution costs while we have a **net metering system.**
- But these investments are necessary for the network to be efficient in long run …

POLICY IMPLICATION

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- To solve **lack of incentives** from utilities to invest, one option can be government intervention through subsidising the investments.
  DSOs can receive **public transfer payments** for their DG and prosumer related investments.

- Problem: the information on investment costs are not usually available to regulators. Therefore, a **menu of contracts** should be designed by the regulator to solve the problem of asymmetric information.

NEXT STEPS

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1. What type of menu of contracts should the regulator design?

2. What about net purchasing system?

REFERENCES

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Brown, D.P. and Sappington, D. (2015). 'On the Design of Distributed Generation Policies: Are Common Net Metering Policies Optimal?', University of Alberta working paper, October 2015a.

Brown, D.P. and Sappington, D. (2016a). 'Optimal policies to promote efficient distributed generation of electricity', University of Alberta working paper no. 2016-01.

Brown, David P. and Sappington, David E.M. (2016b). 'On the Role of Maximum Demand Charges in the Presence of Distributed Generation Resources', USAEE Working Paper No. 16-280. Available at SSRN: https://ssrn.com/abstract=2853620 or http://dx.doi.org/10.2139/ssrn.2853620

EPRS, 2016. European Parliamentary Research Service Briefing on Electricity 'Prosumers', November 2016. Available at: http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593518/EPRS_BRI(2016)593518_EN.pdf

Gautier, A., Jacqmin, J. and Poudou, J.C. (2016). 'The Prosumers and the Grid', Submission for the 65th annual meeting of AFSE, March 10, 2016. https://afse2016.sciencesconf.org/99255/document

Jenkins, J.D. and Pérez-Arriaga, I.J. (2016). 'Improved regulatory approaches for the remuneration of electricity distribution utilities with high penetrations of distributed energy resources', *The Energy Journa*l, vol. 37, no. 3, pp.89-118.

Rodríguez Ortega, M.P., Pérez-Arriaga, J.I., Rivier Abbad, J., Peco Gónzalez, J. (2008). 'Distribution network tariffs: a closed question?', *Energy Policy*, vol. 36, no. 5, pp.1712–1725.

Sotkiewicz, P.M. and Vignolo, J.M. (2007). 'Towards a cost causation-based tariff for distribution networks with DG', *IEEE Transactions on Power Systems*, vol. 22, no. 3, pp.1051-1060.

Yamamoto, Yoshihiro, "Pricing Electricity from Residential Photovoltaic Systems: A Com- parison of Feed-in Tariffs, Net Metering, and Net Purchase and Sale," *Solar Energy*, 86(9), September 2012, 2678-2685.

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