Research Intern Interview

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Differentially Private Electricity Market

Motivation

- Local electricity markets (LEMs) are an abundant source of individuals' data, e.g., **financial data and electricity transactions**.
- Our goal is to **unlock** the benefits of **electricity market outputs** for social good

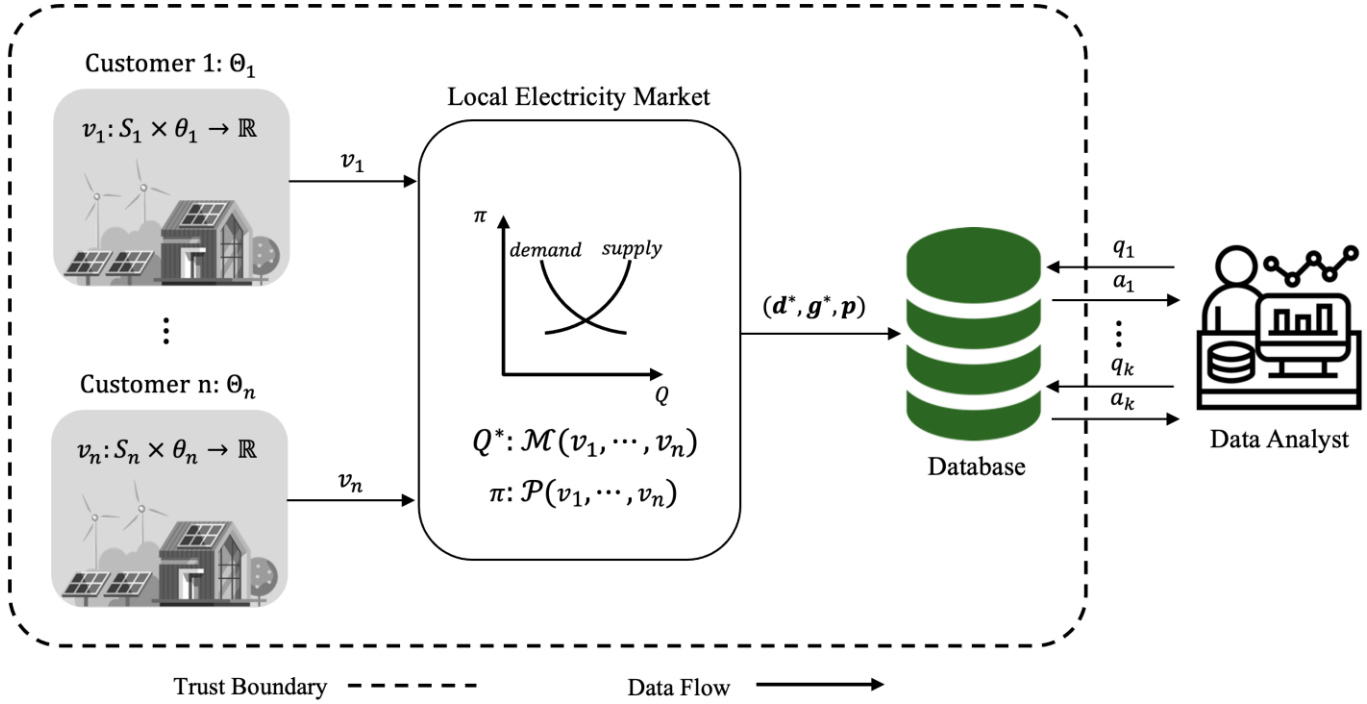
  E.g., fair pricing, more transparent and competitive energy markets, coordination between sequential markets.
- Privacy-aware market participants are worried about the leakage of their private information via statistical releases of the market outputs.

Data privacy laws, e.g., General Data Protection Regulation (GDPR) passed by the EU, requires LEMs to implement a Privacy by Design paradigm for preserving the privacy of individuals.

Problem setup

- The **main question** motivating this project is:

How to publicly release the market-clearing outputs while simultaneously maintain the privacy of market participants?



A high-level view of the problem setup

Required Properties

- Maintaining the **fidelity** of the market
    - Input perturbation mechanisms are not applicable.
- Guaranteeing the **feasibility** of the solution for the market
    - Output perturbation mechanism are not applicable.
- Maintaining the **quality** of the market clearing solution with respect to the social welfare
    - Additive noise mechanisms do not consider the quality of the mechanism output.

Our Approach: Exponential Electricity Markets

- We leverage the **exponential mechanism** to privately solve a market-clearing problem.
- It makes it possible to **explicitly include the social welfare** in the privacy mechanism and privately select from a range of arbitrary solutions.

Exponential (D, $\mathcal{R}$, q: $\mathcal{X}^n \rightarrow \mathcal{R}$, ε):

1. Let $\Delta =$ GS (q).
2. Output $r \in \mathcal{R}$ with probability proportional to:

$$GS(q) = \max_{r \in \mathcal{R},\, x \sim x' \in \mathcal{X}^n} \|q(x,r) - q(x',r)\|_1$$

$$\Pr[r] = \frac{\exp\left(\frac{\varepsilon . q(D,r)}{2\Delta}\right)}{\sum_{r' \in \mathcal{R}} \exp\left(\frac{\varepsilon . q(D,r')}{2\Delta}\right)} \longrightarrow \text{Normalizing factor}$$

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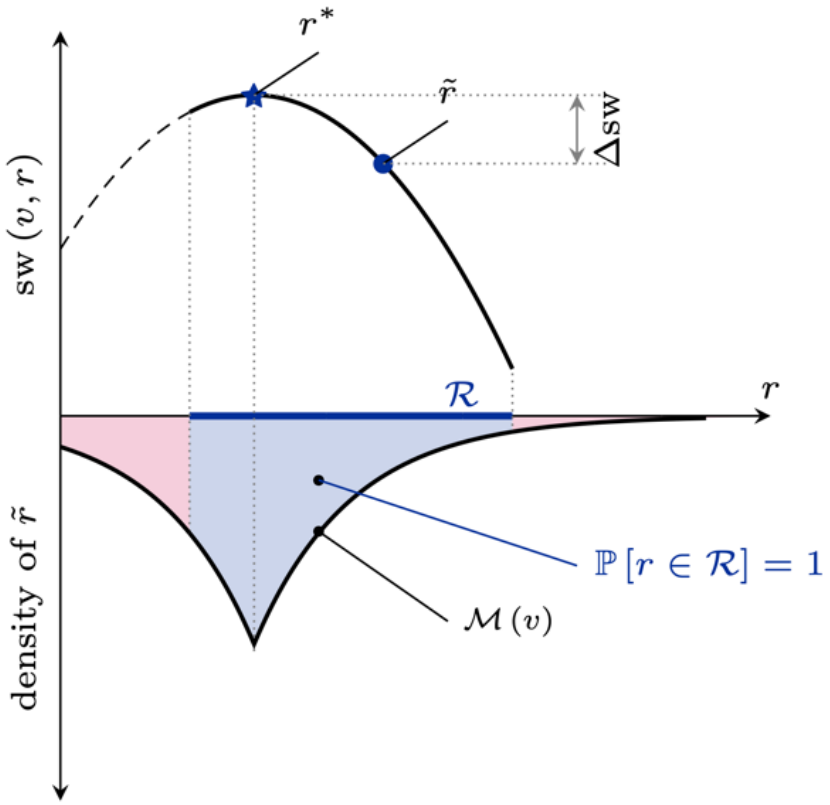
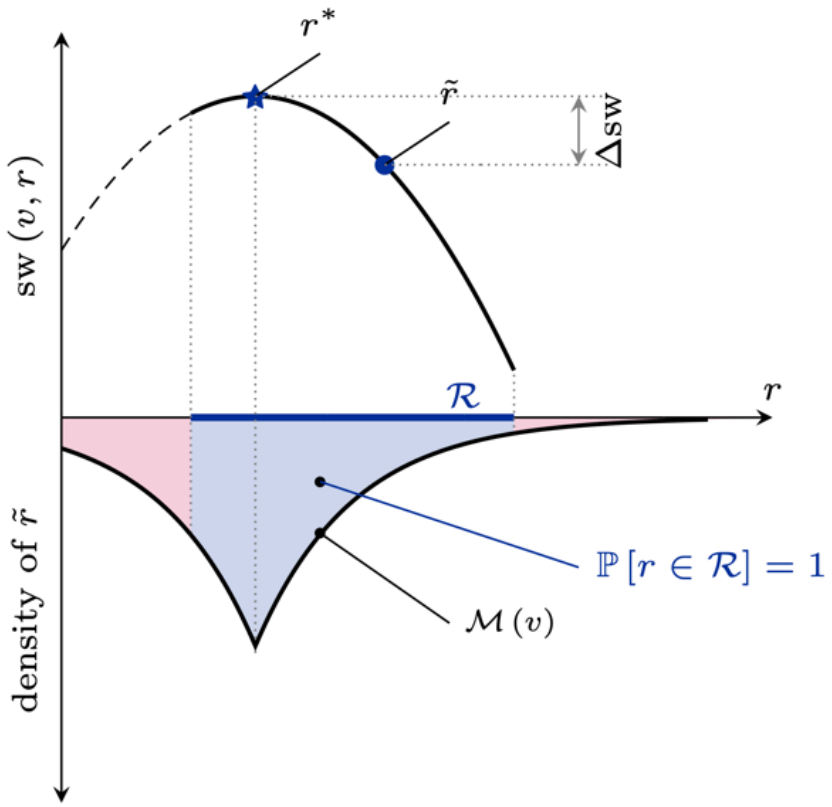


A high-level view of the proposed market-clearing mechanism.

Performance Guarantee

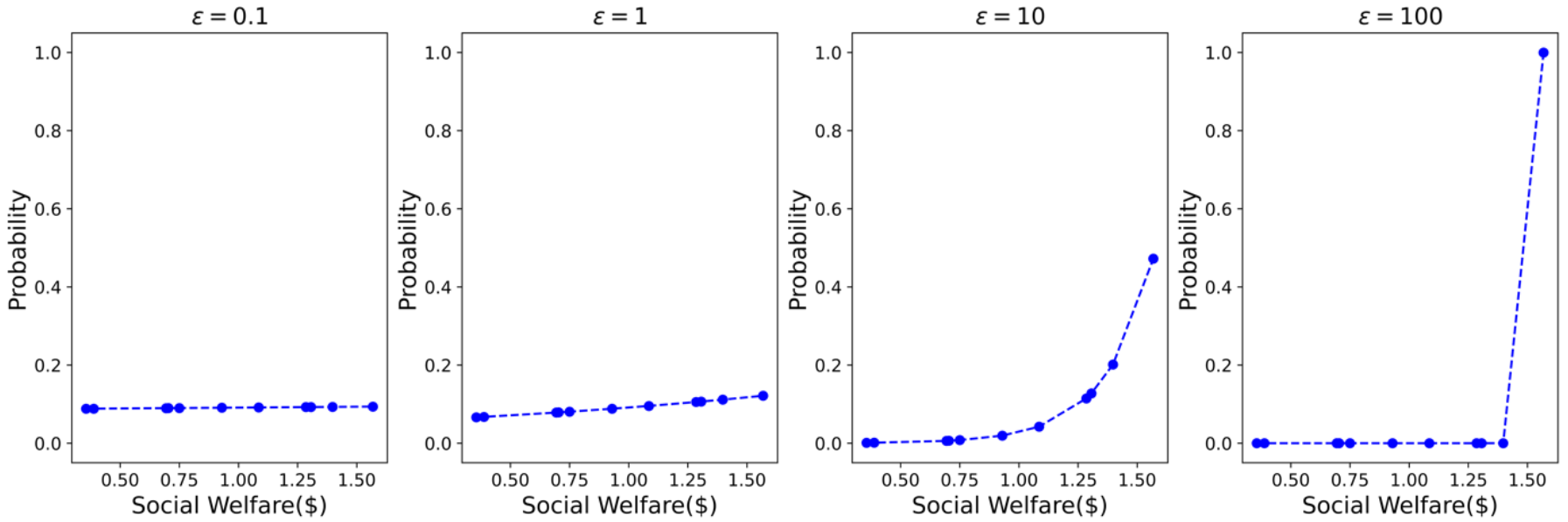
- With probability at least $1-\delta$, the gap between the optimal solution and the private solution holds in the following inequality:

$$\Delta \mathrm{sw}(v, r) \leq \frac{2}{\epsilon} \ln\left(\frac{|\mathcal{R}|}{\delta}\right)$$



Results

- Probability distribution over the possible social welfares.



Higher privacy loss parameter ϵ leads to more discrimination between the outputs of the market-clearing problem.

Thank You