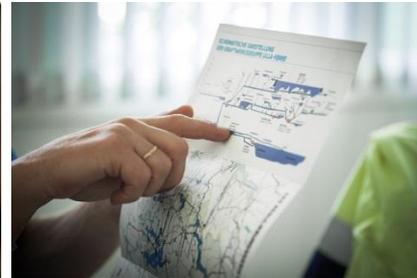


The Merit Order Effect of Wind and PV Generation in Germany

Estimation and Implications

Johanna Cludius

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Main findings

- Considerable merit order effects 2008-2012 & likely to grow in the future
- Likely overcompensates exempt industry for contribution to costs of RES support policy
- Costs could be more equally distributed between industry and households

1 Overview

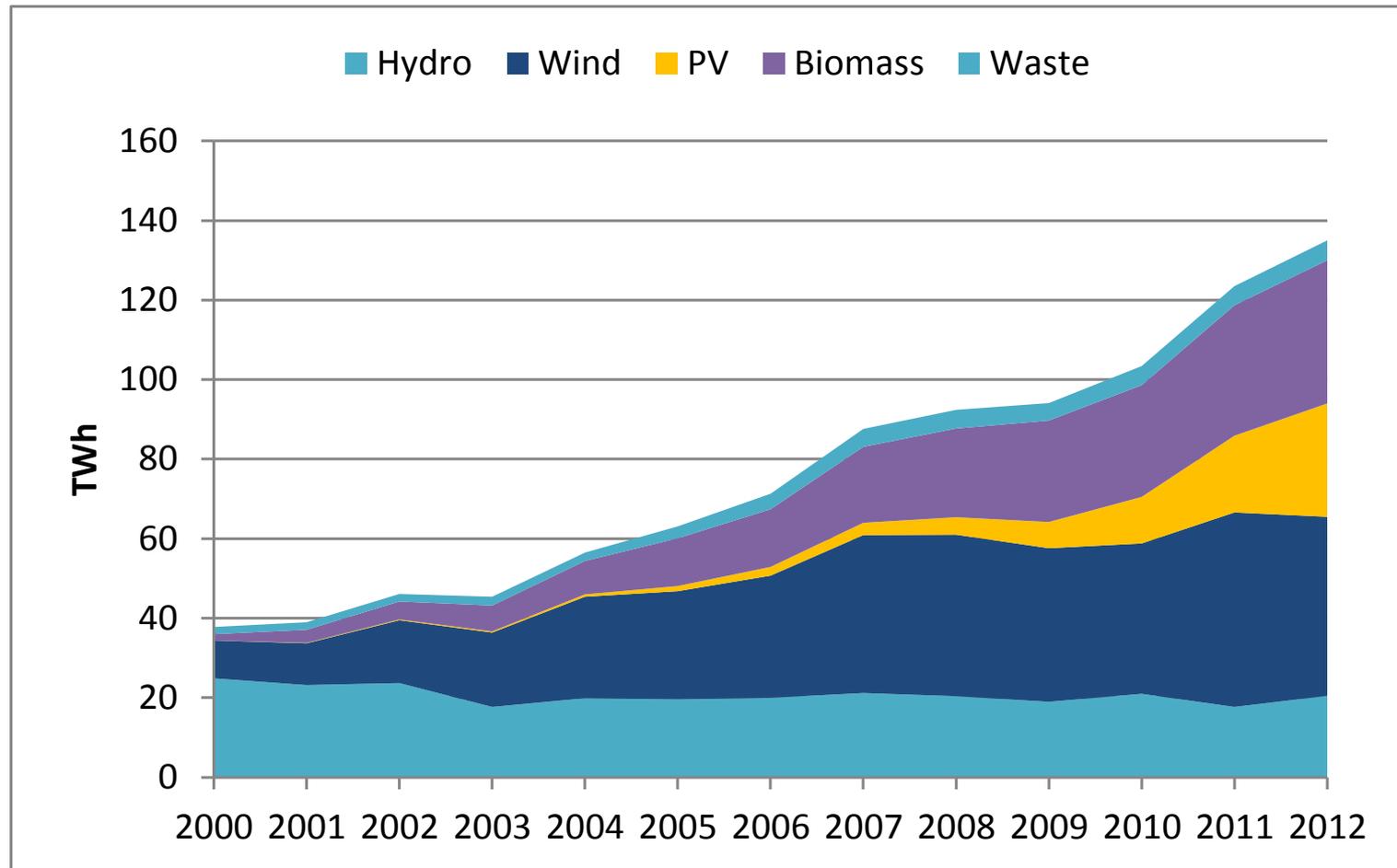
2 Data

3 Methods

4 Results

5 Conclusions

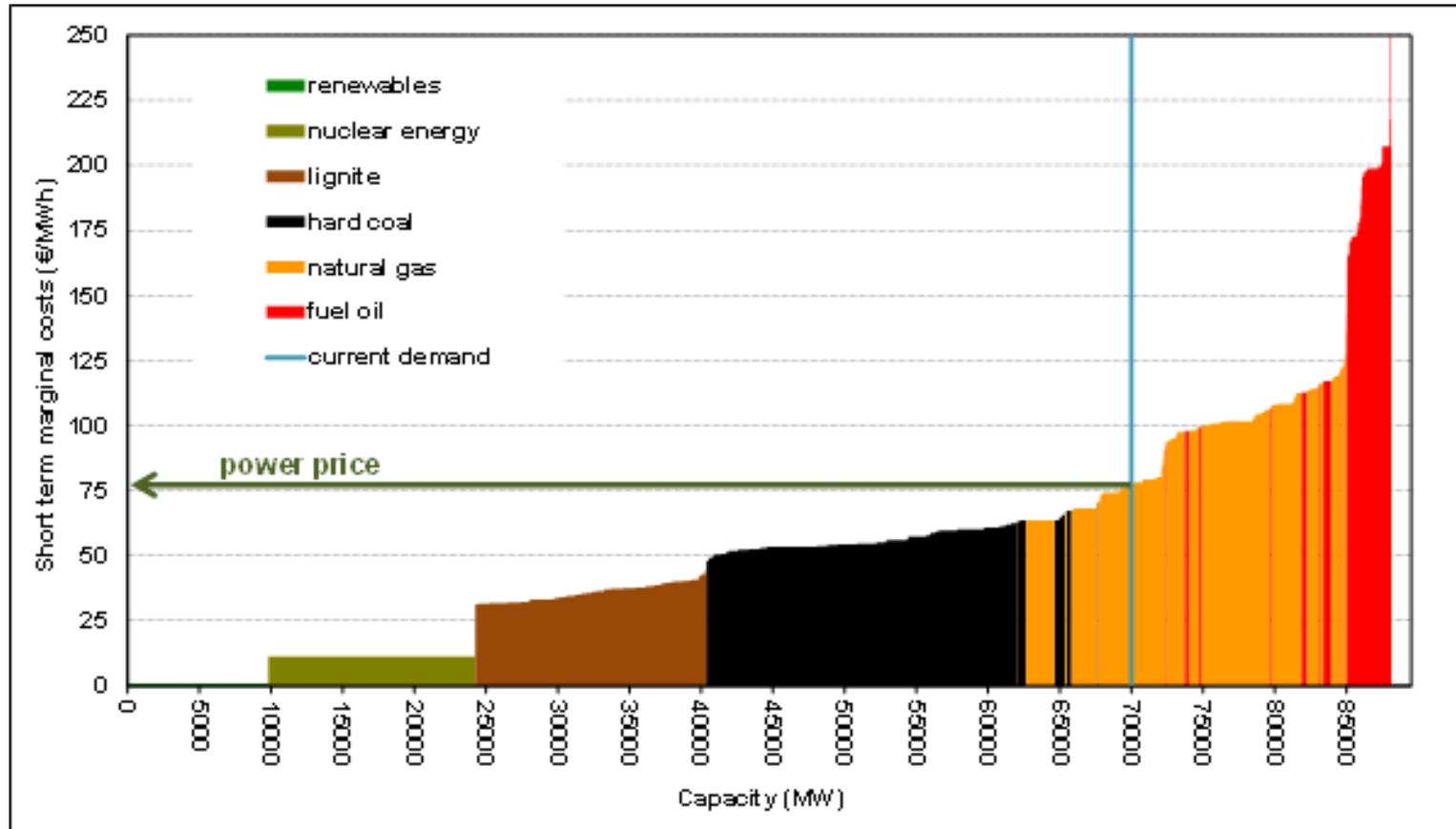
Generation from RES in Germany



Renewable Energy Support Act (EEG)

- Priority feed-in, purchase guarantee, fixed prices
- Cost passed on to consumers in form of a surcharge
 - Privileged group (mainly energy-intensive industry) pay reduced surcharge of 0.05 ct/kWh
 - Non-privileged group (households, small business) pay full surcharge of 1.12 ct/kWh (2008) - 3.59 ct/kWh (2012)
 - Costs depend on: expansion path of RES, remuneration rates, but also CO₂ prices, fuel prices and other economic indicators, which influence electricity prices
- Goal: At least 80% renewables in electricity consumption in 2050

Stylized German merit order curve



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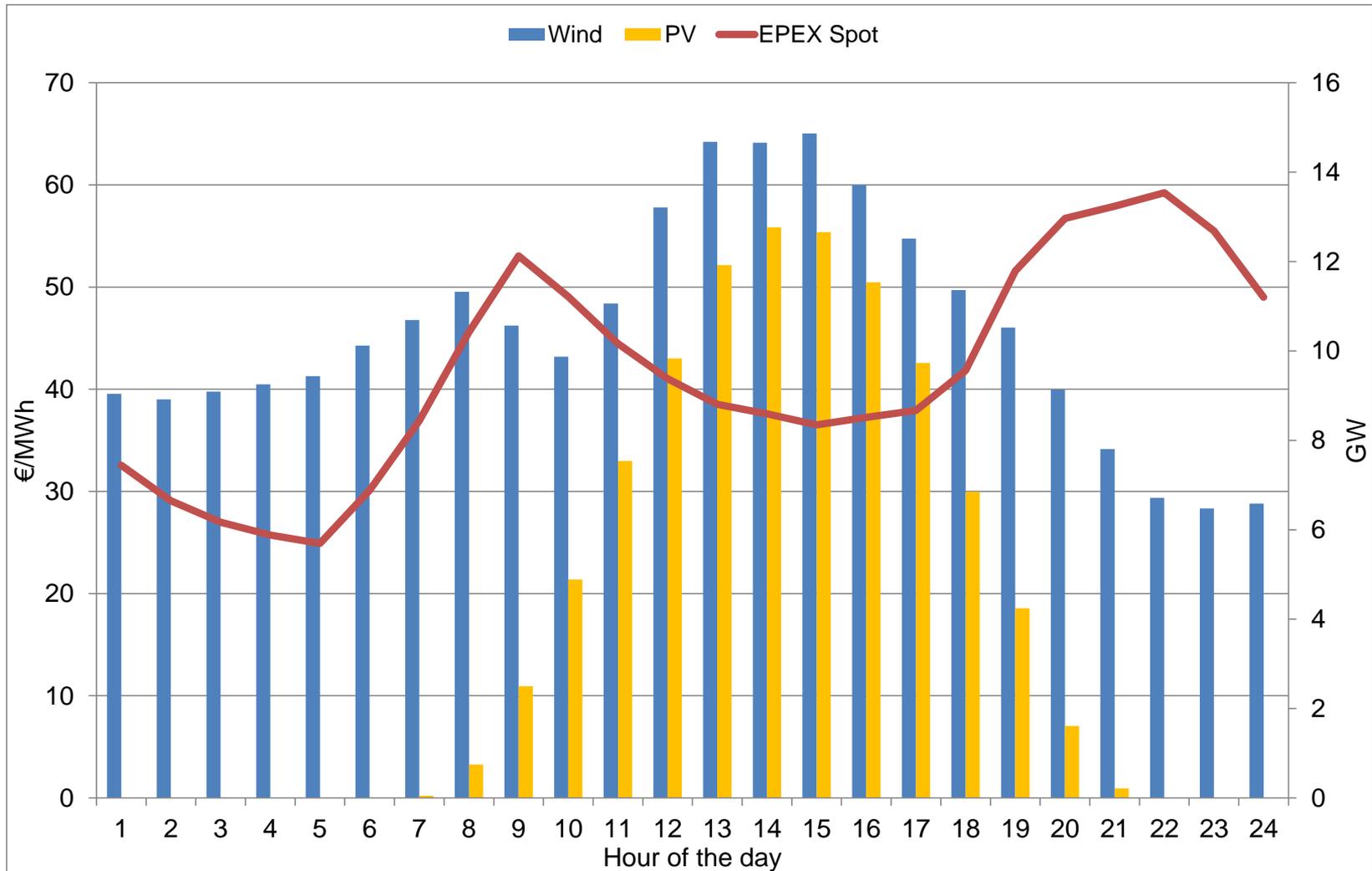
5 Conclusions

Summary statistics and data characteristics

	2008			2009			2010			2011			2012		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Spot (€/MWh)	65.76	-102.00	494.00	38.86	-500.00	182.00	44.49	-20.00	132.00	51.12	-36.82	117.49	42.59	-221.99	210.00
Wind (GW)	4.62	0.14	19.23	4.41	0.13	20.63	4.31	0.12	22.75	5.58	0.10	25.21	5.24	0.14	24.09
PV (GW)							1.10	0.00	9.04	2.20	0.00	13.62	3.19	0.00	22.20
Load (GW)	56.42	34.31	76.76	52.48	28.98	72.97	55.77	34.61	79.88	55.35	32.39	76.43	53.46	29.20	74.48
Obs.		8,783			8,760		8,760	3,983 for PV		8,760			8,784		

- Hourly time-series data
- EPEX Spot price, EEX: Wind, PV in-feed, entso-e: Total load
- All series stationary (ADF and Phillips-Perron Test)
- Sensitivity analysis with daily averaged data in first differences (non-stationary in levels)

26/04/2012 – A sunny and windy day



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Estimation method

$$\begin{aligned}
 \text{Spot}_t = & \beta_1 \text{wind}_t + \beta_2 \text{pv}_t + \beta_3 \text{load}_t \\
 & + \sum_{k=1}^{23} \beta_{k+3} \text{dh}_{kt} + \sum_{l=1}^7 \beta_{l+26} \text{dd}_{lt} + \sum_{m=1}^{11} \beta_{m+33} \text{dm}_{mt} + \sum_{n=1}^4 \beta_{n+44} \text{dy}_{nt} + u_t
 \end{aligned}$$

- EPEX Spot dependent on wind and pv in-feed and total load + seasonal dummies
- OLS regression with Newey-West standard errors
- Assumption: Inelastic demand in the short run
- Assumption: Omitted variables (fuel prices, etc.) uncorrelated with explanatory variables
- Alternative specifications lead to very similar results

Total average merit order effect

$$\begin{aligned} \text{Total average MO effect}_y = \\ \beta_{1y} \times \text{load-weighted av(wind)}_y + \beta_{2y} \times \text{load-weighted av(PV)}_y \end{aligned}$$

- Specific yearly effects multiplied by load-weighted average wind and PV in-feed

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Specific merit order effects of wind and PV

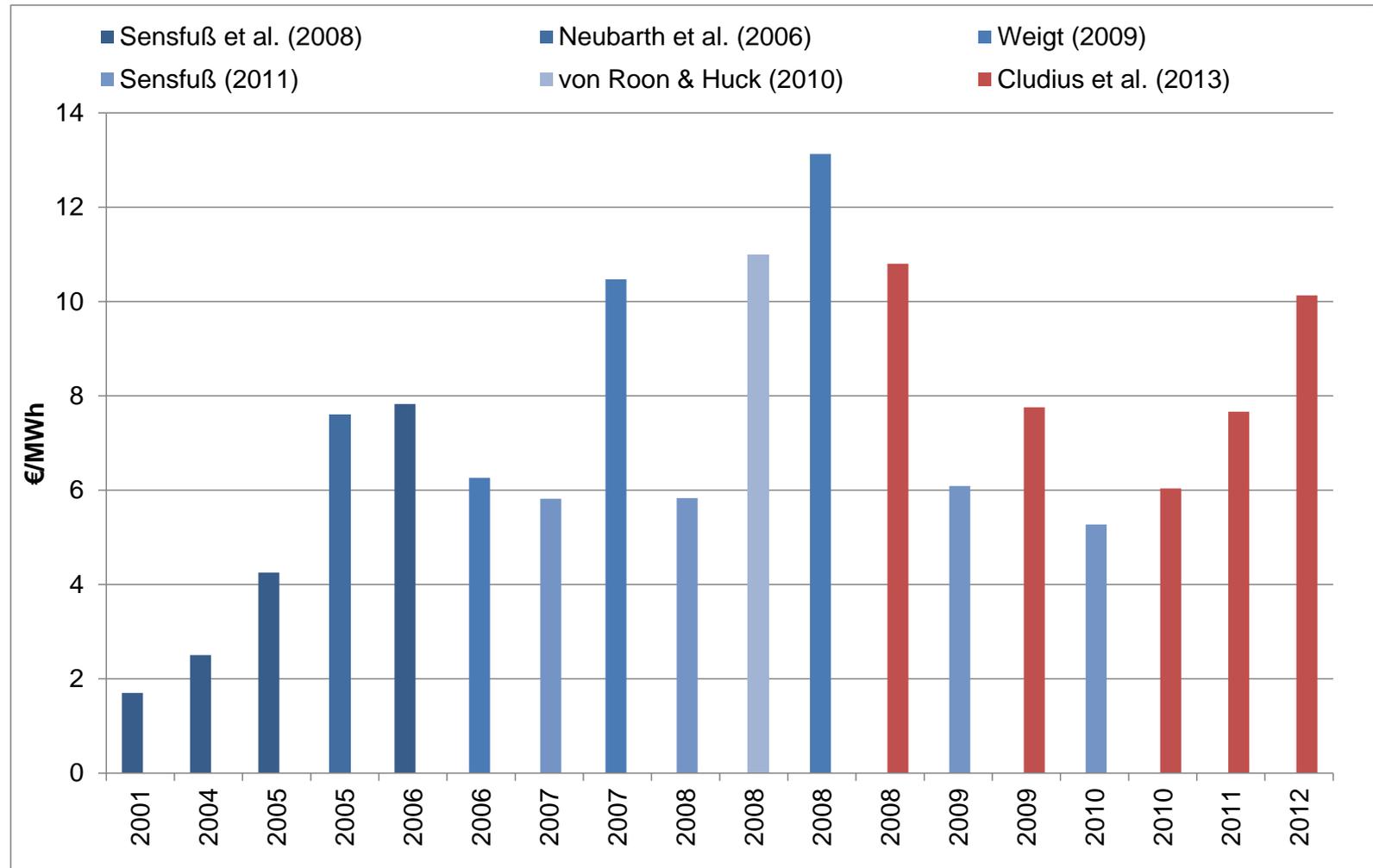
	2008	2009	2010 (first half)	2011	2012
Wind	-2.27*** (0.09)	-1.72*** (0.18)	-1.15*** (0.07)	-0.97*** (0.05)	-1.07*** (0.06)
PV			-0.84*** (0.16)	-0.90*** (0.07)	-1.29*** (0.11)
Load	2.58*** (0.07)	1.36*** (0.06)	1.27*** (0.06)	1.13*** (0.05)	1.65*** (0.15)
Hourly dummies	X	X	X	X	X
Daily dummies	X	X	X	X	X
Monthly dummies	X	X	X	X	X
Yearly dummies	X	X	X	X	X
Adjusted R2	0.80	0.66	0.81	0.81	0.69
DW-Statistic	0.54	0.64	0.42	0.42	0.33
Observations	8,783	8,760	3,983	8,760	8,784
Time frame	01/01/2008 - 31/12/2008	01/01/2009 - 31/12/2009	19/07/2010 - 31/21/2010	01/01/2011 - 31/21/2011	01/01/2012 - 31/21/2012
Newey-West standard errors in parentheses, robust to heteroskedasticity and *** significant at the 99% confidence level					

Average total effects

	2008	2009	2010 (2nd half)	2011	2012
Wind specific effect (€/MWh)	-2.27***	-1.72***	-1.15***	-0.97***	-1.07***
Load-weighted average wind in-feed per hour (GW/h)	4.76	4.51	4.41	5.63	5.20
Wind total effect (€/MWh)	-10.80	-7.76	-5.06	-5.49	-5.58
PV specific effect (€/MWh)			-0.84***	-0.90***	-1.29***
Load-weighted average PV in-feed per hour (GW/h)			1.17	2.41	3.52
PV total effect (€/MWh)			-0.98	-2.17	-4.56
Total average merit order effect of wind and PV (€/MWh)	-10.80	-7.76	-6.04	-7.67	-10.13

- Higher effects in years with high demand, high fuel prices
- Additionally: Regulatory effects, cf. 2009
- Recently, effects rising because of additional RES capacity

Compared to results of other studies



Distribution of costs in 2012

Benefits and costs of EEG in 2012	Merit order effect (ct/kWh)	Surcharge (ct/kWh)
Privileged group (energy-intensive companies)	-1.01	0.05
Non-privileged group (households)		3.59

- Merit order effect likely overcompensates energy-intensive industry for contribution to cost of EEG
- Results for 2012 imply reduced surcharge could be set at 1 ct/kWh instead of 0.05 ct/kWh
- Surcharge for households would be reduced if surcharge for industry closer to merit order effect

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Conclusions

- Considerable merit order effects averaging 10 €/MWh in 2012
- Benefits and costs of EEG could be distributed more equally
 - Raise reduced surcharge
 - Pass merit order effect on to households
- Limitations: Long-term effects, e.g. environmental and energy security benefits, investment in generation / network capacity

Corresponding author

Johanna Cludius

The University of New South Wales

Sydney, Australia

E-Mail: j.cludius@unsw.edu.au

Öko-Institut e.V.

Schicklerstr. 5-7

10179 Berlin

E-Mail: j.cludius@oeko.de



Thank you for your attention!

Do you have any questions?



Forecasting merit order effects

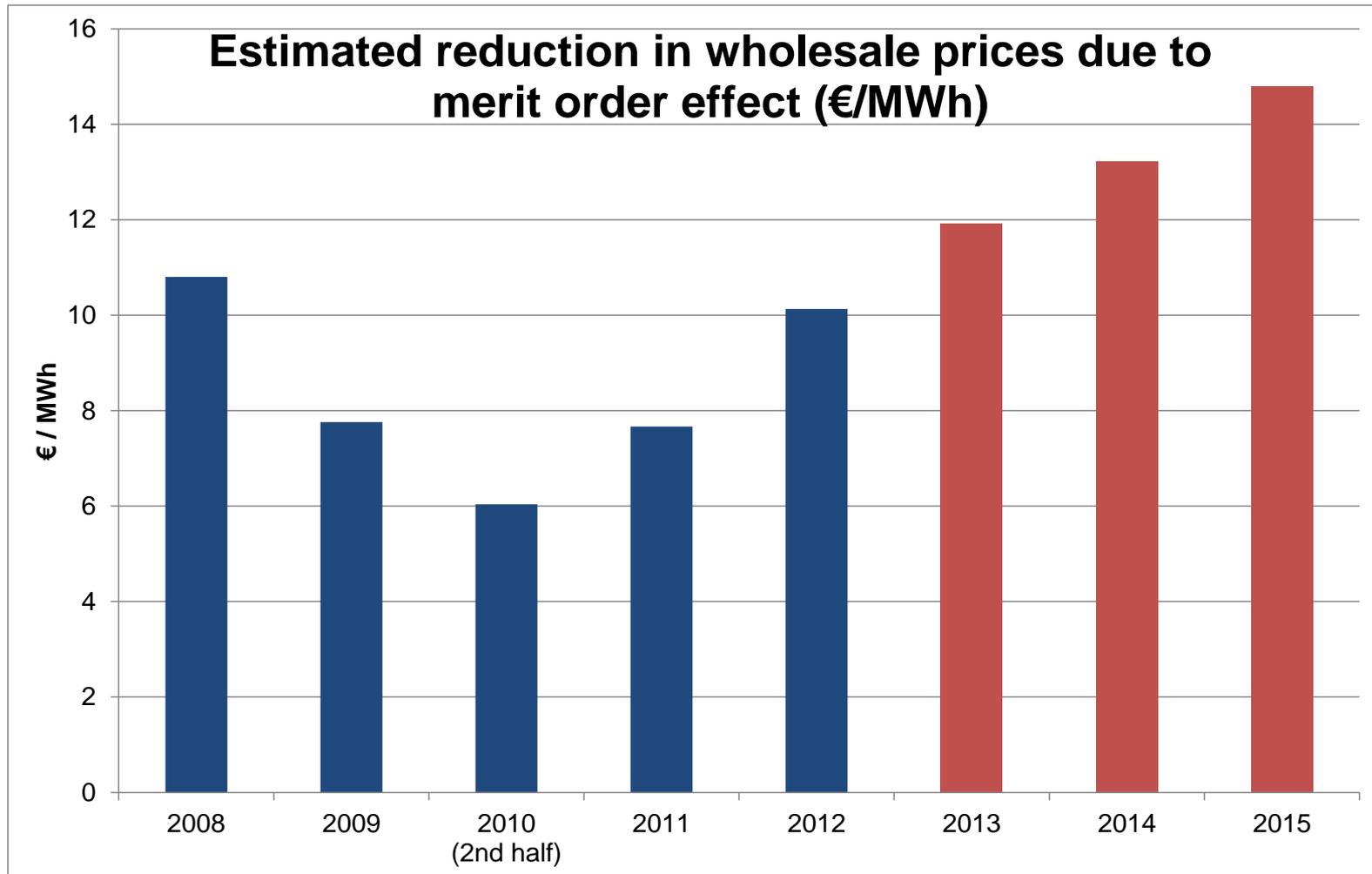
- 2012 data on spot prices, wind, PV, load

- Scale data to meet forecast by TSOs

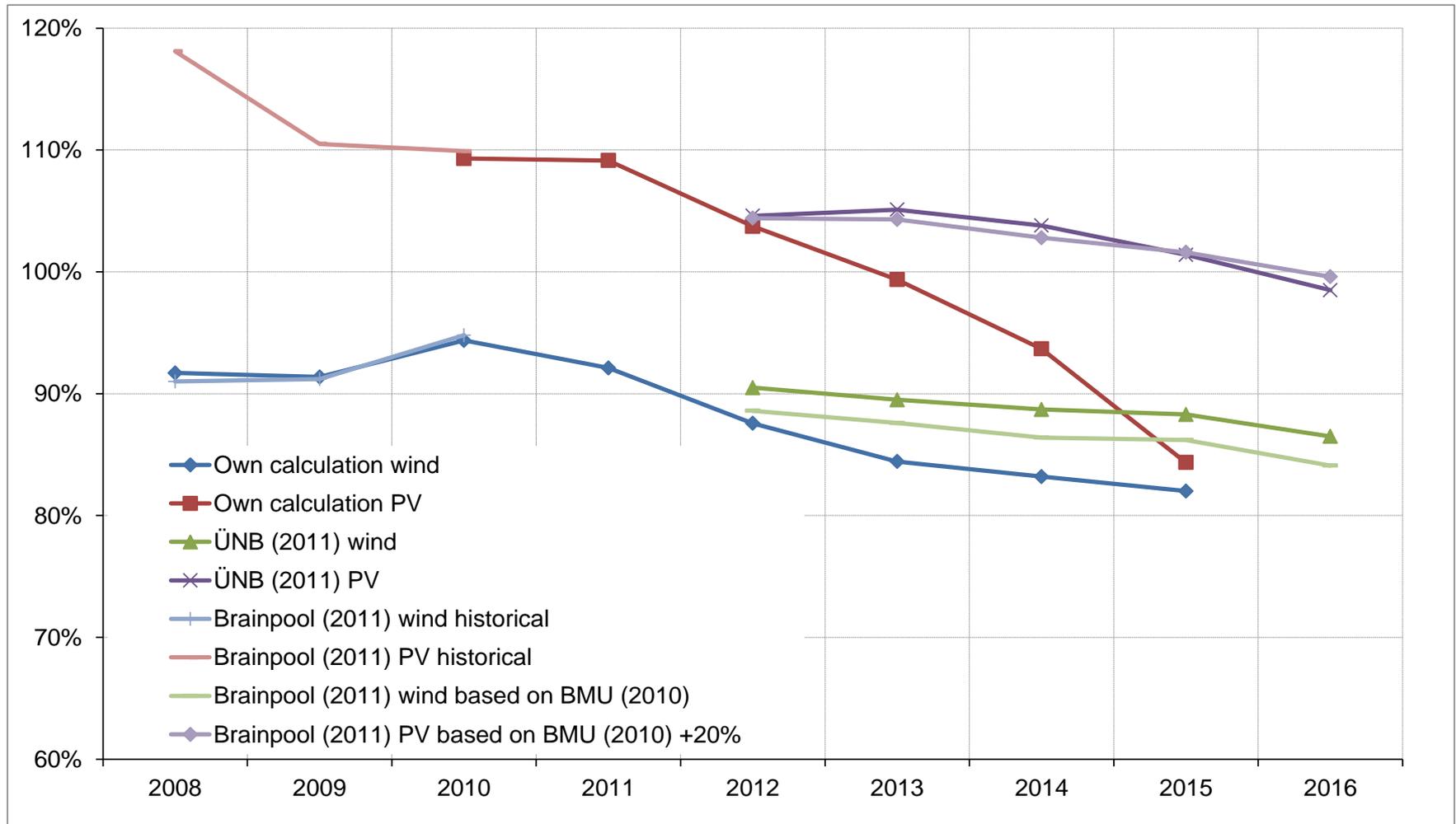
TWh	2013	2014	2015	2016	2017
PV	35	41	50	53	53
Wind onshore	56	59	61	65	68

- Apply estimated specific merit order effects, differentiated by load level
- Assumption: Conditions (fuel prices, climatic, conventional power plant fleet) identical to 2012; constant load
- Predicted average merit order effects
- Predicted revenue factors for wind and PV

Forecast merit order effects



Revenue factors for wind and PV



Sensitivity analysis using daily averages

	2008	2009	2010 (first half)	2011	2012	2010-12
Wind	-2.21*** (0.21)	-1.53*** (0.23)	-1.13*** (0.12)	-0.94*** (0.10)	-1.20*** (0.09)	-1.09*** (0.06)
PV			-0.001 (0.65)	-0.96*** (0.28)	-0.91*** (0.26)	-0.88*** (0.18)
Load	2.07*** (0.18)	0.73*** (0.21)	0.94*** (0.22)	0.75*** (0.15)	1.45*** (0.27)	1.09*** (0.17)
Hourly dummies	X	X	X	X	X	X
Daily dummies	X	X	X	X	X	X
Monthly dummies	X	X	X	X	X	X
Yearly dummies	X	X	X	X	X	X
Adjusted R2	0.78	0.51	0.77	0.74	0.66	0.69
DW-Statistic	2.56	2.68	2.54	2.64	2.33	2.40
Observations	8,783	8,760	3,983	8,760	8,784	21,527
Time frame	01/01/2008 - 31/12/2008	01/01/2009 - 31/12/2009	19/07/2010 - 31/21/2010	01/01/2011 - 31/21/2011	01/01/2012 - 31/21/2012	19/07/2010 - 12/12/2012
Newey-West standard errors in parentheses, robust to heteroskedasticity and autocorrelation						
*** significant at the 99% confidence level						

Sensitivity analysis using daily averages

	2008	2009	2010 (2nd half)	2011	2012
Wind specific effect (€/MWh)	-2.21***	-1.53***	-1.13***	-0.94***	-1.20***
Load_weighted average wind feed-in per hour (GW/h)	4.76	4.51	4.41	5.63	5.20
Wind total effect (€/MWh)	-10.52	-6.87	-5.00	-5.27	-6.22
PV specific effect (€/MWh)			-0.001	-0.96***	-0.91***
Average PV feed-in per hour (GW/h)			1.17	2.41	3.52
PV total effect (€/MWh)			0.00	-2.32	-3.19
Total average merit order effect of wind and PV (€/MWh)	-10.52	-6.87	-5.01	-7.59	-9.41