Potsdam Institute for Climate Impact Research

Real-Time Electricity Pricing with Heterogeneous Consumers and Variable Renewable Energy Supply: Welfare and Distributional Effects

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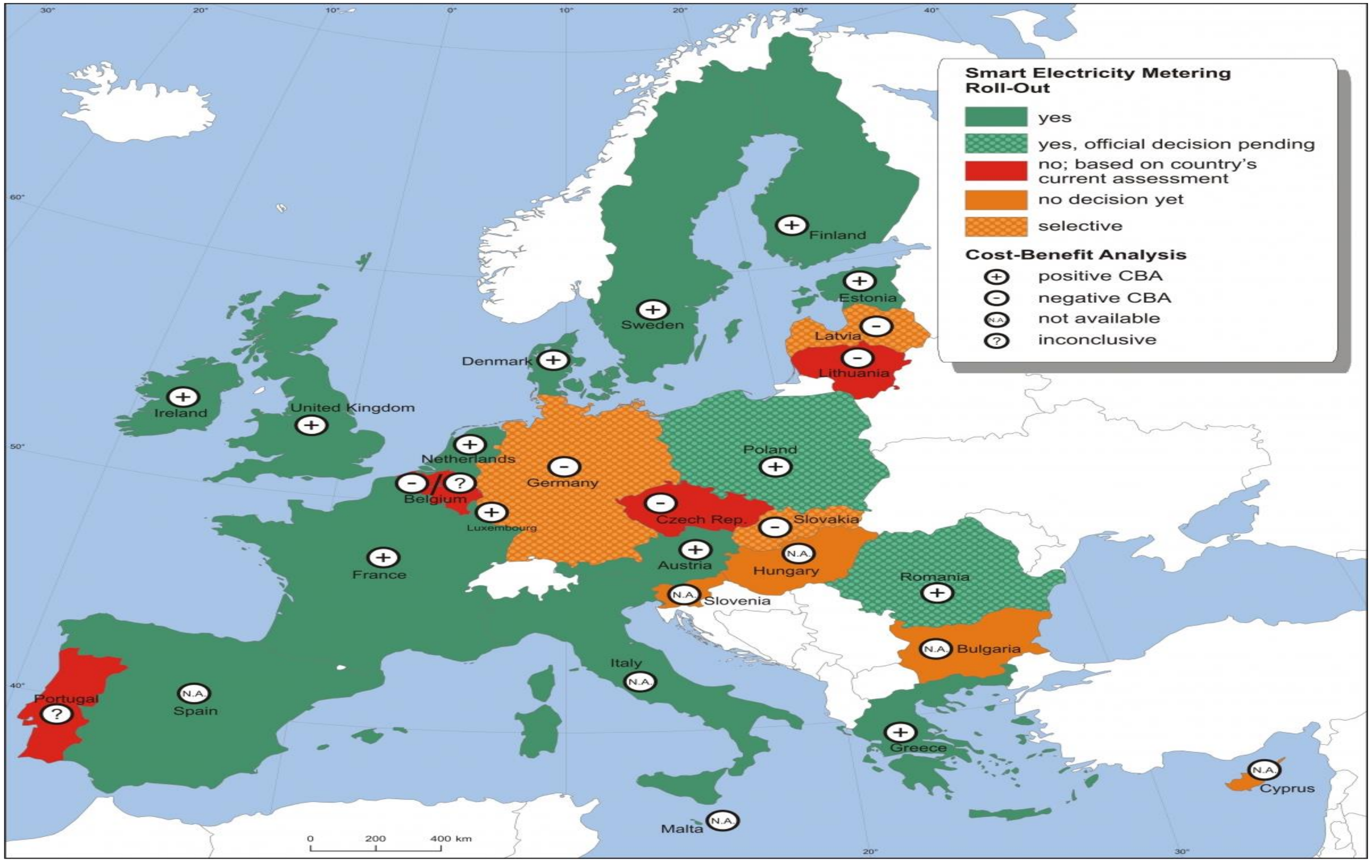
Motivation

a) vRES entry causes growing need/benefit of price responsive demand.

b) Large-scale smart meter roll-out in EU power systems.

c) How to catch most of potential welfare gains from real-time pricing?

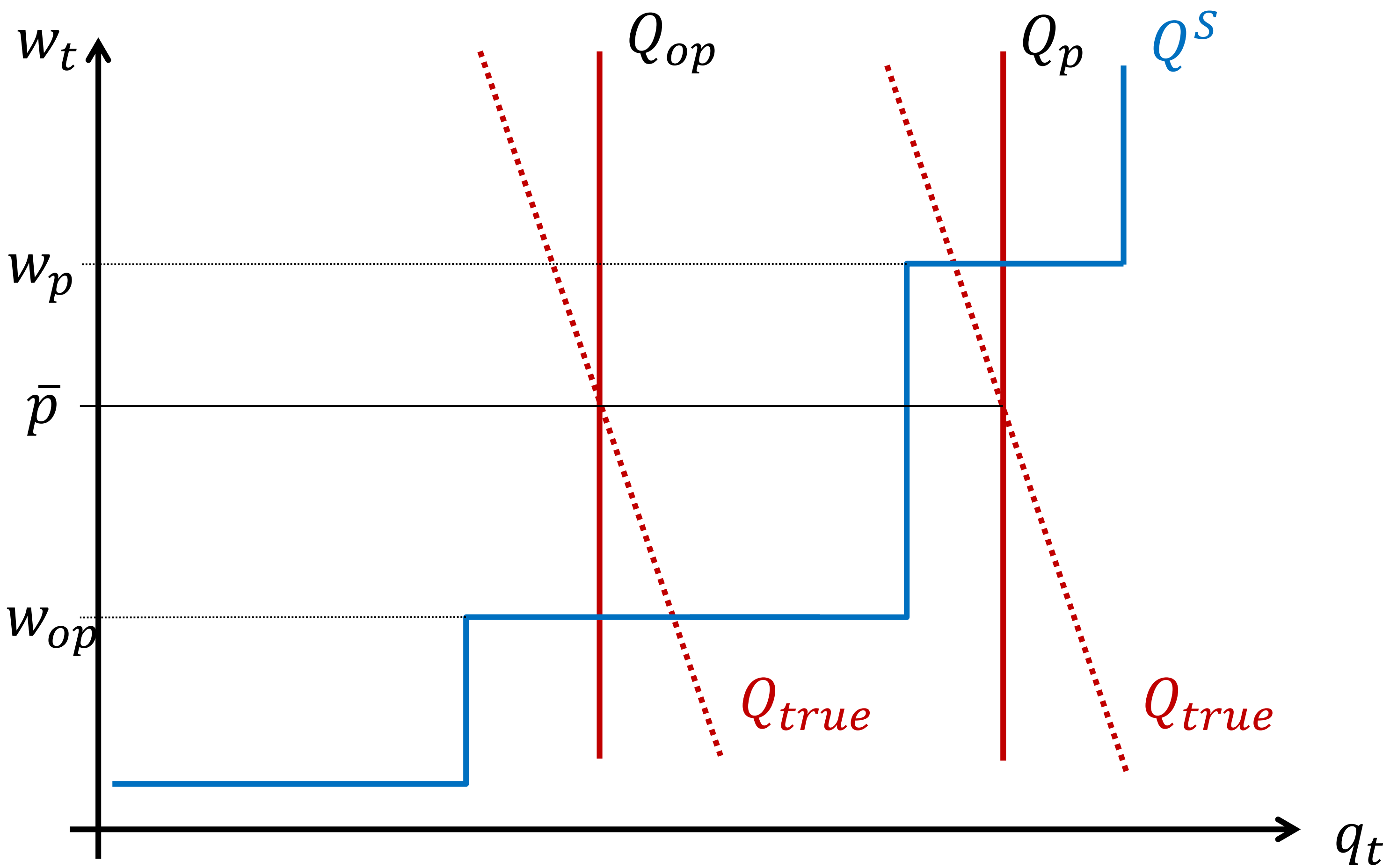


Source: *European Commission JRC and DG ENER*

Motivation

Lack of **Real-time pricing (RTP)** is the **fundamental market flaw**

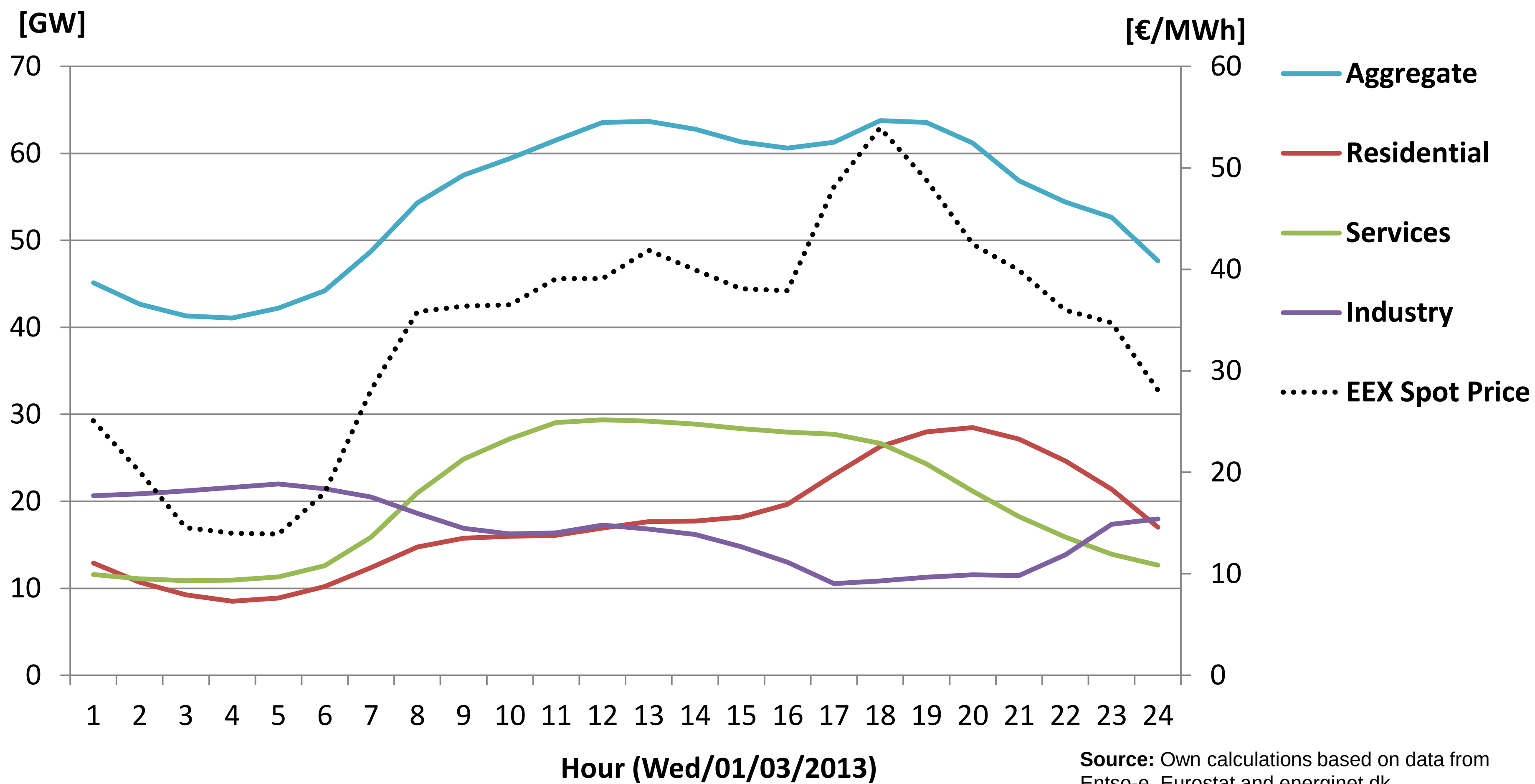
Allocative Inefficiency in real electricity markets from flat pricing:



Motivation

Problem: Social Acceptance Barriers to Dynamic Retail Pricing

Largest efficiency gains may stem from potential **“losers” of RTP:**



Source: Own calculations based on data from Entso-e, Eurostat and energinet.dk

Motivation
Research Questions

1. How does the amount of **redistributed costs from RTP adoption** change in a market with variable electricity supply?

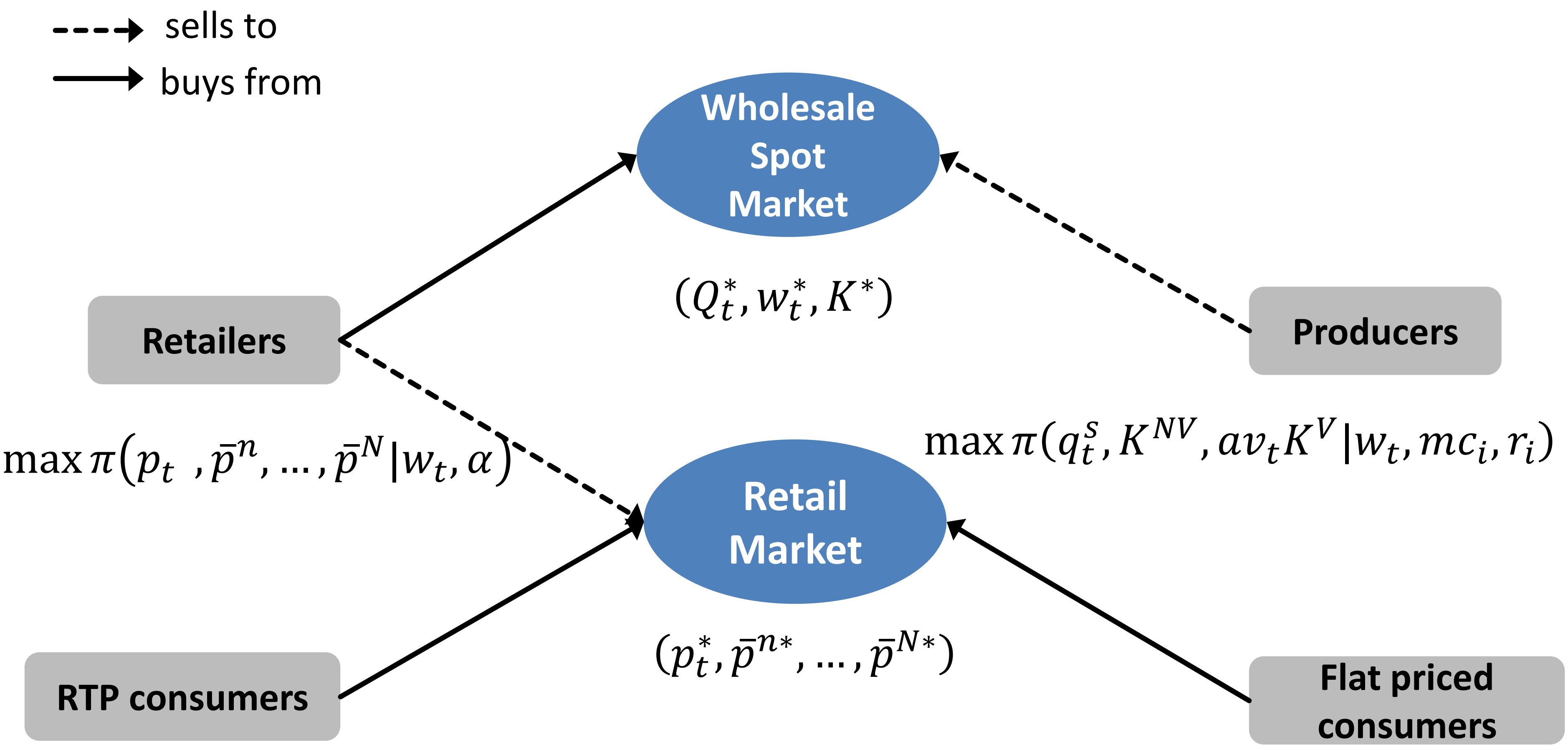
2. What are the **welfare gains left on the table if mainly large (industrial) consumers with „flat" demand profiles** adopt RTP ?

Content

METHOD

Long-Run Partial Equilibrium Model

(Borenstein & Holland 2005)



$\alpha Q_t^D(\cdot) = \sum_n^N \alpha^n q_t^n(p_t | a_t^n)$

$(1 - \alpha) Q_t^D(\cdot) = \sum_n^N (1 - \alpha^n) q_t^n(\bar{p}^n | a_t^n)$

$$q_t^d(p) = a_t p^{-\varepsilon}$$

Method

Perfect competition in retail sector **(zero-profits)**

- Retail **real-time prices** p_t in hour t:

$$\pi = \sum_t^T (p_t - w_t) * \alpha Q_t^D(p_t) = 0$$

- **Flat rates for each consumer type** $\bar{p}^n$ (no cross subsidization):

$$\pi^n = \sum_t^T (\bar{p}^n - w_t) * (1 - \alpha^n) * q_t^n(\bar{p}^n | \alpha^n) = 0, \ \forall n \in N$$

- Uniform **flat price** $\bar{p}$ (cross subsidization):

$$\pi = \sum_t^T (\bar{p} - w_t) * (1 - \alpha) Q_t^D(\bar{p}) = 0$$

Method
Create heterogeneous consumption time series …

Hour	Residential [GW]	Services&Trade [GW]	Industry [GW]	Total Demand [GW]
1	15.09	12.25	12.54	39.87
2	13.89	12.04	12.45	38.39
⋮	⋮	⋮	⋮	⋮
8760	16.82	13.03	17.21	47.06
Total [GWh]	**136,000 (27%)**	**145,835 (29%)**	**224,269 (44%)**	**506,104**

- **Entso-e:** Total hourly electricity demand data (2013)
- **Eurostat:** Final annual sector-specific electricity consumption
- **BDEW:** Standard Load Profiles (SLPs) **H0 (Residential)** and **G0 (Trade & Services);** Industry demand equals residual demand

PRELIMINARY RESULTS

Results

With **higher vRES** supply, total **redistribution of costs is lower**

Bill changes if all customers switched to RTP w/o changing consumption behaviour*:

vRES share in GEC	Residential [€ mio/year]	Services [€ mio/year]	Industry [€ mio/year]	Total Redistribution [€ mio/year]
0%	-8.40 (-0.15%)	795.74 (13.62%)	-790.98 (-8.80%)	799.40
~40%	247.40 (1.82%)	414.83 (2.84%)	-662.45 (-2.95%)	662.45
~50%	182.28 (1.19%)	209.04 (1.27%)	-391.31 (-1.54%)	391.31
~60%	114.10 (0.59%)	-43.39 (-0.21%)	-70.62 (-0.22%)	114.00

***Assumption:** Uniform flat rate

Results
The „peakier“ the demand pattern, the higher the overall consumer surplus gains from RTP

Total consumer surplus ***gains*** for given ***aggregate*** RTP shares **[€ mio./year]**

α	α^n	No vRES	60% vRES in GEC
10% RTP Share	**Residential (34%)**	164.27	249.24
	Services&Trade (32%)	171.25	237.55
	Industry (21%)	119.52	190.79
20% RTP Share	**Residential (72%)**	330.85	502.83
	Services&Trade (67%)	351.80	488.14
	Industry (44%)	254.18	405.03

- Surplus gains from putting ***only industrial customers*** on RTP to achieve $\alpha = 10\%\ or\ \alpha = 20\%$ are ~**20% lower** on average.
- Surplus gains are on average **33% higher with 60% vRES share.**

Preliminary Results

Annual surplus gains from switching to RTP **per average kWh** consumed by **switchers** to RTP:

Scenario I ($\alpha^n = 50\%$)	Residential [€/kWh*a]	Services [€/kWh*a]	Industry [€/kWh*a]	All [€/kWh*a]
No vRES	22.27 (240.25)*	21.49 (266.69)	15.05 (288.28)	14.12 (681.45)
~60% in GEC	30.51 (361.48)	28.04 (369.88)	24.05 (458.70)	24.51 (1081.52)

*Total gains in brackets in mio.€/year

- „Peakier“ consumers switching to RTP gain more per average kWh consumed (20% to 30%).
- Benefits are on average **about 30% higher** in the vRES market.

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CONCLUSION

Conclusion & Outlook

- **Efficiency gains from adopting RTP increase significantly** with vRES shares.
- **Potential redistribution of costs becomes less important** with high vRES shares.
- **Significant portion of potential welfare gains may be lost** if mainly largest but „flat consuming“ (industrial) consumers adopt RTP (or similar mechanisms).

What to do with this:

- **General aim:** providing insights for designing measures to induce as much **efficiency in retail pricing (adoption of RTP)** as possible.
- Are there other, e.g. **cognitive barriers to RTP adoption**, that should be included in the model **(Internalities)**?

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