Dealing with renewables integration in the European balancing phase: A comparative study of the Belgian and French imbalance markets

Mathieu RICHARD

Université Paris Dauphine – CEA/i-tésé

Supervisors: David Proult, Fabien Roques, Boris Solier

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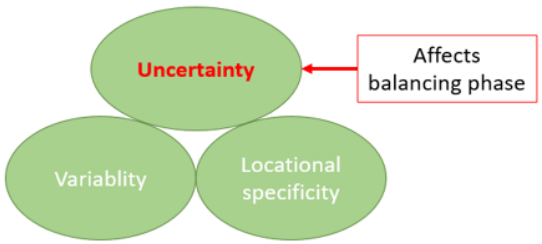
Summary

Introduction

- Increasing share of RES (wind+solar) in power mix $\rightarrow$ New balancing challenges due to their weather dependency



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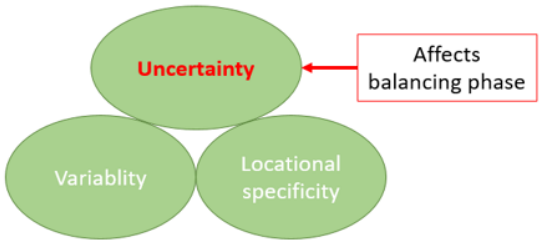
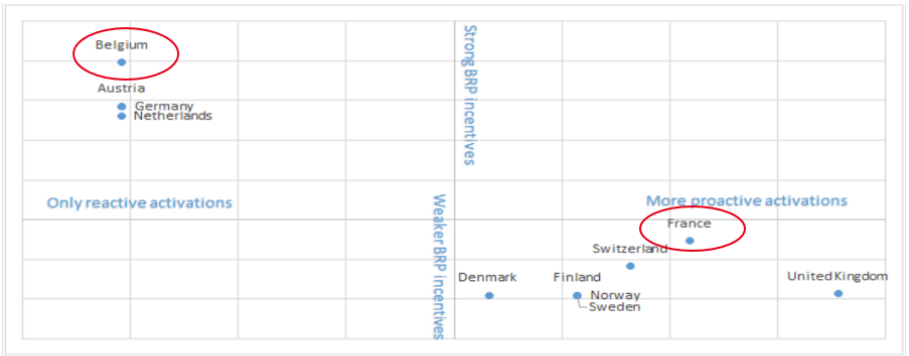


- Harmonization of imbalance markets (IBMs) remains poor at EU level due to different balancing philosophies across countries (Vandezande et al., 2010, 2009)



Classification of Northern European balancing markets based on activation philosophy and BRP incentives (Haberg & Doorman, 2016)

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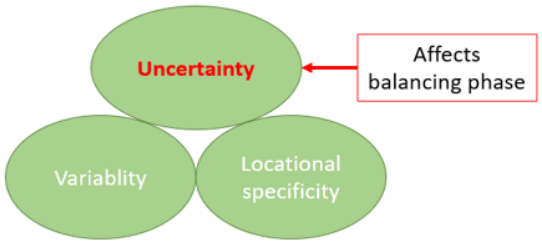

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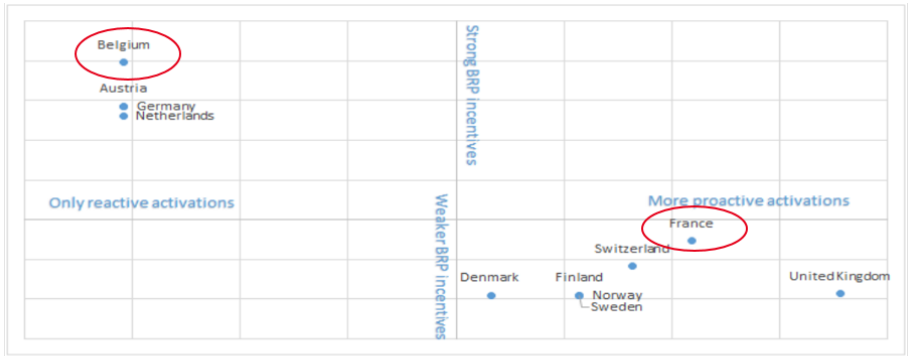

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- **Push towards an harmonized scheme based on reactive philosphy (Belgian's model)**

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- Ex-post market between TSOs (Transmission System Operators) and market players (Balancing Responsible Parties, BRPs)
- Any imbalance (deviation from schedule) of a BRP is settled at imbalance price
- Imbalance prices are based on the price of reserve energy activated in order to balance the system

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Belgium (reactive balancing philosophy) and France (proactive balancing philosophy) rely on very different IBM designs:
BE: Single Marginal IBM vs FR: Dual weighted average IBM

Research questions and contributions

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2. We find that RES integration leads to similar effects on reserve energy volumes by direction in Belgium and France

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2. We find that RES integration leads to similar effects on reserve energy volumes by direction in Belgium and France
3. We provide a set of potential explanations to understand our result linking RES integration and reserve energy activation dynamic

Literature

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- Short-term market design participates to reduce potential additional needs for reserve due to RES integration (Hirth and Ziegenhagen, 2015; Koch and Hirth, 2019; Ocker and Ehrhart, 2017)

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- BRPs pratice passive imbalance (voluntary deviation from schedule) by adjusting their position according to the level of the expected imbalance (Koch and Maskos, 2019)
- IBM as a "classical" market where imbalance level does not depend only on random shock but reacts to imbalance prices (Eicke et al., 2021)

IMB price arbitrage

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BRP short

(not enough energy)

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BRP buys to TSO its energy deficit volume at IBM price

BRP long

(too much energy)

BRP sells to TSO its energy surplus volume at IBM price

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$$Financial\ short = P_{DA} - P_{IBM}$$
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- Financial variables mimic for each period what would have been the level of reward/penalty in €/MWh for a BRP by direction
- It tells us if the preferred deviation (maximising BRP profit, if any) is in line with system balancing needs

Expectation on financial incentives

Is there an IBM design that appears better suited to engage BRPs in the real-time balancing of the system?

Belgium		System position	
		long	short
BRP position	long	*Marginal Downward Price* $+ \alpha$	*Marginal Upward Price* $+ \alpha$
	short		

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France		System position	
		long	short
BRP position	long	$Weighted\ Average\ Downward\ Price * (1-k)$	$Weighted\ Average\ Upward\ Price * (1+k)$
	short	$Weighted\ Average\ Downward\ Price * (1+k)$	$Weighted\ Average\ Upward\ Price * (1-k)$

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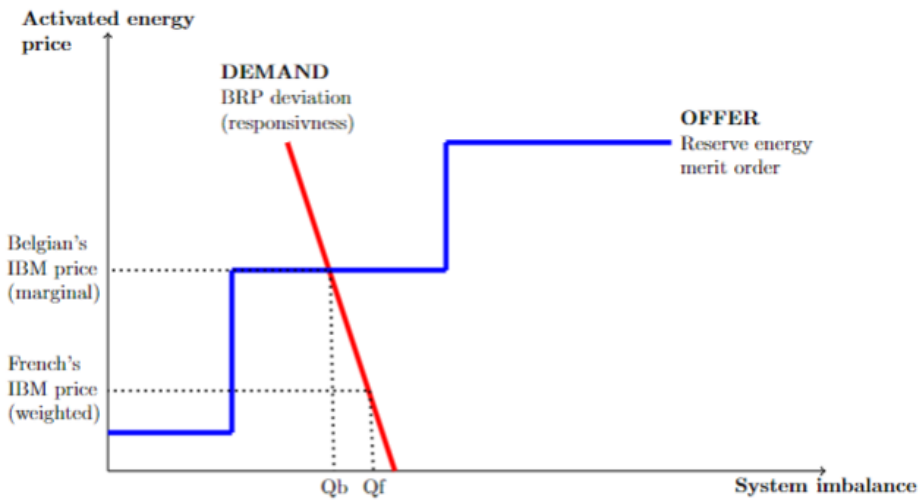

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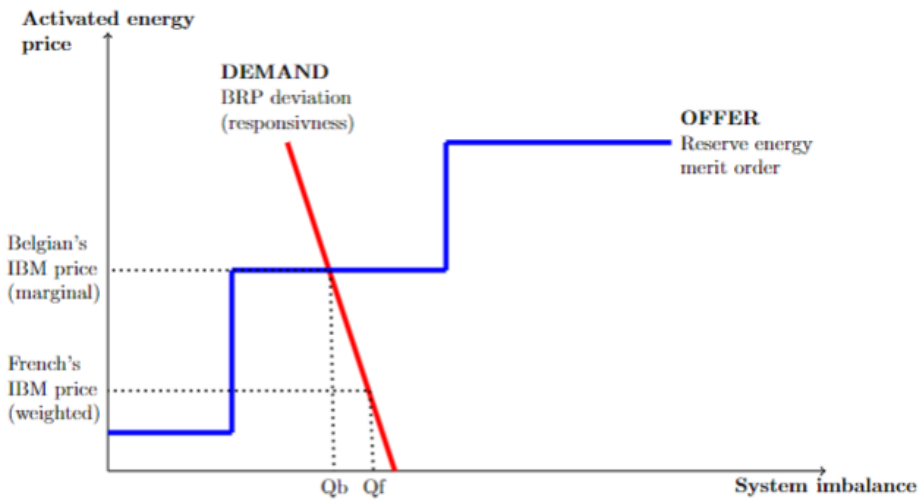

Expectation1: The Belgian system through imbalance prices, would give higher incentives for BRPs to actively participate to balance the system in real-time

Expectation on RES effects on reserve energy volumes

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- Deman and Boucher (2023) point out an asymmetrical effect of RES on upward and downward secondary reserve energy in France
- Increasing RES production tends to raise the likelihood of the Turkish system to be long (Sirin and Yilmaz, 2020)

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Expectation 2: We expect an asymmetrical effect in France but we are agnostic about effect on Belgium

Data

- Based on 2021 data (15 min for Belgium, 30 min for France, except DA prices that are hourly data)

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	Belgium						France					
	downward energy	*upward energy*	*financial long*	*financial short*	*Day-Ahead price*	*RES*	*downward energy*	*upward energy*	*financial long*	*financial short*	*Day-Ahead price*	*RES*
Metric	*MWh*	*MWh*	*€/MWh*	*€/MWh*	*€/MWh*	*%*	*MWh*	*MWh*	*€/MWh*	*€/MWh*	*€/MWh*	*%*
Mean	*4*	*7*	*-5,68*	*5,68*	*104,12*	*0,18*	*285*	*297*	*-5,87*	*-4,83*	*109,17*	*0,11*
Median	*1*	*1*	*6,23*	*-6,23*	*77,83*	*0,16*	*197*	*213*	*-4,21*	*-4,20*	*78,45*	*0,10*
Maximum	*27*	*44*	*358,45*	*408,84*	*620,00*	*0,68*	*1967*	*1667*	*79,95*	*122,10*	*620,00*	*0,40*
Minimum	*0*	*0*	*-408,84*	*-358,45*	*-70,00*	*0,00*	*0*	*0*	*-124,25*	*-106,66*	*-66,18*	*0,00*
Std. Dev.	*6*	*10*	*98,62*	*98,62*	*79,45*	*0,14*	*302*	*305*	*25,39*	*27,58*	*84,32*	*0,07*
Skewness	*2*	*2*	*-0,05*	*0,05*	*1,64*	*0,65*	*1*	*1*	*-0,36*	*-0,04*	*1,69*	*0,86*
Kurtosis	*5*	*4*	*4,49*	*4,49*	*6,34*	*2,72*	*5*	*5*	*4,93*	*4,70*	*6,10*	*3,34*
Observations	*35040*	*35040*	*35040*	*35040*	*35040*	*35040*	*17520*	*17520*	*17520*	*17520*	*17520*	*17520*

Cleaned data

Methodology

- Stationnarity checks for all variables by performing ADF test including seasonal and moment of the day dummies
- ARMAX modeling, consistent with previous works studying short term power markets (Deman and Boucher, 2023; Hickey et al., 2012)

Research question

Specification

Main controls

Expectation

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Main controls	infra-hourly and seasonal dummies	System state dummy, load, nuclear, gas, infra-hourly and seasonal dummies
Expectation	*Superiority of Belgian's design*	*Asymmetric in France, agnostic in Belgium*

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Dependant variable (€/MWh)	Belgium		France	
	fi_short	**fi_long**	**fi_short**	**fi_long**
constant	-50.38***	50.38***	-19.13***	12.63***
system_state	83.61***	-83.61***	28.13***	-25.76***
ln(equi_up)	-2.38***	2.38***	-0.06	-0.07
ln(equi_down)	1.16***	-1.16***	0.05	0.06
Adjusted R-squared	0.62	0.62	0.68	0.68
S.E. of regression	60.15	60.15	15.57	14.43
Akaike info criterion	11.03	11.03	8.33	8.18
Schwarz criterion	11.06	11.06	8.35	8.20
Hannan-Quinn criterion	11.04	11.04	8.34	8.18
Durbin-Watson stat	1.95	1.95	1.99	1.99

Note: *p < 0.1; **p < 0.05; ***p < 0.01, Newey–West estimators are applied for calculating robust standard errors

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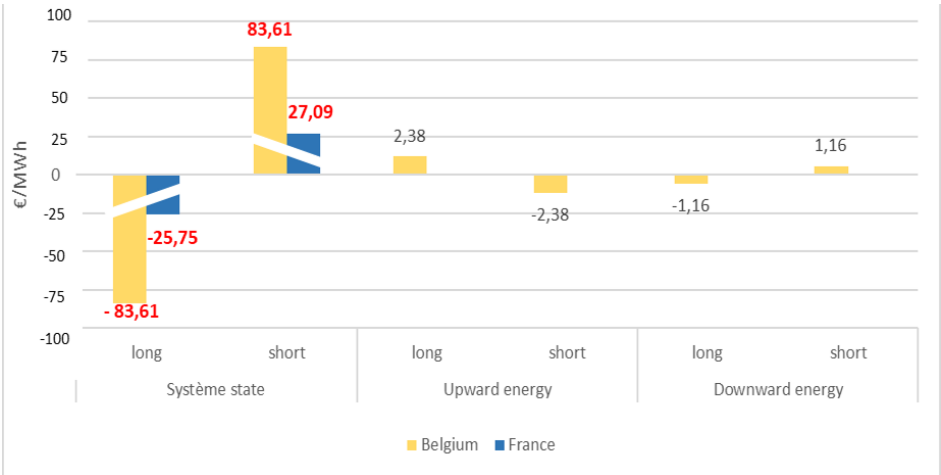

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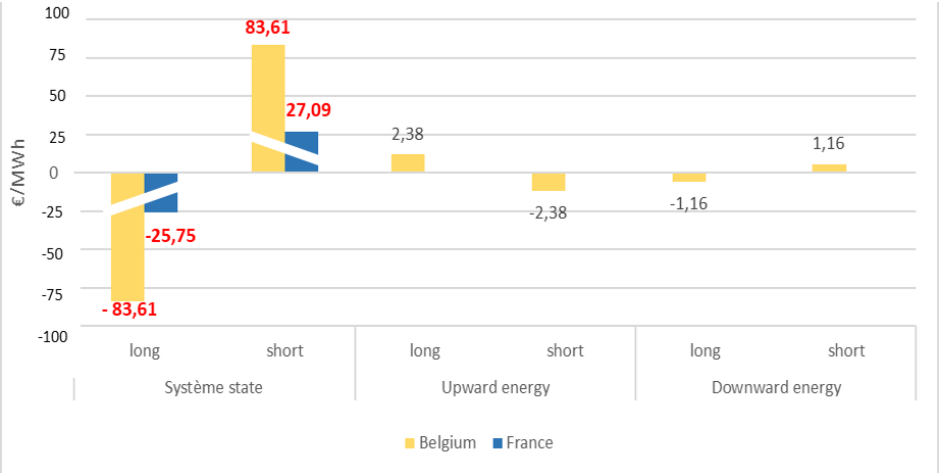
- System state is the main driver for IBM incentives in both countries



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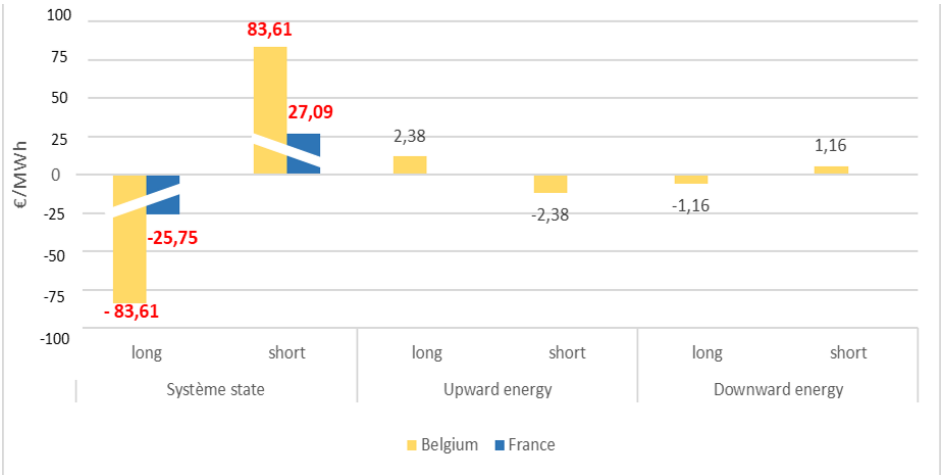
- Much larger financial incentives in Belgium according to system position



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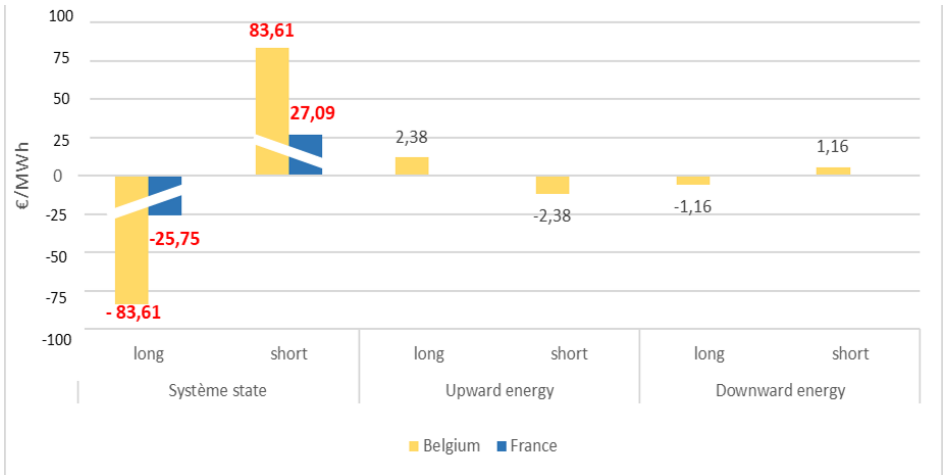

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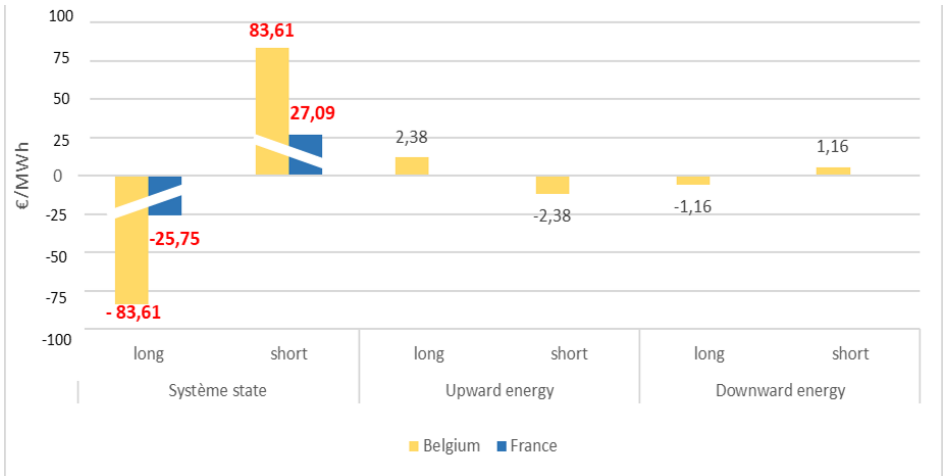

Expectation 1 confirmed: superiority of Belgian's IBM

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Dependant variable log(MWh)	Belgium		France	
	up_energy	**down_energy**	**up_energy**	**down_energy**
constant	-9.83	6.70*	-14.05**	49.26***
system_state	-3.28***	2.86***	-0.64***	0.80***
ln(res)	-0.11***	0.26***	-0.40***	0.45***
Adjusted R-squared	0.51	0.40	0.44	0.48
S.E. of regression	2.94	3.22	2.35	2.29
Akaike info criterion	5.00	5.18	4.50	4.50
Schwarz criterion	5.03	5.20	4.57	4.52
Hannan-Quinn criterion	5.01	5.18	4.56	4.51
Durbin-Watson stat	1.91	1.96	1.99	1.99

Note: *p < 0.1; **p < 0.05; ***p < 0.01, Newey–West estimators are applied for calculating robust standard errors

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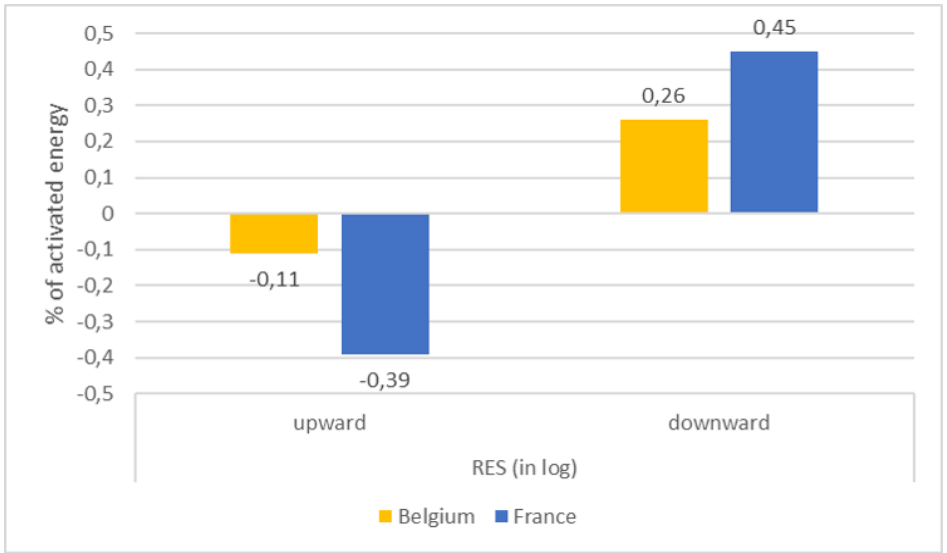

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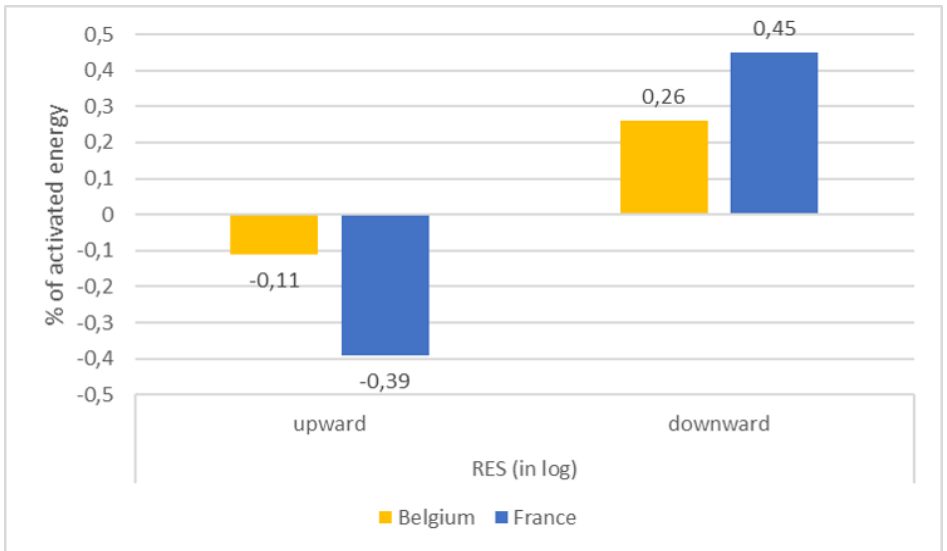

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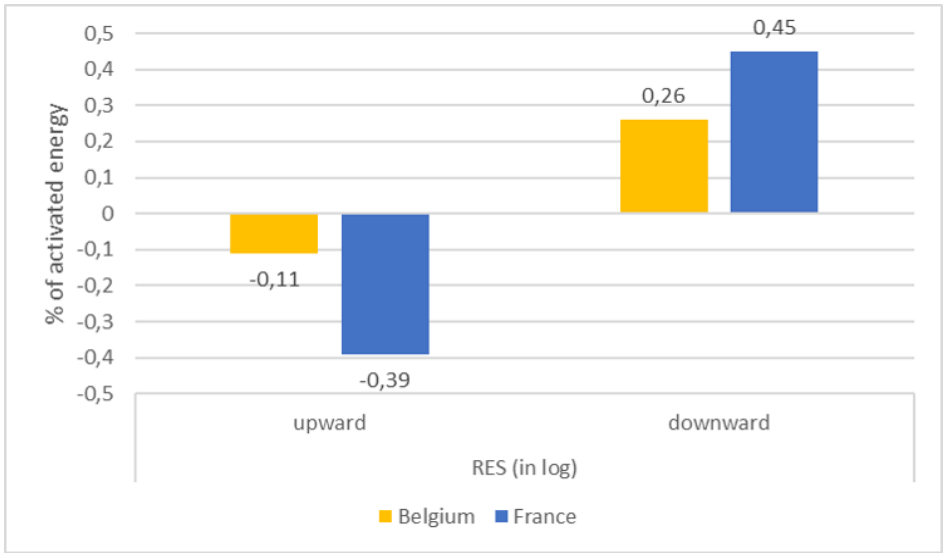

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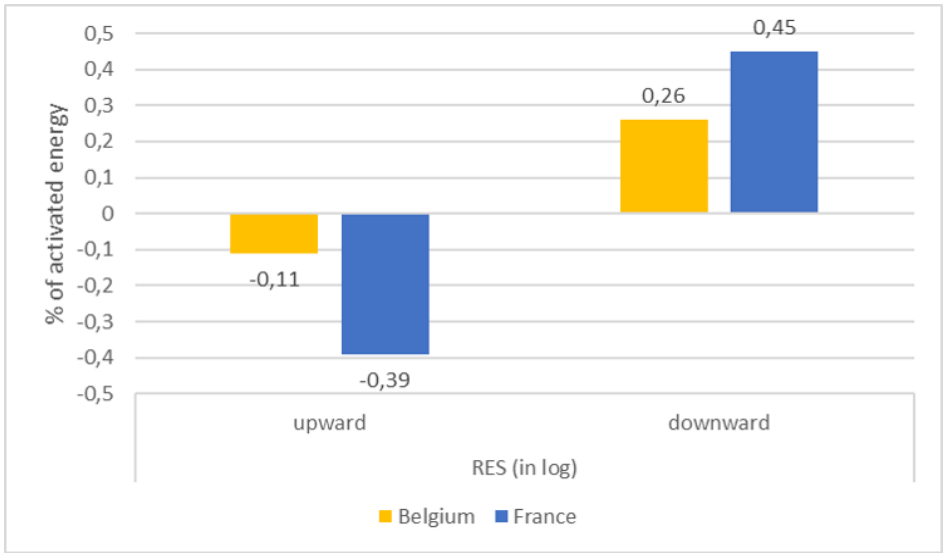

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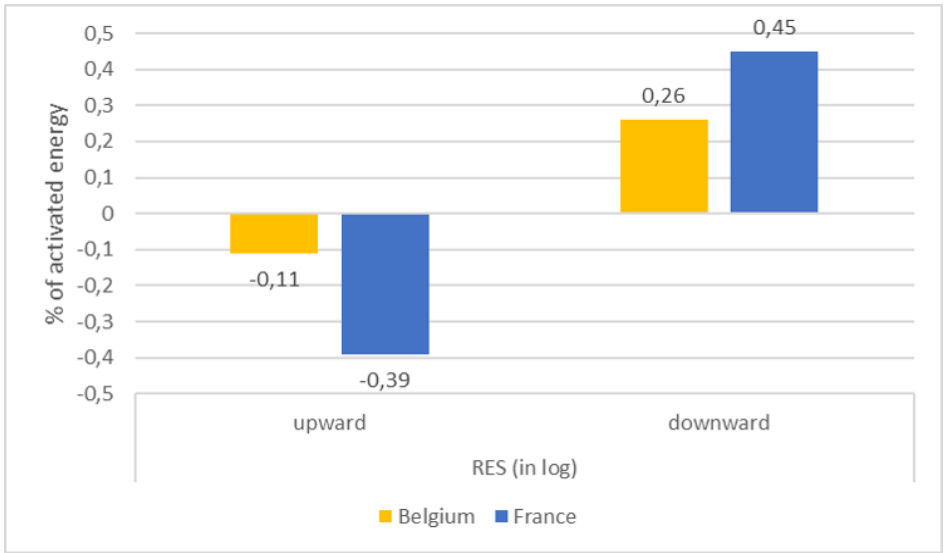

Expectation 2: Asymmetrical effect in both countries

Discussion

Why are we observing an asymmetrical effect of RES on upward and downward reserve energy volumes ?

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Asymmetrical effect *when RES share increases (more downward volumes needed and less upward volumes needed)*

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Potential cause	Consequence
Lack of balancing opportunity on ID market	**Asymmetrical effect** *when RES share increases (more downward volumes needed and less upward volumes needed)*

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Why are we observing an asymmetrical effect of RES on upward and downward reserve energy volumes ?

Potential roots of cause	Potential cause	Consequence
Physical limitation *of downward capacity on ID market* or **Voluntary limitation** *of downward capacity on ID market*	**Lack of balancing opportunity on ID market**	**Asymmetrical effect** *when RES share increases (more downward volumes needed and less upward volumes needed)*

Discussion

Physical limitation of downward capacity on ID market

$\uparrow$ RES in power mix $\Rightarrow$ Few dispatchable plants planned to be online

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Surplus of RES on Intraday

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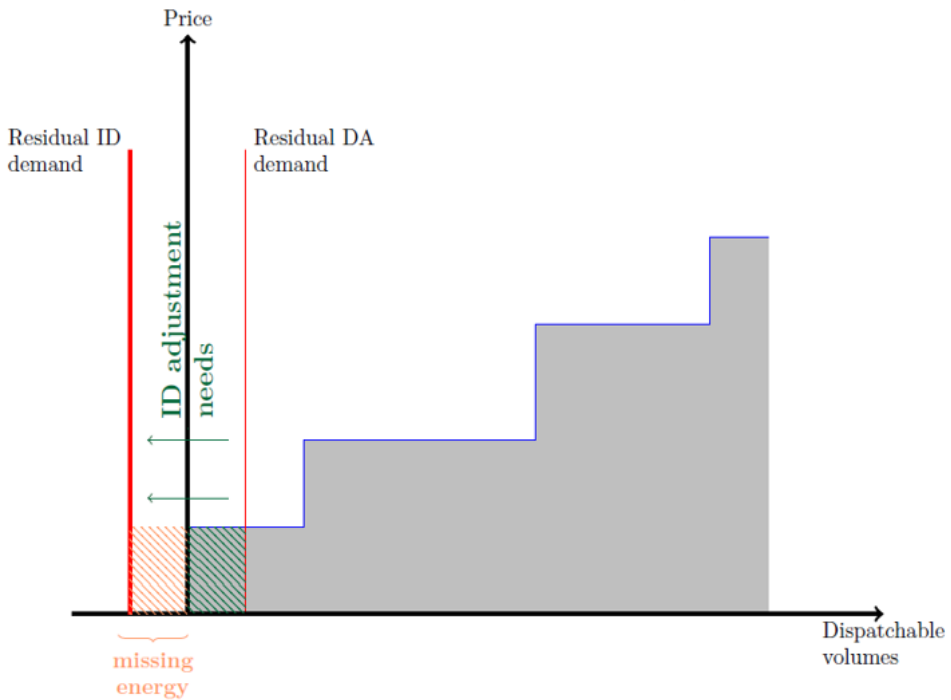

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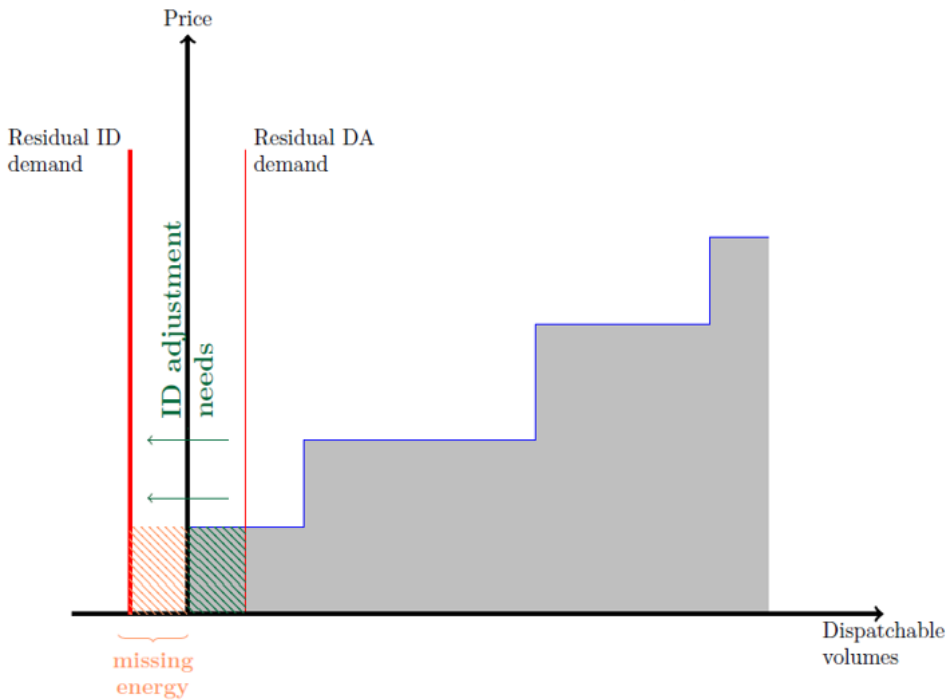

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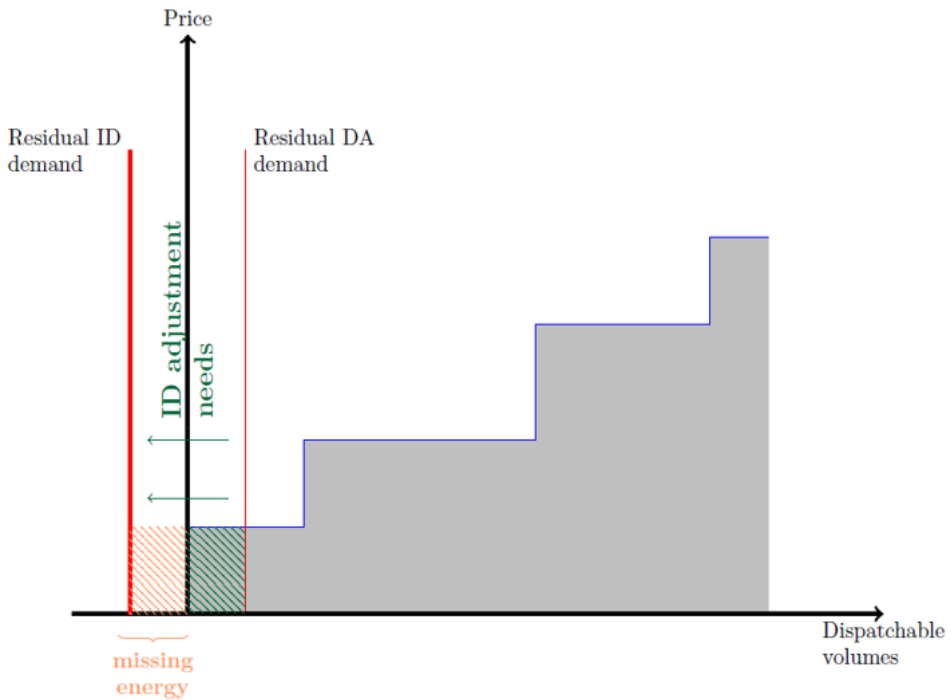

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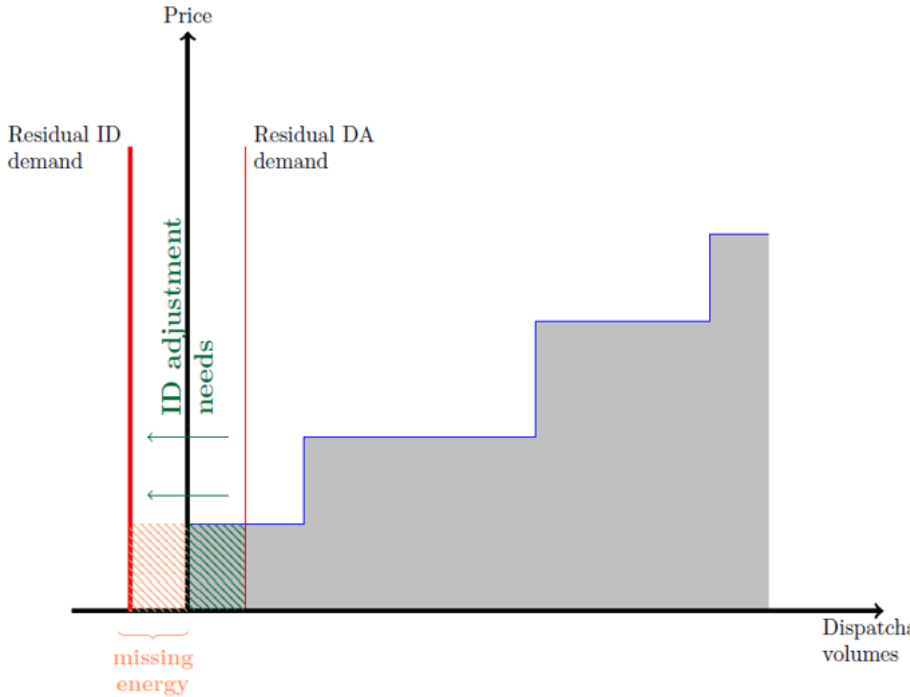

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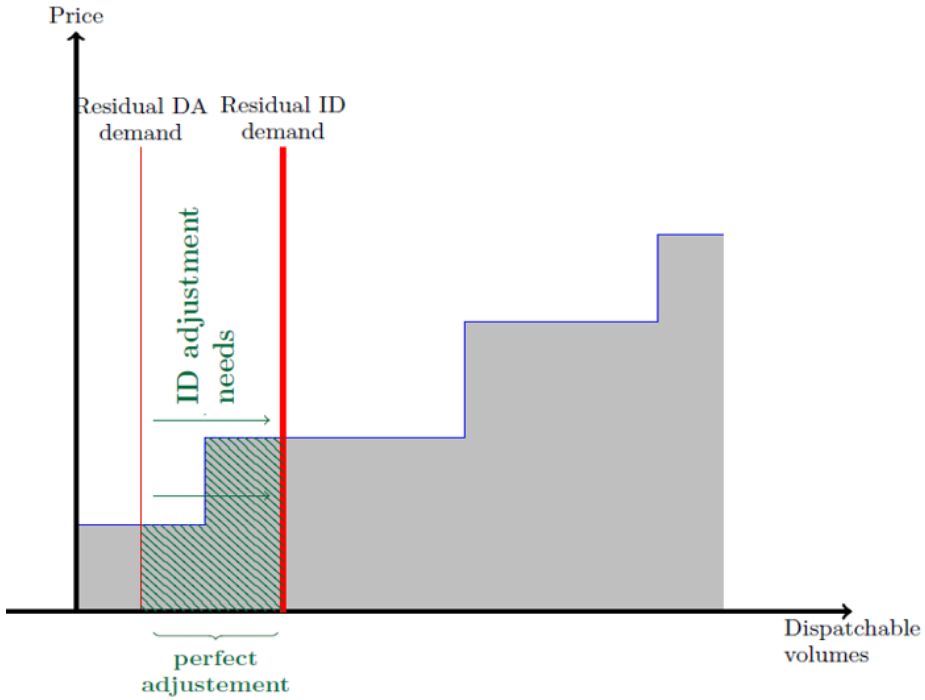

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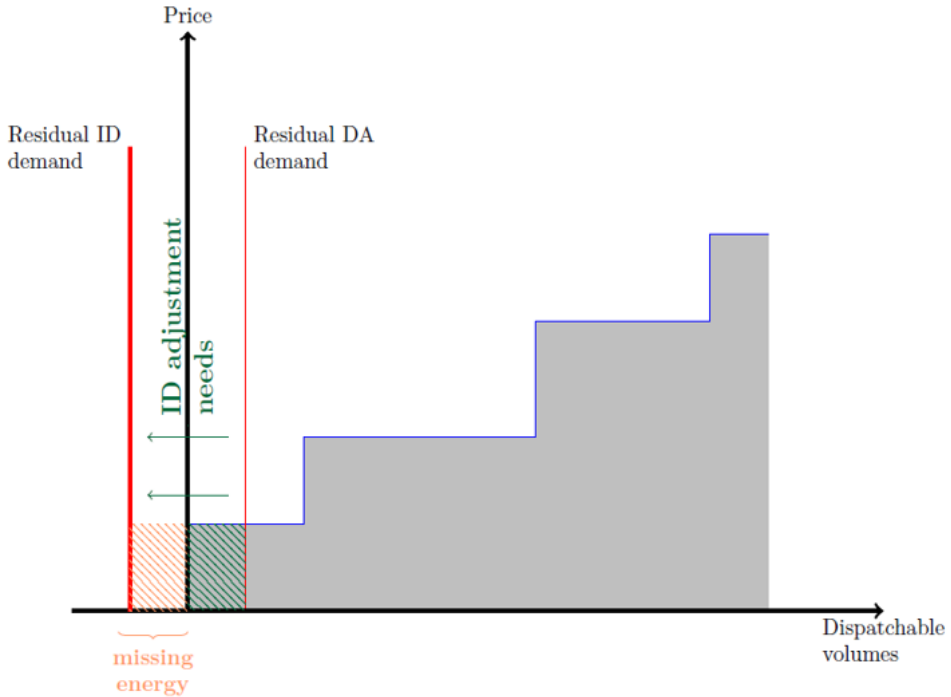

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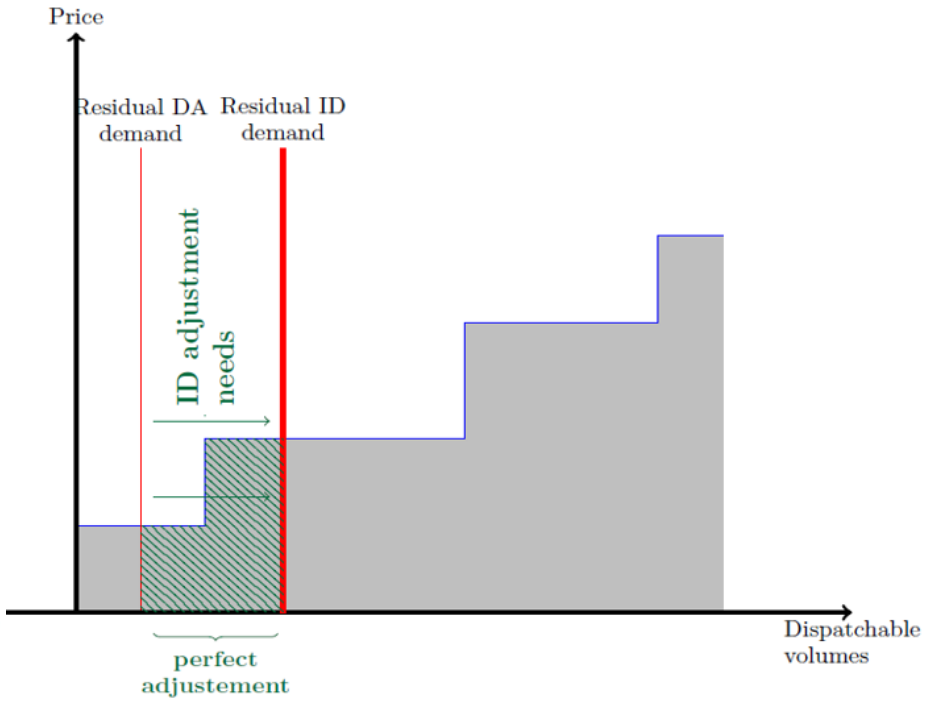

Enough energy in ID ⇒ no imbalance in real-time

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Voluntary limitation of downward capacity on ID market

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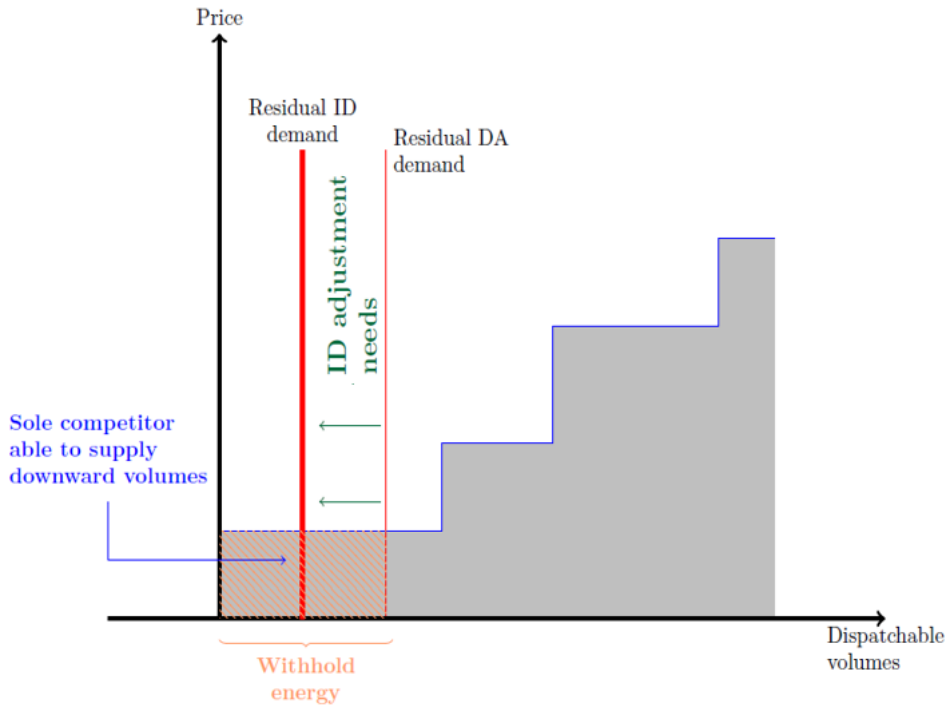

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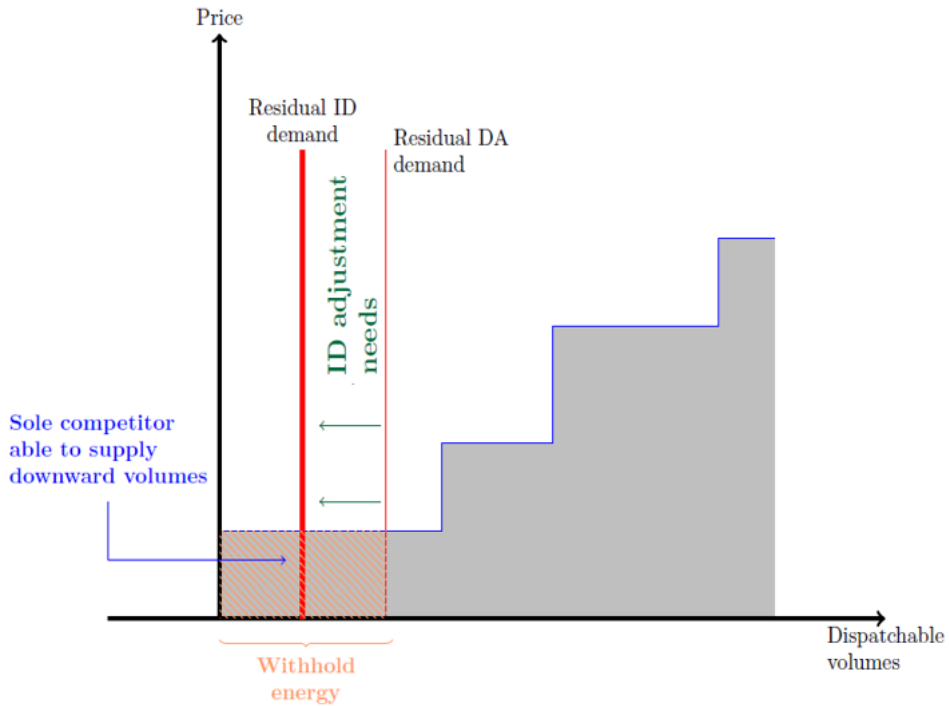

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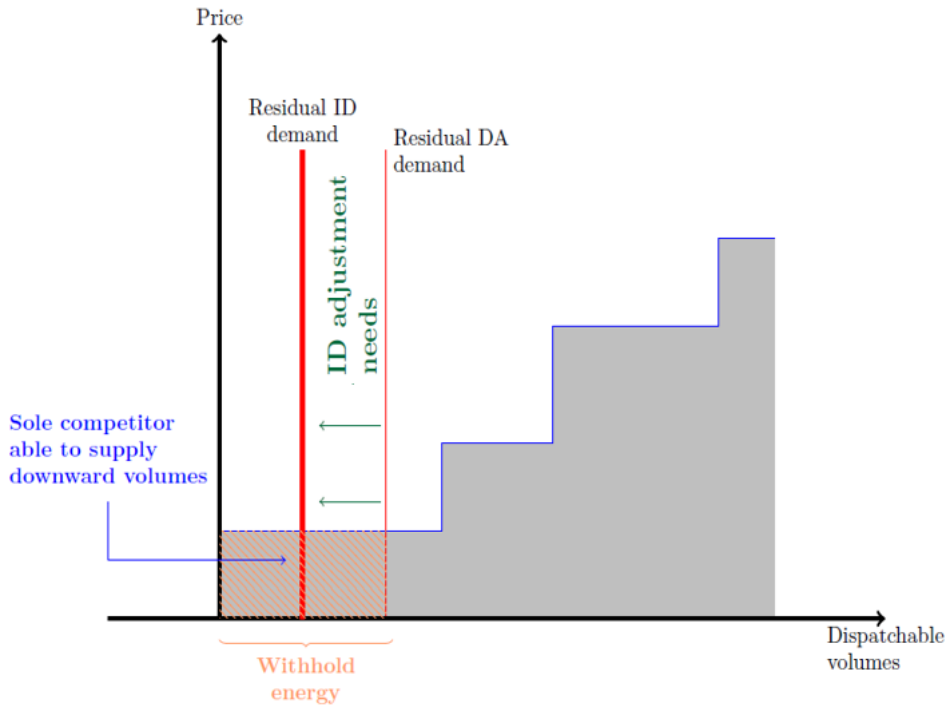

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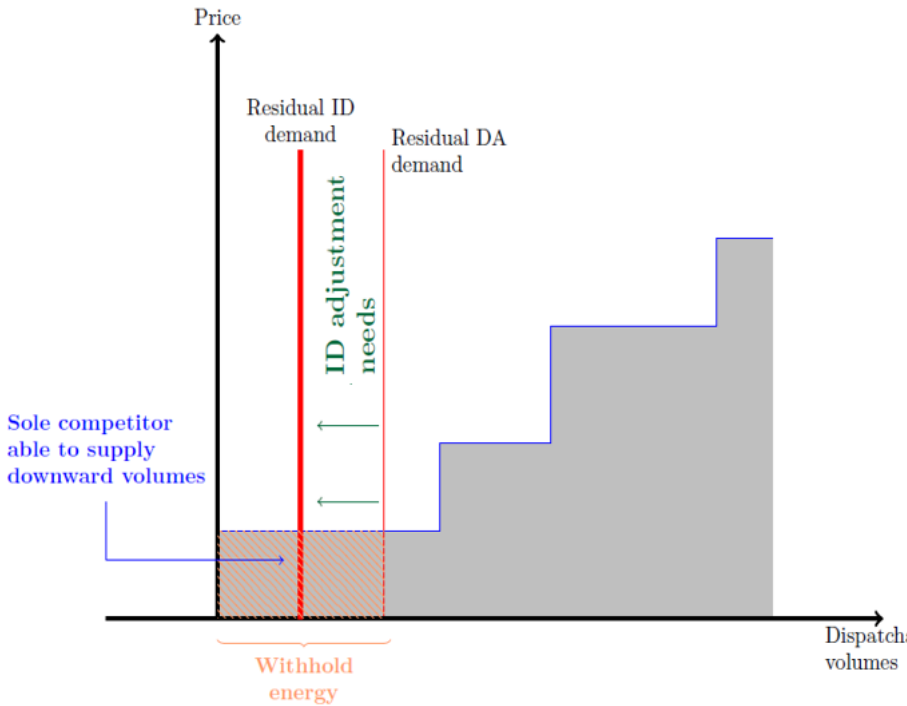

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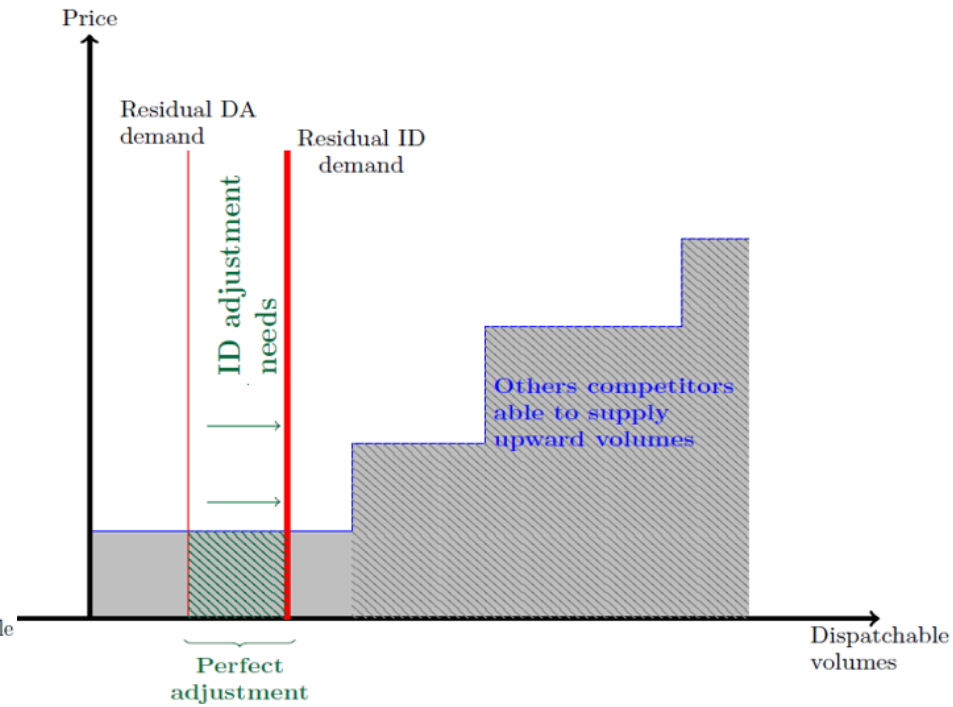

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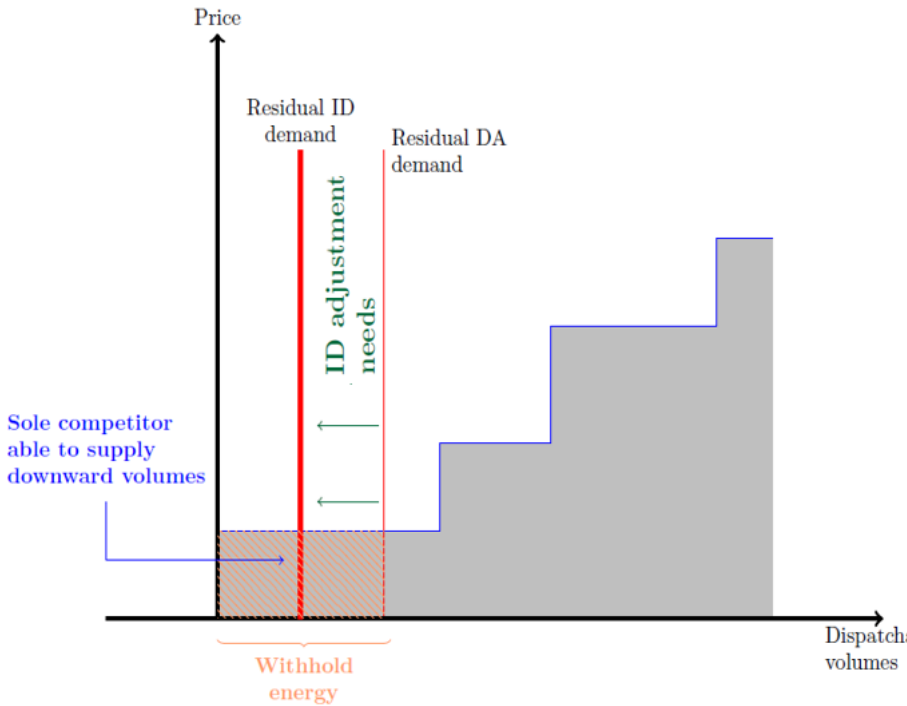

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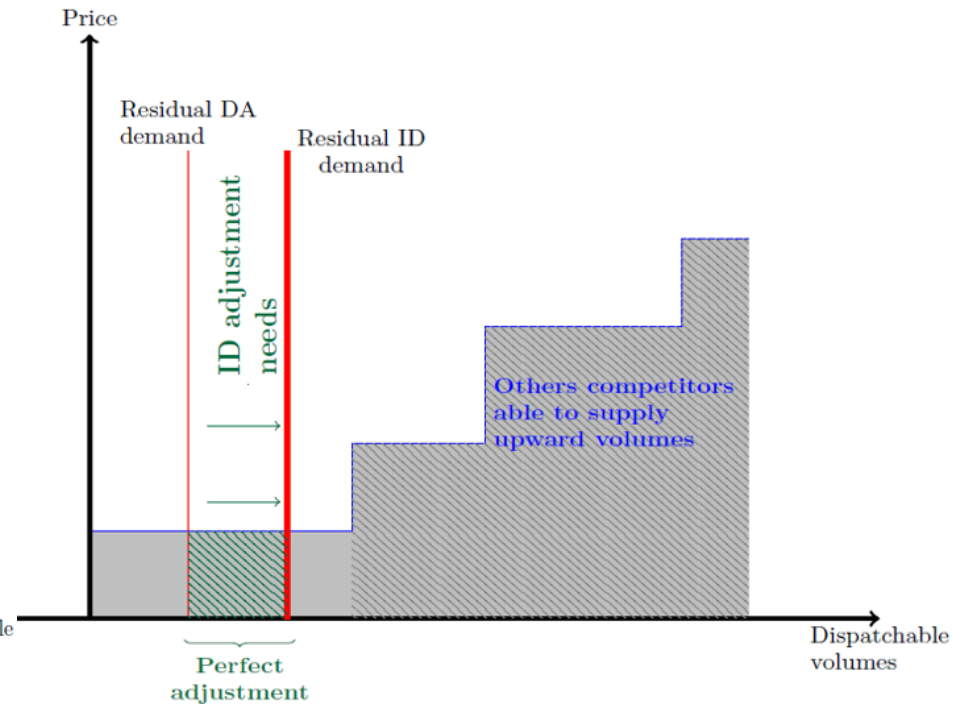

Perfect adjustment in ID ⇒ no imbalance in real-time

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ELIA proposal: *Consumer-Centric Market Design*

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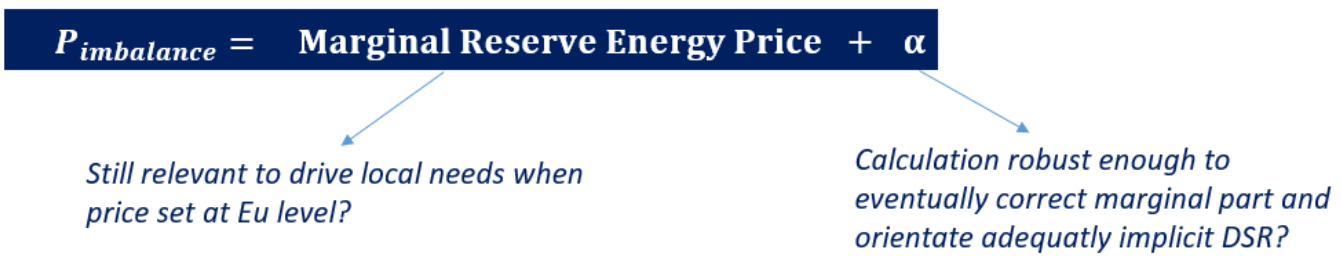
Review of imbalance pricing principle?



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- Magnitude of these effects is larger in France and could be explained by the historically low involvement level of BRPs in real-time balancing of the system due to weak financial incentives provided through IBM
- Intraday market failure could be at the root of this asymmetrical effect

Future research

By identifying an asymmetrical effect of RES on reserve energy needs and proposing a set of potentials explanations in order to explain such phenomenon, our work highlights new issues for futures works:

However our work still suffers from some limitations:

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- Test the potential non-linear relationship between RES penetration and reserve energy through more sophisticated models

Thank You

Contact: mathieu.richard@dauphine.eu

References

Borggrefe, F., Neuhoff, K., 2011. Balancing and Intraday Market Design: Options for Wind Integration. SSRN Electron. J. https://doi.org/10.2139/ssrn.1945724

Deman, L., Boucher, Q., 2023. Impact of renewable energy generation on power reserve energy demand. Energy Econ. 128, 107173. https://doi.org/10.1016/j.eneco.2023.107173

Eicke, A., Ruhnau, O., Hirth, L., 2021. Electricity balancing as a market equilibrium: An instrument-based estimation of supply and demand for imbalance energy. Energy Econ. 102, 105455. https://doi.org/10.1016/J.ENECO.2021.105455

Goodarzi, S., Perera, H.N., Bunn, D., 2019. The impact of renewable energy forecast errors on imbalance volumes and electricity spot prices. https://doi.org/10.1016/j.enpol.2019.06.035

Håberg, M., Doorman, G., 2016. Classification of balancing markets based on different activation philosophies: Proactive and reactive designs, in: 2016 13th International Conference on the European Energy Market (EEM). Presented at the 2016 13th International Conference on the European Energy Market (EEM), pp. 1–5. https://doi.org/10.1109/EEM.2016.7521272

Hickey, E., Loomis, D.G., Mohammadi, H., 2012. Forecasting hourly electricity prices using ARMAX–GARCH models: An application to MISO hubs. Energy Econ. 34, 307–315. https://doi.org/10.1016/j.eneco.2011.11.011

Hirth, L., 2013. The market value of variable renewables. Energy Econ. 38, 218–236. https://doi.org/10.1016/j.eneco.2013.02.004

Hirth, L., Ziegenhagen, I., 2015. Balancing power and variable renewables: Three links. Renew. Sustain. Energy Rev. 50, 1035–1051. https://doi.org/10.1016/J.RSER.2015.04.180

Koch, C., Hirth, L., 2019. Short-term electricity trading for system balancing: An empirical analysis of the role of intraday trading in balancing Germany's electricity system. Renew. Sustain. Energy Rev. 113, 109275. https://doi.org/10.1016/J.RSER.2019.109275

References

Ocker, F., Ehrhart, K.M., 2017. The "German Paradox" in the balancing power markets. Renew. Sustain. Energy Rev. 67, 892–898. https://doi.org/10.1016/J.RSER.2016.09.040

Sirin, S.M., Yilmaz, B.N., 2020. Variable renewable energy technologies in the Turkish electricity market: Quantile regression analysis of the merit-order effect. Energy Policy 144. https://doi.org/10.1016/j.enpol.2020.111660

Vandezande, L., Meeus, L., Belmans, R., Saguan, M., Glachant, J.-M., 2010. Well-functioning balancing markets: A prerequisite for wind power integration. Energy Policy, Large-scale wind power in electricity markets with Regular Papers 38, 3146–3154. https://doi.org/10.1016/j.enpol.2009.07.034

Vandezande, L., Saguan, M., Meeus, L., Glachant, J.-M., Belmans, R., 2009. Assessment of the implementation of cross-border balancing trade between Belgium and the Netherlands, in: 2009 6th International Conference on the European Energy Market. Presented at the 2009 6th International Conference on the European Energy Market, pp. 1–6. https://doi.org/10.1109/EEM.2009.5207126