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Does Cross-Border Electricity Trade Stabilize the Market Value of Wind and Solar Energy? Insights from a European Panel Analysis

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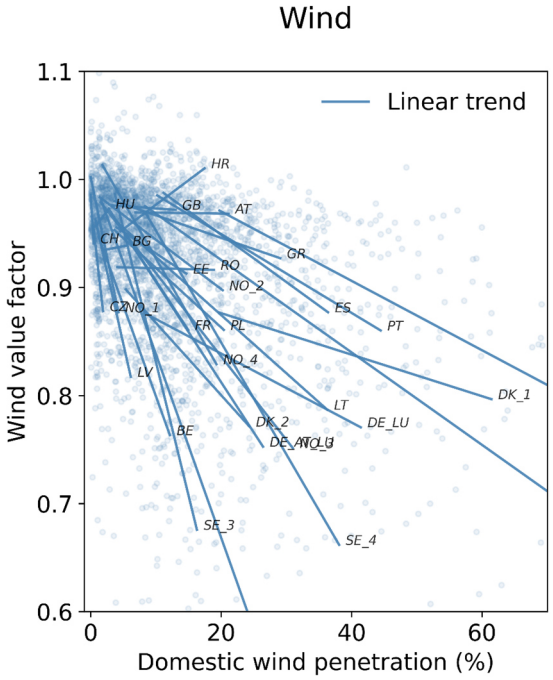
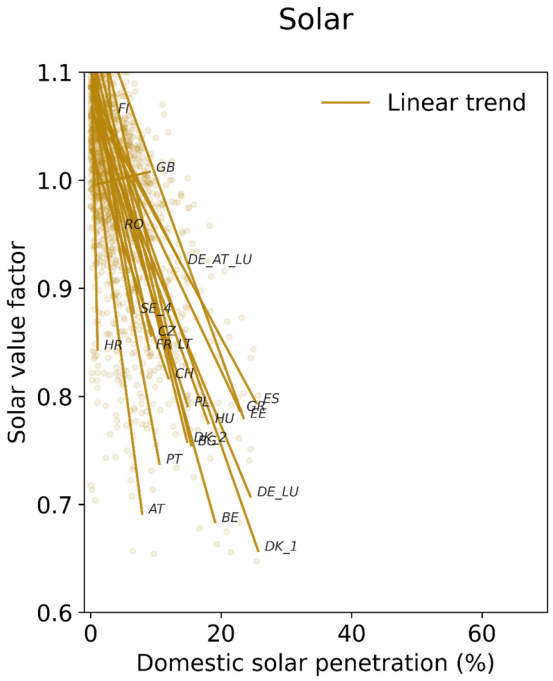
Motivation

- Negative effect of domestic wind & solar market penetration on market value is well-explored
- …but cross-border effects receive less attention
- We estimate cross-border effects on renewable market value across 30 European bidding zones
  - Jointly estimate domestic and spatial effect of wind/solar market penetration
  - Estimate moderating effect of market connectedness
  - Control for market features that determine the value drop



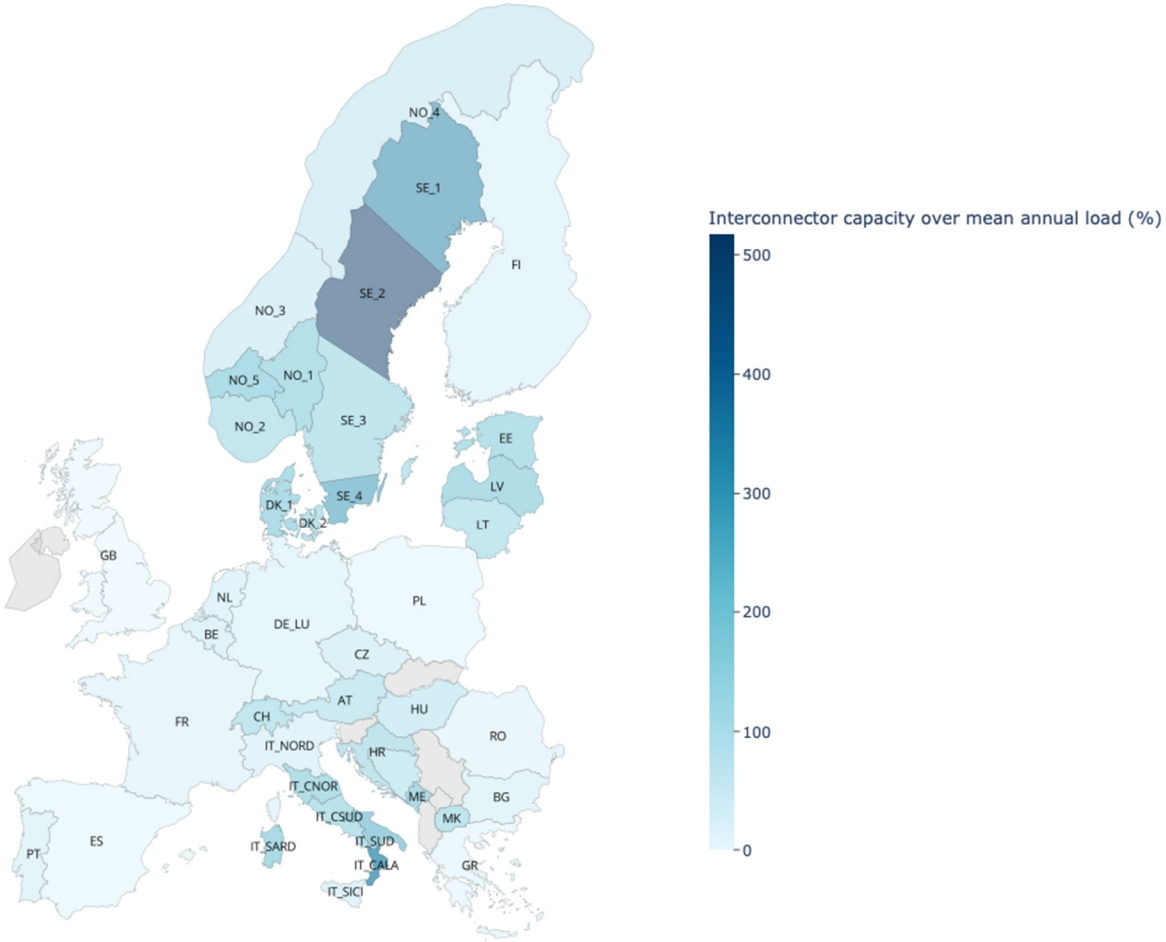


Model variables and expected effects

	Variables	Expected effects
Dependent	Value factor of wind (solar)	
Independent	Domestic wind (solar) penetration	Negative
	Neighboring wind (solar) penetration	Negative
	Interconnector capacity	Positive / negative
	Controls	
	Reservoir hydro capacity	Positive
	Pumped hydro capacity	Positive
	Coefficient of variation of wind (solar) generation	Negative
	Correlation of wind (solar) generation and system load	Positive
	Clean gas-coal price ratio	Negative

Data

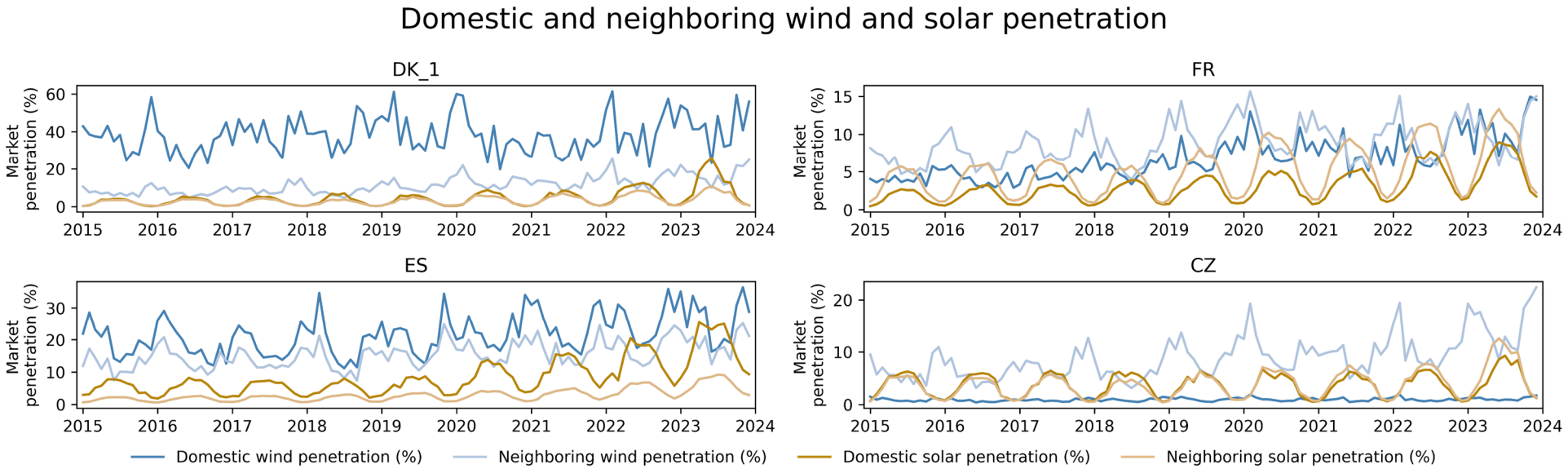
- We use electricity market data from 2015-2023 aggregated at the monthly level
- Data retrieved from ENTSO-E TP and national authorities



Modelling spatial effects

- We model the effect of wind/solar market penetration across a bidding zone's direct neighbors on domestic market value (*spatial lag of X* approach)

- Wind/solar market penetration of bidding zone i's neighbor j is weighted by normalized interconnector capacity between i and j



Identification strategy

- Renewable generation is weather-driven but cross-border flows and hydro electricity generation are endogenous to prices

- We use capacities instead of flows/generation
  - Interconnector capacity
    - Approximated by annual 95% quantile of hourly bilateral commercial exchanges
  - Hydro pumped storage and reservoir capacity
  - All capacity data normalized by mean annual zonal load

Model specification

- Fixed effects (FE) estimation eliminates the variation we are interested in
- *Random effects within-between model* (Mundlak, 1978, Bell & Jones, 2014)
- Idea: Split up variation in $X_{i,t}$ into two parts:
  - Variation within entities: $X_{i,t} - \overline{X_i}$
  - Variation between entities: $\overline{X_i}$
- *Within* effects $\beta(X_{i,t} - \overline{X_i})$ are equivalent to coefficients from a FE model
- *Between* effects $\beta(\overline{X_i})$ explicitly model heterogeneity at the zone level

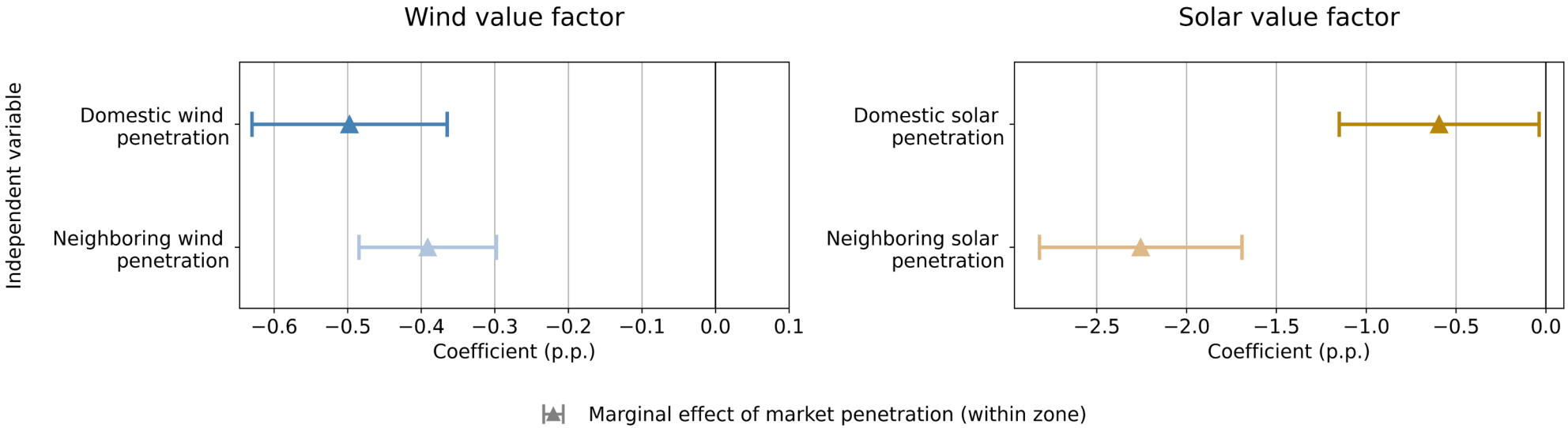
Model specification

$$VF_{i,t}^{w} = \beta_0 + \beta_1 \ddot{P}_{i,t}^{w} + \beta_2 \bar{P}_i^{w} + \beta_3 \ddot{P}_{sp}{}_{i,t}^{w} + \beta_4 \overline{P_{sp}}_i^{w}$$
$$+\beta_5 I_i + \beta_6 \ddot{P}_{i,t}^{w} * I_i + \beta_7 \ddot{P}_{sp}{}_{i,t}^{w} * I_i + \beta_8 \ddot{P}_{i,t}^{s}$$
$$+\beta_9 \bar{P}_i^{s} + \beta_{10} \ddot{P}_{sp}{}_{i,t}^{s} + \beta_{11} \overline{P_{sp}}_i^{s}$$
$$+\beta' C + \beta' \ddot{P}_{i,t}^{w} * \ddot{C} + \beta' \ddot{P}_{i,t}^{w} * \bar{C} + \gamma' D_t + \varepsilon_{i,t}$$

- $VF_{i,t}^{w}$ — Value factor of wind
- $\ddot{P}_{i,t}^{\{w,s\}} = P_{i,t}^{\{w,s\}} - \bar{P}_i^{\{w,s\}}$ — Domestic wind/solar market penetration (within zone)
- $\ddot{P}_{sp}{}_{i,t}^{\{w,s\}} = P_{sp}{}_{i,t}^{\{w,s\}} - \overline{P_{sp}}_i^{\{w,s\}}$ — Neighboring wind/solar market penetration (within zone)
- I_i — Interconnector capacity
- C — Vector of controls
- D_t — Month and year dummies
- $\varepsilon_{i,t}$ — Error term

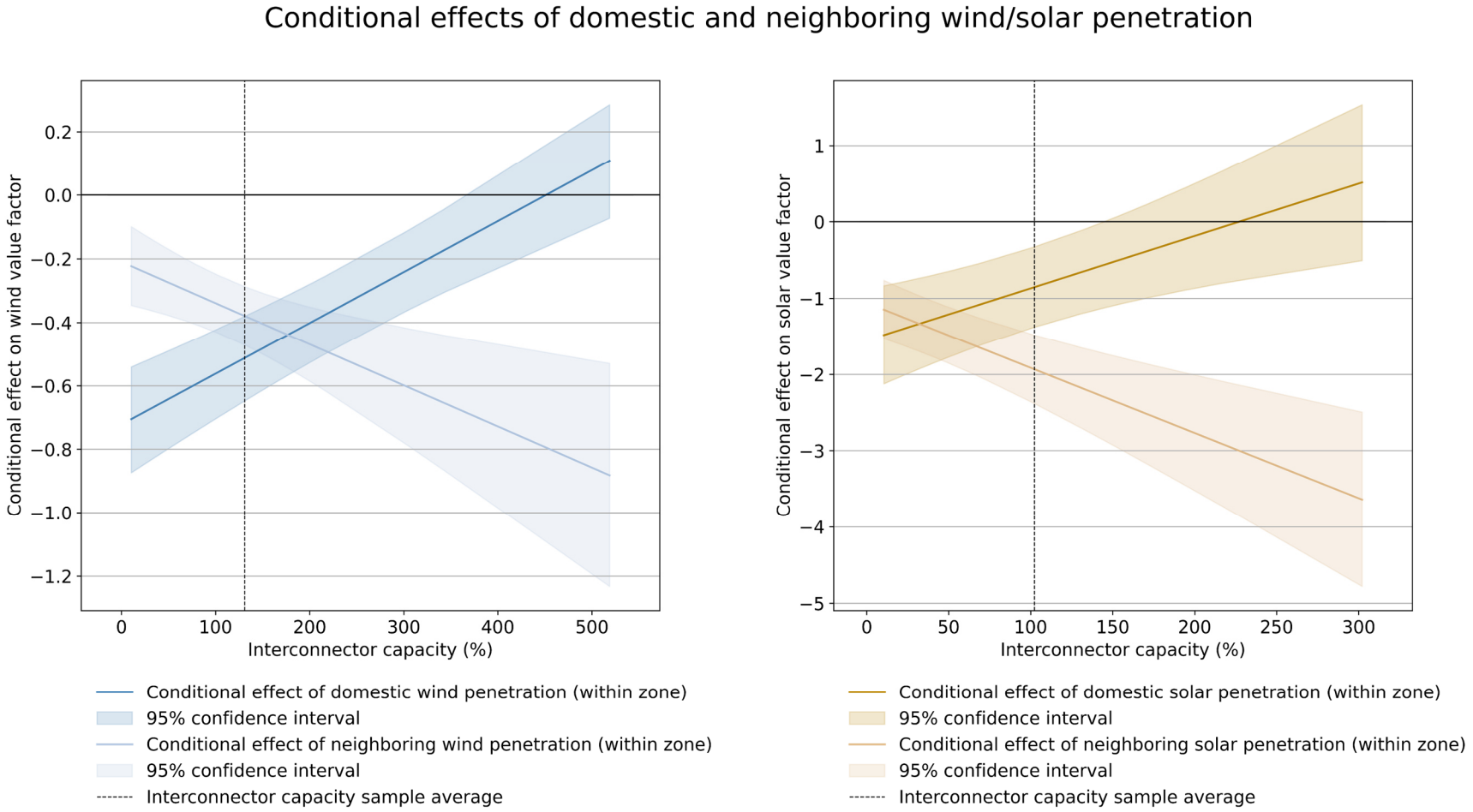
Results

- We find substantial domestic and cross-border effects of market penetration on market value
- Domestic effect of solar is stronger (because of simultaneity)
- Cross-border effect of solar is stronger (because of geographic smoothing of wind)



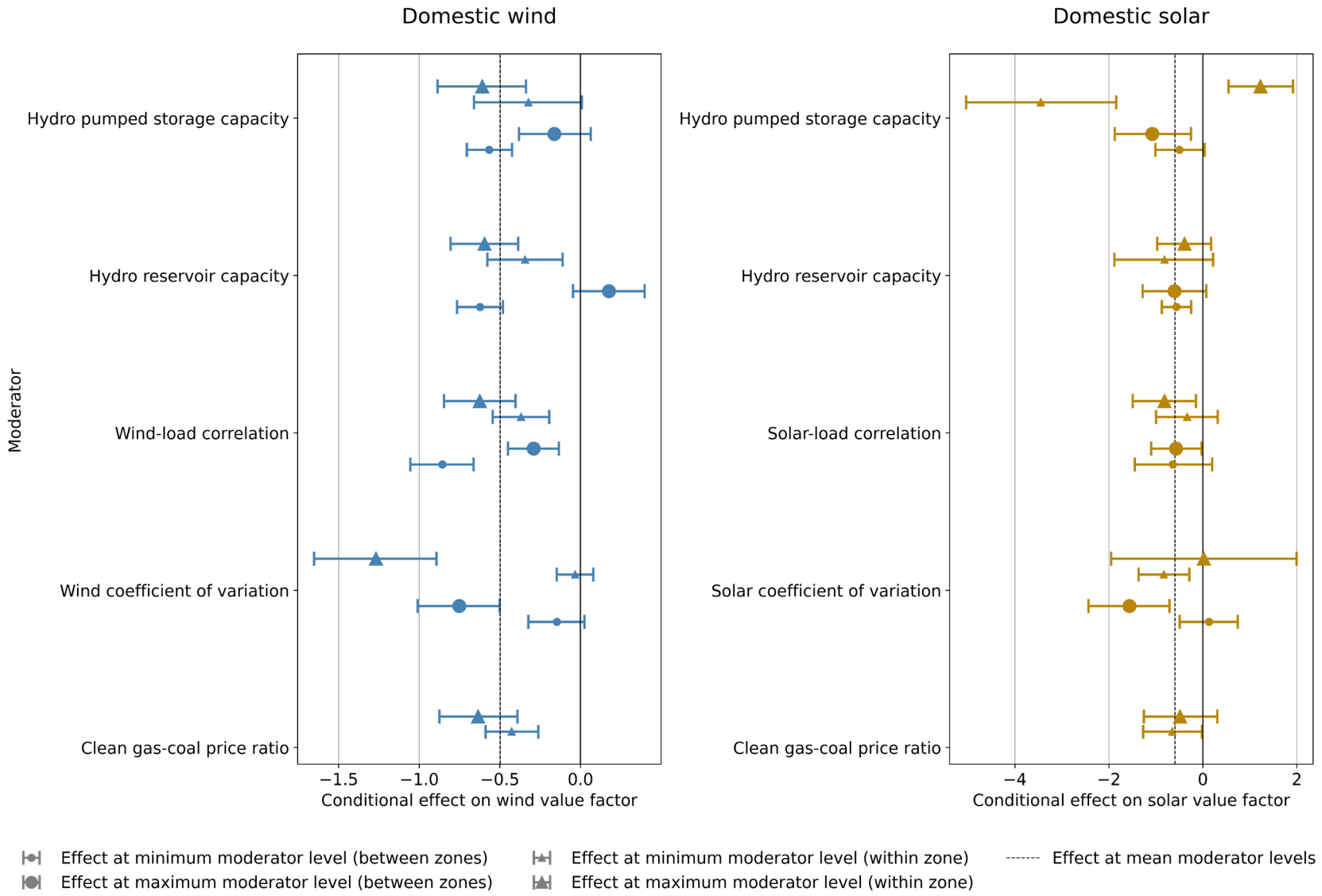
Results

- Connectedness mitigates domestic value drop (through exports)
- …but exacerbates cross-border spillovers (through imports)



Results

- We can identify more factors that mitigate the wind value drop



Conclusion

- We confirm the negative effect of domestic wind/solar market penetration on market value
- In addition, we find substantial spatial effects which are stronger for solar
- Connectedness of price zones mitigates the domestic value drop but exacerbates spillover effects
- Hydro flexibility, load correlation and smoother generation profile can mitigate the value drop

Thank you!

	Wind value factor		Solar value factor	
	Within effects	*Between effects*	*Within effects*	*Between effects*
Wind share	-0.498*** (0.068)	-0.168*** (0.014)	0.039 (0.033)	0.125*** (0.027)
Wind share, spatially lagged	-0.391*** (0.048)	-0.269*** (0.032)	0.264*** (0.053)	0.12*** (0.029)
Solar share	0.171** (0.081)	-0.169*** (0.062)	-0.594** (0.284)	-1.44*** (0.127)
Solar share, spatially lagged	0.173** (0.071)	0.447*** (0.052)	-2.256*** (0.287)	-1.874*** (0.191)
Trade capacity		-0.001 (0.003)		-0.007 (0.006)
Hydro pumped storage capacity	-0.021 (0.033)	0.034*** (0.004)	0.124* (0.067)	0.039*** (0.007)
Hydro reservoir capacity	0.079** (0.035)	0.023*** (0.003)	0.13 (0.112)	-0.027*** (0.01)
Clean gas-coal price ratio	-0.007 (0.008)		0.023 (0.015)	
Wind-load correlation	0.105*** (0.018)	-0.037 (0.03)		
Wind coefficient of variation	-0.166*** (0.018)	-0.073*** (0.021)		
Wind share*Trade capacity		0.16*** (0.025)		
Wind share spatially lagged*Trade capacity		-0.13*** (0.042)		
Wind share*Hydro pumped storage capacity	-0.596 (0.588)	0.477*** (0.137)		
Wind share*Hydro reservoir capacity	-0.331 (0.24)	0.222*** (0.034)		
Wind share*Clean gas-coal price ratio	-0.124 (0.09)			
Wind share*Wind-load correlation	-0.229* (0.138)	1.567*** (0.324)		
Wind share*Wind coefficient of variation	-1.055*** (0.189)	-1.241*** (0.385)		
Solar-load correlation			0.235*** (0.036)	-0.036 (0.033)
Solar coefficient of variation			0.006 (0.023)	-0.022 (0.031)
Solar share*Trade capacity				0.683*** (0.22)
Solar share spatially lagged*Trade capacity				-0.855*** (0.212)
Solar share*Hydro pumped storage capacity			9.751*** (2.163)	-0.686** (0.282)
Solar share*Hydro reservoir capacity			3.256 (4.884)	-0.058 (0.407)
Solar share*Clean gas-coal price ratio			0.099 (0.236)	
Solar share*Solar-load correlation			-0.566 (0.461)	0.163 (0.83)
Solar share*Solar coefficient of variation			0.271 (0.36)	-2.363*** (0.698)
Intercept and year/month dummies	Yes		Yes	
R^2	0.506		0.643	
Observations	2650		1941	