Quantifying the asymmetric effects of renewable energy on the electricity merit-order curve

Kyriaki Tselika
PhD Research Scholar
Norwegian School of Economics
Department of Business and Management Science

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Renewable energy and the electricity sector

Renewable energy is playing a crucial role in mitigating climate change worldwide but at a cost. Its intermittent nature.

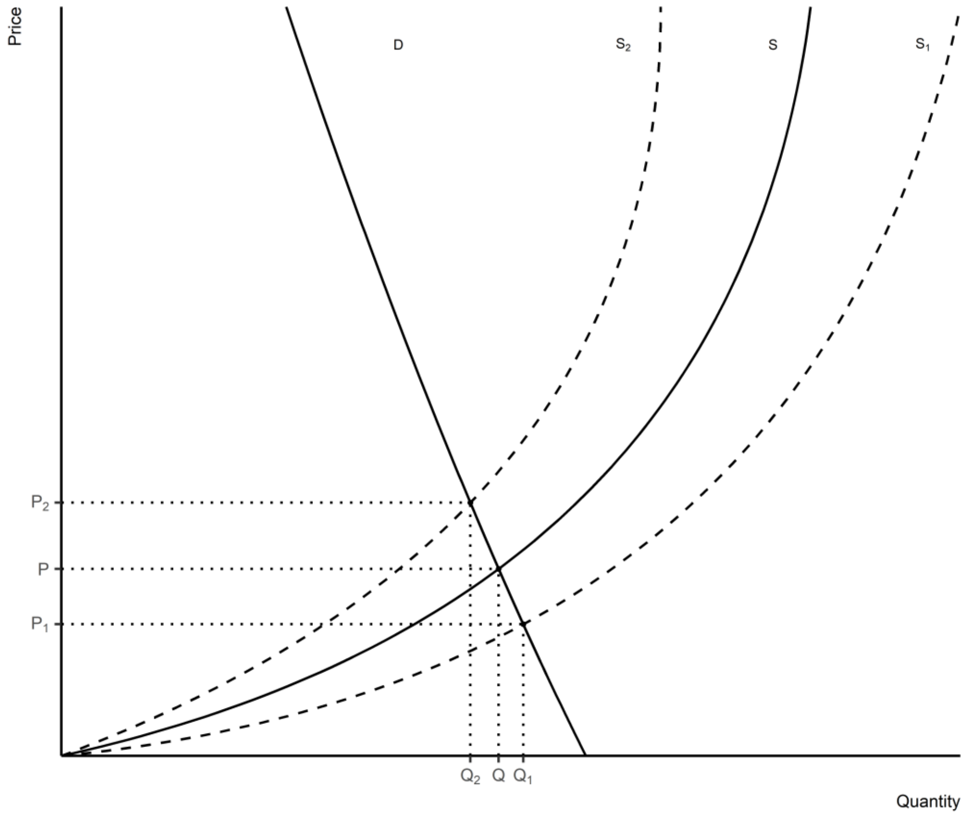
It can challenge the system's reliability and future security of electricity supply.

In addition, the renewable penetration in the system can jeopardize future investments in renewable energy and flexible systems (for instance, storage facilities) due to the Merit-order effect.

The Merit-order effect states that an increase in renewable energy will reduce electricity prices. This effect has been widely investigated and validated.

Until now, electricity prices and renewable energy models have assumed that an increase in renewable energy would have a proportionate decrease in electricity prices as a decrease of renewables would increase prices.

The electricity merit-order curve



- We can see that an increase in supply from S to S1, for instance, by renewable sources is decreasing electricity prices as expected from P to P1.
- When supply is reduced from S to S2 prices increase from P to P2.
- What we notice in the graph is that changes in supply can create asymmetric changes in electricity prices.
- Therefore, prices can be more sensitive to increases or reductions in renewable energy production.

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Research Questions

Do renewable sources have an asymmetric effect on electricity prices?

Do renewable sources have an asymmetric effect on electricity transmission between areas?

Does congestion between regions amplify this asymmetric effect?

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Data and Method

- Data from Denmark and Sweden for the period 1.1.2016-31.12.2019

- Asymmetric fixed-effects models for Panel Data (Allison, 2019): This method allows us to use the high frequency data and control for hourly fixed effects.

- In order to investigate asymmetries, difference scores for predictor variables can be decomposed into positive and negative components. Thus:

$$X_{it}^{+} = X_{it} - X_{it-1} \; if \; (X_{it} - X_{it-1}) > 0, \text{ otherwise } 0,$$
$$X_{it}^{-} = -(X_{it} - X_{it-1}) \; if \; (X_{it} - X_{it-1}) < 0, \text{ otherwise } 0.$$

We calculate the individual accumulations of the positive and negative changes in X such as:

$$Z_{it}^{+} = \sum_{s=1}^{t} X_{is}^{+} \quad \text{and} \quad Z_{it}^{-} = \sum_{s=1}^{t} X_{is}^{-}$$

Then the model simply becomes:

$$Y_{it} = \mu_t + \beta^{+} Z_{it}^{+} + \beta^{-} Z_{it}^{-} + \alpha_i + \varepsilon_{it}$$

- Estimating 2 price models, 3 transmission models and 2 congestion models.

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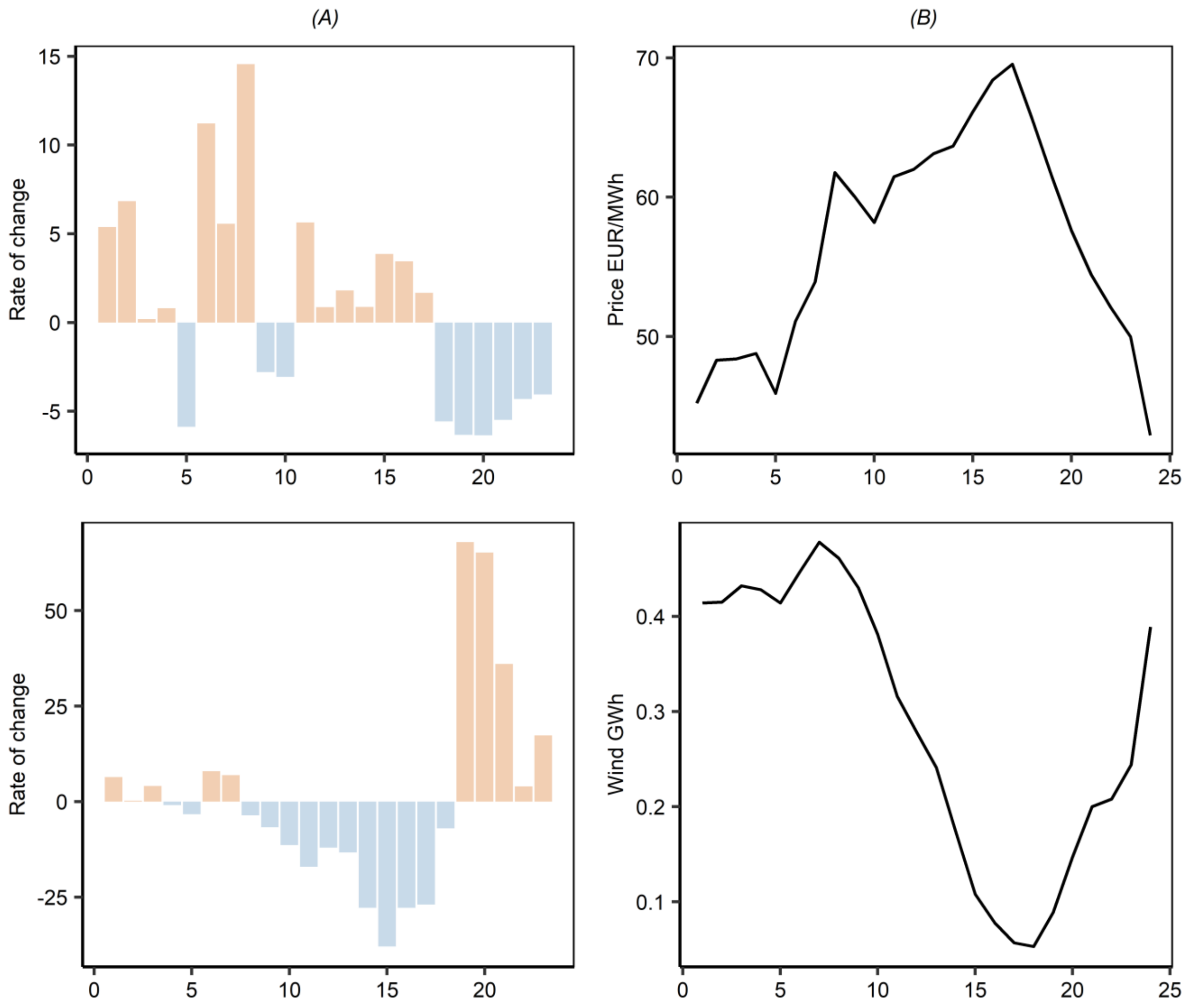
The rate of change of wind and electricity prices



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Results (I) - The estimates of the price models for the DK1 and DK2 regions

Variables	P^{DK2}	P^{DK1}
W^{+}_{DK2}	-9.242***	-9.352***
W^{-}_{DK2}	10.136***	9.834***
W^{+}_{DK1}	-2.006***	-3.413***
W^{-}_{DK1}	2.071***	3.438***
W^{+}_{SE3}		-1.711***
W^{-}_{SE3}		1.226***
W^{+}_{SE4}	-3.012***	
W^{-}_{SE4}	1.63***	
Intercept	0.10	-0.016***

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Results (II) - The estimates of the net transmission

Variables	$NT^{DK2-SE4}$	$NT^{DK1-SE3}$	$NT^{DK1-DK2}$
W_{DK2}^{+}	1332.39***	240.95***	81.216***
W_{DK2}^{-}	-1224.03***	-247.263***	-101.813***
W_{DK1}^{+}	94.547***	196.18***	-127.506***
W_{DK1}^{-}	-108.323***	-195.845***	134.803***
W_{SE3}^{+}		-223.877***	
W_{SE3}^{-}		213.185***	
W_{SE4}^{+}	-495.551***		168.888***
W_{SE4}^{-}	412.704***		-143.176***
Intercept	8.15***	4.734***	-3.873***

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Results (III) - The estimates of prices with congestion

When there is congestion between DK1-DK2 the asymmetric effect of wind in DK2 are intensified. Originally, an increase in WDK2 will decrease prices by -5.308 and a decrease in wind will increases prices by 5.851.

An increase in WDK2 will decrease prices by -6.513 while a decrease in WDK2 will increase prices by 8.625. We can see how congestion amplifies the asymmetric effects of wind on prices.

We notice a similar pattern for wind in DK1. The asymmetric effects for WSE4 are not significant.

We notice stronger asymmetries due to congestion between DK2-SE4 as well. The effect is stronger for wind in DK2.

Overall, we can see that congestion can increase asymmetries in electricity markets. Thus, when there is congestion the market can be more risky with unexpected events.

Implications

Participants

- The asymmetric effects could create more risk in the market.
- Organizations could use the information on market uncertainty to discover future profit opportunities.

Government

- This information should be considered by governments to optimally allocate transmission capacity between bidding zones and understand the fundamental variables that control electricity price fluctuations.
- The transmission and congestion results support the need for higher interconnection capacity between bidding zones.

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Thank you!

Contact: kyriaki.tselika@nhh.no