Adders and Real-Time Market for Reserve in Integrated European Balancing Markets

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Motivation

- Integration of European balancing markets
- Standardization of markets’ operation to harness the benefit of the integration
  - ISHM (Imbalance Settlement Harmonization Methodology)
  - Cross-border platforms’ *pricing methodology*

- Analyse the introduction of *adders* on the imbalance and/or balancing price

Motivation	
Balancing Markets	Single Zone Multi-Zone Adder on the Energy Price
Analytical Model	Fringe Agents Optimal Strategy Market Equilibrium Cross-Border Setting
Policy Insight	Single Zone Multi-Zone
Conclusion	

European Balancing Markets

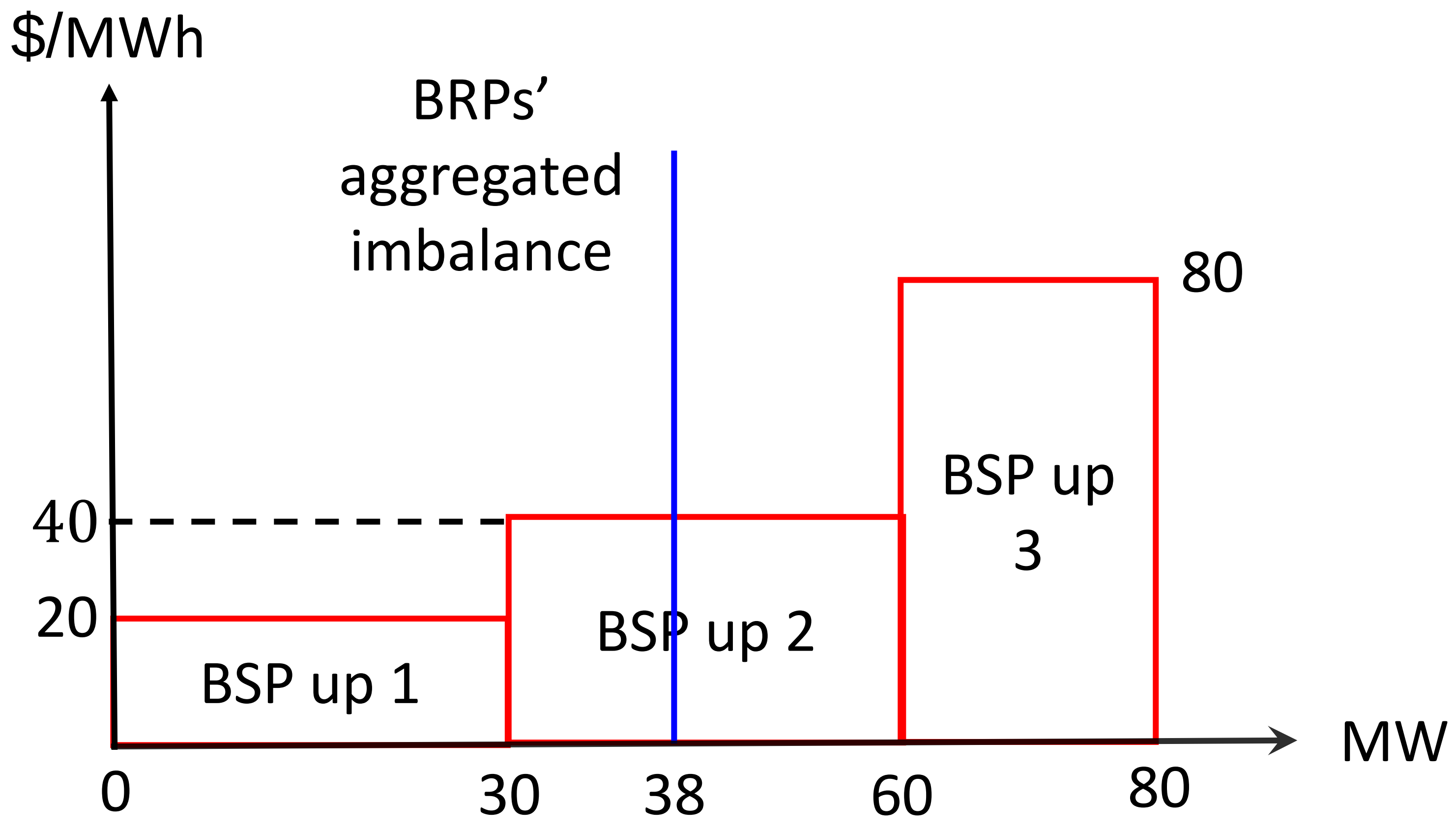
- Balancing Responsible Party (BRP)
  - ➢ Owner of a portfolio of assets
  - ➢ Creates imbalances with respect to its forward position
  - ➢ Consumes flexibility

- Balancing Service Provider (BSP)
  - ➢ Flexible asset
  - ➢ Belongs to a BRP
  - ➢ Supplies flexiblity

- Transmission System Operator (TSO)
  - ➢ Balances the market
  - ➢ Activates balancing energy to cover energy imbalances

Balancing the Market

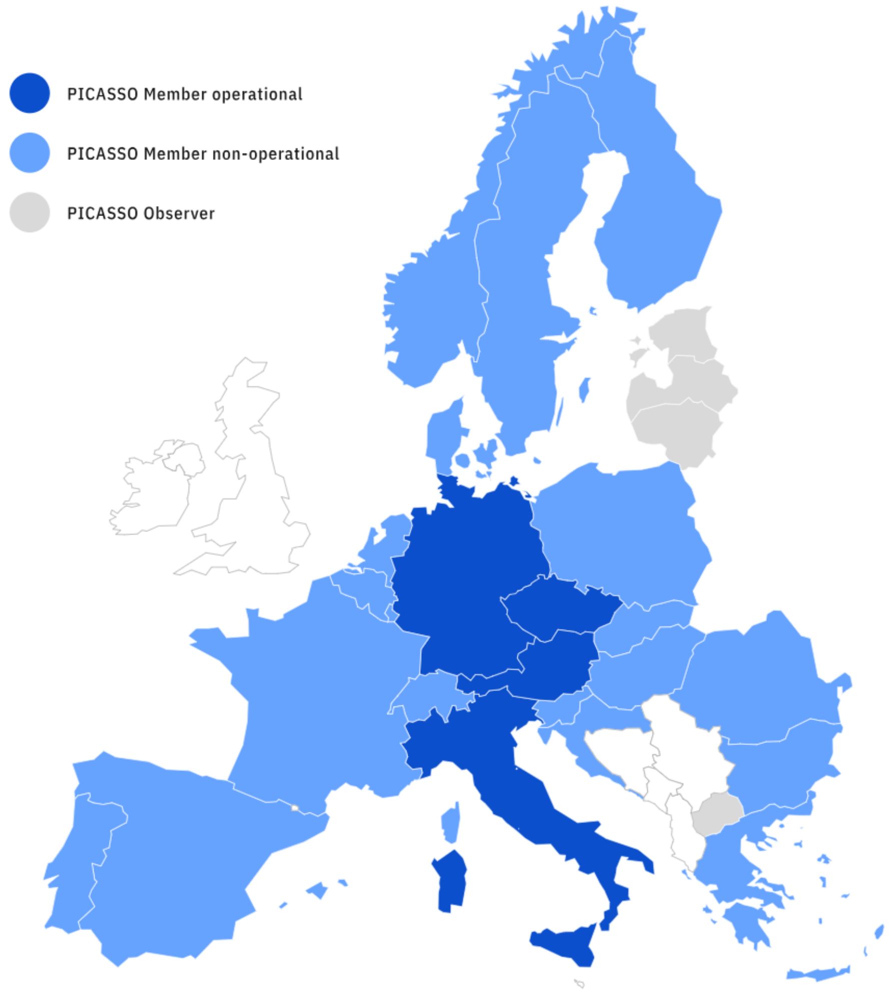
- Last step in the sequence of electricity markets
- Used to maintain grid frequency
- Uniform Auction



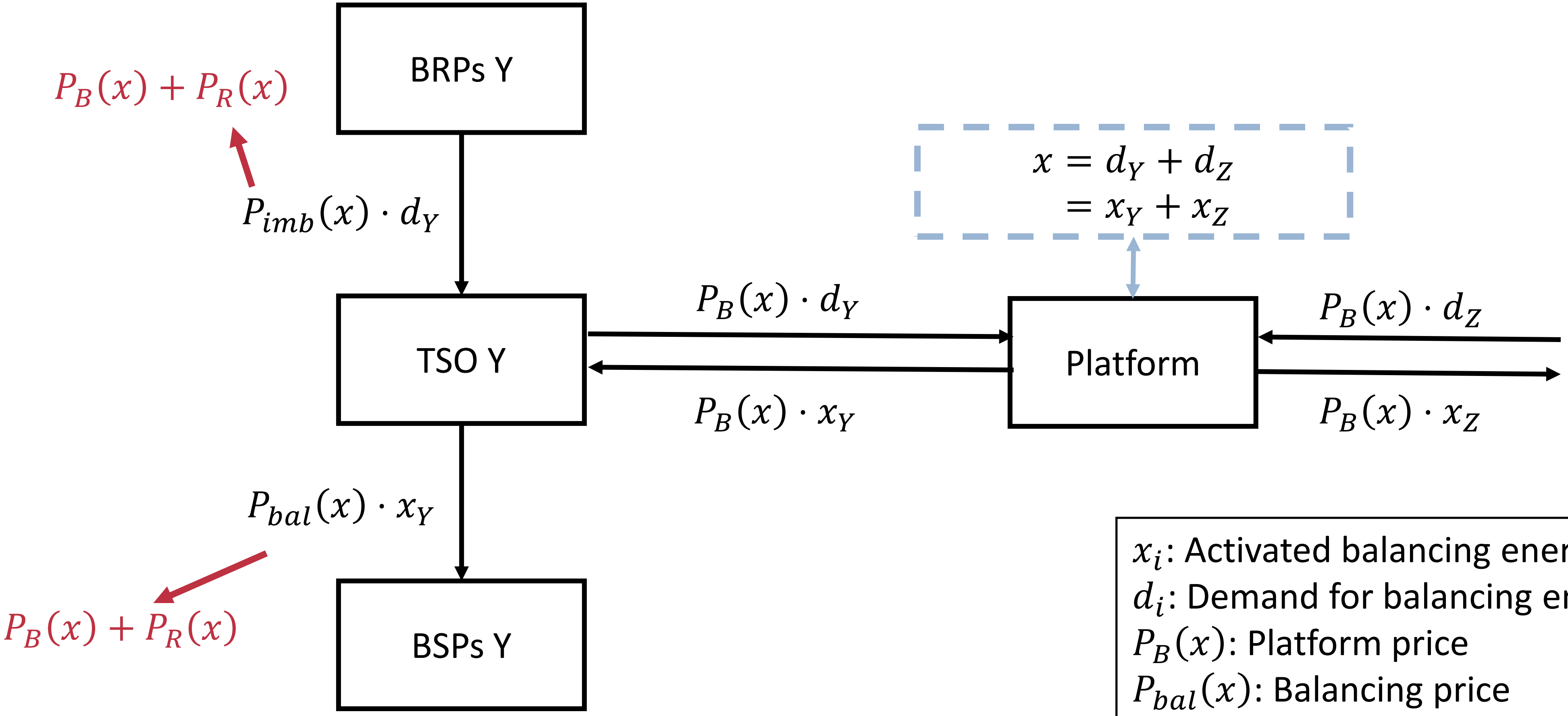
European Balancing Market Integration

- Cross Border balancing platforms
  - MARI for mFRR
  - PICASSO for aFRR

- Other works on the interaction between aFRR and mFRR
  - Interactions of Imbalance Settlement with Energy and Reserve Markets in Multi-Product European Balancing Markets
  - Efficient Dispatch in Cross-Border Balancing Platforms: Elastic Demand through Parametric Cost Function Approximation



Cross-Border Balancing Platforms



x_i: Activated balancing energy in zone i
d_i: Demand for balancing energy in zone i
$P_B(x)$: Platform price
$P_{bal}(x)$: Balancing price
$P_{imb}(x)$: Imbalance price

Designs Considered

	Balancing Price $\boldsymbol{P_{bal}}$	Imbalance Price $\boldsymbol{P_{imb}}$	Reserve Price
No adder	P_B	P_B	0
Adder on imbalance	P_B	$P_B + \boldsymbol{P_R}$	0
Adder on balancing and imbalance	$P_B + \boldsymbol{P_R}$	$P_B + \boldsymbol{P_R}$	0
RT market for reserve	$P_B + \boldsymbol{P_R}$	$P_B + \boldsymbol{P_R}$	$\boldsymbol{P_R}$

Assets with 50 MW of capacity, 35 MW is dispatched in balancing by TSO

- 35 MW of balancing energy is remunerated at the balancing price
- 15 MW of available balancing capacity is remunerated at the reserve price

Why an Adder on the Energy Price ?

Incentivize flexible assets that cannot prequalify to participate in the balancing process

- Hold BRPs responsible for the balancing capacity they use
- Implicit acknowledgement of the real-time value of balancing capacity

➢ Crude approximation of co-optimization of balancing energy and balancing capacity

What market equilibria emerge from the different application of adders ?

What happens in a cross border setting?

Motivation

Balancing Markets

- Single Zone
- Multi-Zone
- Adder on the Energy Price

Analytical Model

- Fringe Agents Optimal Strategy
- Market Equilibrium
- Cross-Border Setting

Policy Insight

- Single Zone
- Multi-Zone

Conclusion

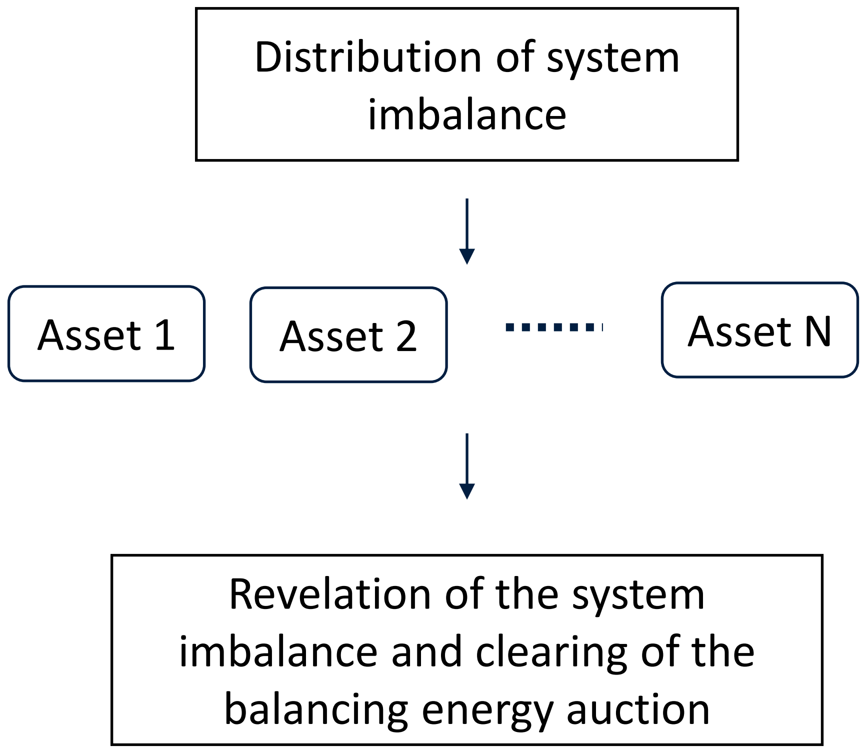
Game Theory Model

Fleet of flexible assets with two actions

1. Submit a price-quantity balancing energy bid
2. Do reactive balancing

Analytical model with a continuum of fringe agents

1. Characterize optimal strategies given exogenous prices
2. Derive equilibrium based on them



Set of Action

Distribution of balancing and imbalance prices

Asset C

- Balancing auction → Included in the balancing merit order and dispatched when the balancing price get higher than the price component of the bid p → $\mathbb{E}[P_{bal} - C | P_{bal} \geq p]$
- Reactive balancing → Self-scheduling in reaction to the expected imbalance price → $\mathbb{E}[P_{imb}] - C$

$$P_{bal} = P_B$$
$$P_{imb} = P_B$$

Optimal Strategy: No Adder

If doing balancing,

- Optimal to bid at the marginal cost in the auction
  - Bid less than marginal, risk making a loss
  - Bid more than marginal cost, risk losing profit

If bid marginal cost in the balancing auction,

- Reactive balancing is weakly dominated by participating in the balancing energy auction

$$P_{bal} = P_B$$
$$P_{imb} = P_B + P_R$$

Optimal Strategy: Adder on Imbalance

- Still optimal to bid marginal cost in the balancing energy auction

- Trade off between risk and higher payoff

$$\mathbb{E}[P_B(\cdot) + P_R(\cdot)] - C \geq \mathbb{E}[P_B(\cdot) - C | P_B(\cdot) \geq C]$$

- Assets with low marginal cost may find it more profitable to do reactive balancing

$$P_{bal} = P_B + P_R$$
$$P_{imb} = P_B + P_R$$

Optimal Strategy: Adder on Imbalance and Balancing

- Not optimal anymore to bid the marginal cost in the balancing energy auction
  - Objective: Be activated as soon as the balancing price is higher than the marginal cost
  - Internalize the value of the adder

$$p = C - P_R(P_{bal}^{-1}(C))$$

- Reactive balancing is weakly dominated by participating in the balancing energy auction

$$P_{bal} = P_B + P_R$$
$$P_{imb} = P_B + P_R$$
+ reserve price

Optimal Strategy: RT Market for Reserve

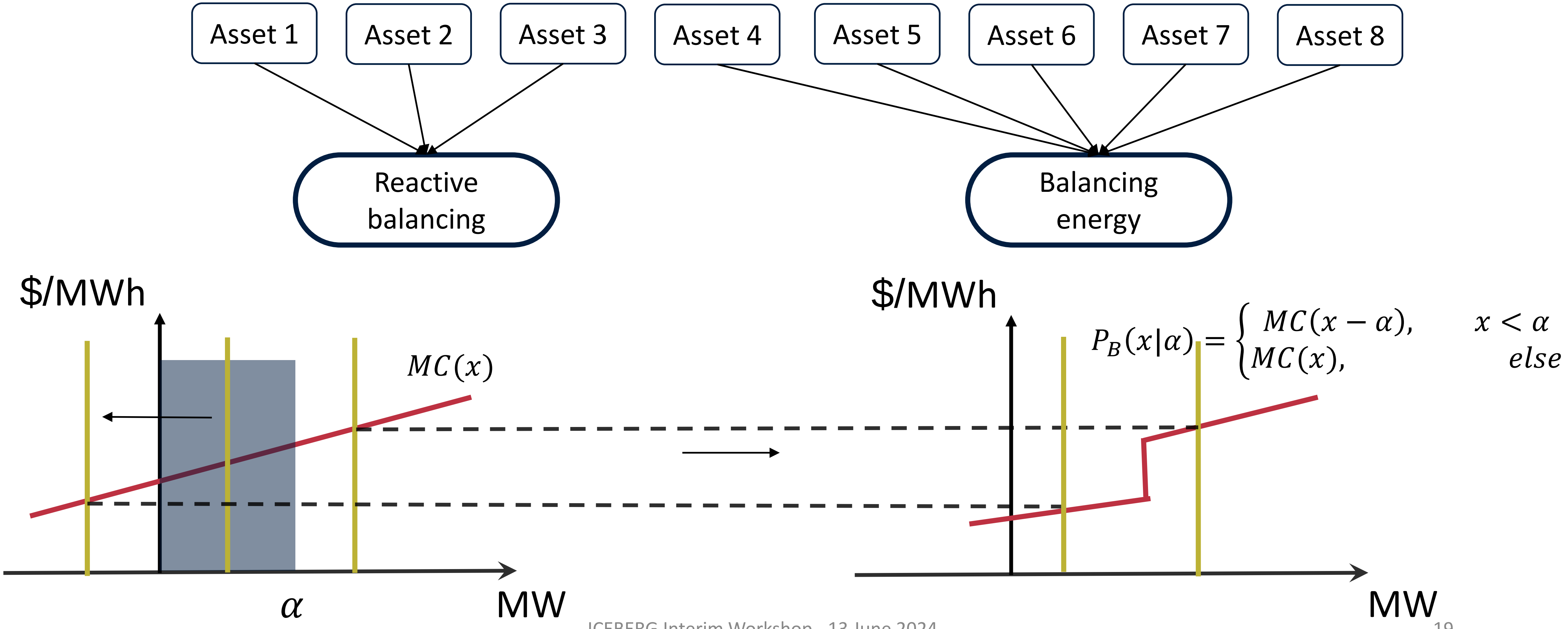
- Restore the incentive to bid at marginal cost in the balancing energy auction
- Reactive balancing is weakly dominated by participating in the balancing energy auction

Single Zone Market Equilibrium

- *No adder* and *RT market for reserve*
  - Everybody bids truthfully in the balancing energy auction

- *Adder on balancing and imbalance*
  - Everybody internalizes the value of the adder in the balancing energy auction
  - Bidding distortion but same outcome

Single Zone Market Equilibrium for Adder on Imbalance (1)



Single Zone Market Equilibrium for Adder on Imbalance (2)

Opportunity cost function for an agent with marginal cost C and a level α of reactive balancing

$$z(\alpha, C) = \mathbb{E}[P_B(\cdot\,|\alpha) + P_R(\cdot)] - C - \mathbb{E}[P_B(\cdot\,|\alpha) - C | P_B(\cdot\,|\alpha) \geq C]$$

Characterization and existence of an equilibrium

1. If $z\big(0, MC(0)\big) < 0$, no reactive balancing is an equilibrium
2. Else, there exists an equilibrium level of reactive balancing α^* such that

$$z\big(\alpha^*, MC(\alpha^*)\big) = 0$$

Single Zone Market Equilibrium Summary

Design	$P_B(\boldsymbol{x})$
No adder	$MC(x)$
Adder on imbalance and balancing	$MC(x) - P_R(x)$
Adder on imbalance	$\begin{cases} MC(x-\alpha^*), & x < \alpha^* \\ MC(x), & else \end{cases}$
RT market for reserve	$MC(x)$

Clearing the Balancing Energy Auction with the Balancing Platform

- Aggregation operator

$$B(q) = \cup_i B_i(q) = \{\pi : B_i(q_i) = \pi \ \forall i, \sum_i q_i = q\}$$

With

- B_i being the offer curve in zone i,
- B being the aggregated offer curve

Platform Price Produced by the Balancing Platform

Design in zone i	$\boldsymbol{B_i(x)}$
No adder	$MC_i(x)$
Adder on balancing and imbalance	$MC_i(x) - \lambda_{R,i}(x)$
Adder on imbalance	$\begin{cases} MC_i(x - \alpha_i), & x < \alpha_i \\ MC_i(x), & else \end{cases}$
RT market for reserve	$MC_i(x)$

- Optimal dispatch is induced by $\cup_i \, MC_i(x)$
- *Adder on balancing and imbalance* and *adder on imbalance* generate lower platform price than benchmark

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- Cross-Border Setting

Policy Insight

- Single Zone
- Multi-Zone

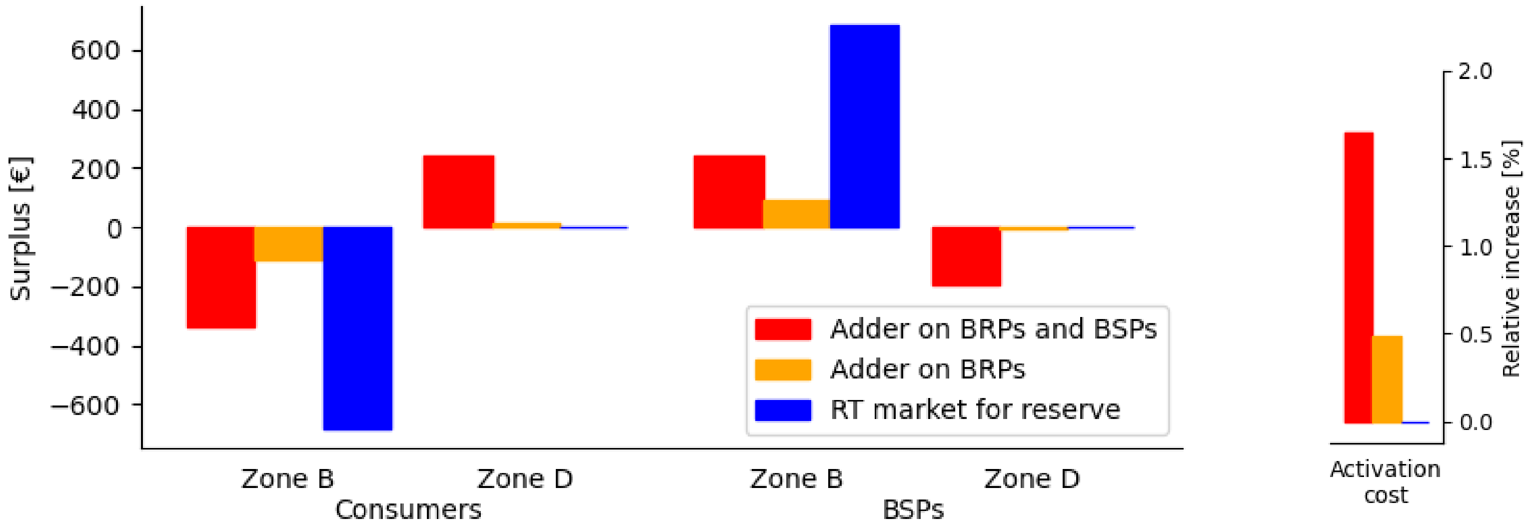
Conclusion

Single Zone

- Inefficiency for the *adder on imbalance*
  - Assumptions that system operators are better than market participants to resolve imbalance

- Other variants generate the same outcome

Multi-Zone



3 adverse effects from the *adder on the imbalance* and *adder on the balancing and imbalance*

1. Out of merit activation leads to an increased activation cost (article 3(m) of the clean energy package).
2. Cross-zonal distributive effect between consumers due to lower platform price. Consumers in zone with adders subsidize the consumption in zone without adder.
3. Discrimination between BSPs from different zones.

- Only intra-zonal redistributive effect for the *RT market for reserve*

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Conclusion

	Optimal Stategies	Single zone equilibrium	Multi-zone equilibrium
No adder	Truthfull bidding	Optimal activation	Optimal activation
Adder on the imbalance price	Some agents may self-activate	Ineficiencies due to out-of-merit activation	Ineficiencies + cross-border distributional effects
Adder on the imbalance and balancing price	Internalization of the adder	Optimal activation	Ineficiencies + cross-border distributional effects
RT market for reserve	Truthfull bidding	Optimal activation	Optimal activation