

Weight restrictions in the DEA benchmarking model for Norwegian electricity distribution companies

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Outline

- Background
- The DEA model and the data
- Why weight restrictions?
- Evaluation of some alternatives
 - Detailed versus aggregate restrictions
- Consequences
- Conclusion

Background

- Norwegian electricity sector
 - Competitive supply and demand for power
 - Regulated transmission and distribution
- Regulatory model revised from 2007
 - $IR_t = 0.5 \cdot K_{t-2}^* + 0.5 \cdot K_{t-2} + JP$
 - K^* based on (normalized) DEA-results
 - Separate models for transmission and distribution
- From 2009
 - $IR_t = 0.6 \cdot K_t^* + 0.4 \cdot K_t$

DEA model

- Input-oriented
- CRS
- One input = TotEx
 - Capital costs based on accounting book values
- Adjusted super efficiency
 - If a company is super efficient in the data set of year t , it is re-evaluated against the data set(s) for previous years
- Efficiency results are normalized
 - Cost weighted average efficiency = 100 %

Output parameters

- "Real" outputs
 - # customers except cottages, # cottage customers, energy delivered
- Network size
 - High voltage lines, network stations, interface (with regional transmission network)
- Environmental ("geography") factors
 - Forest growth, snow fall, corrosion (wind / distance to coast)
 - Geography variables are scaled using HV-lines through air

Choice of output parameters

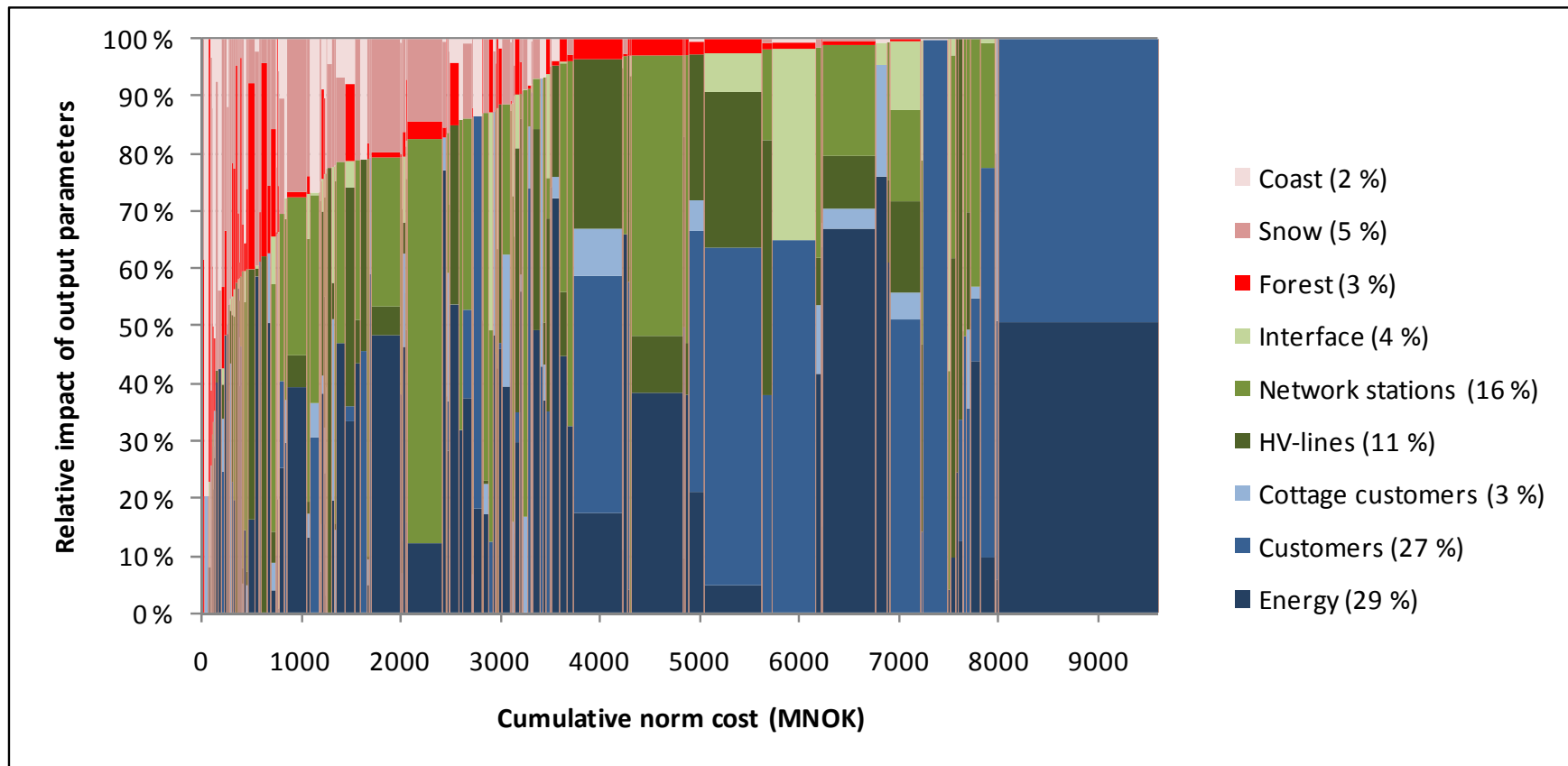
- NVE (2006)
- Large set of candidates
- Criteria
 - Tests of statistical significance
 - Regression of DEA results vs output parameters
 - Banker tests
 - Other arguments

Absolute weights*)

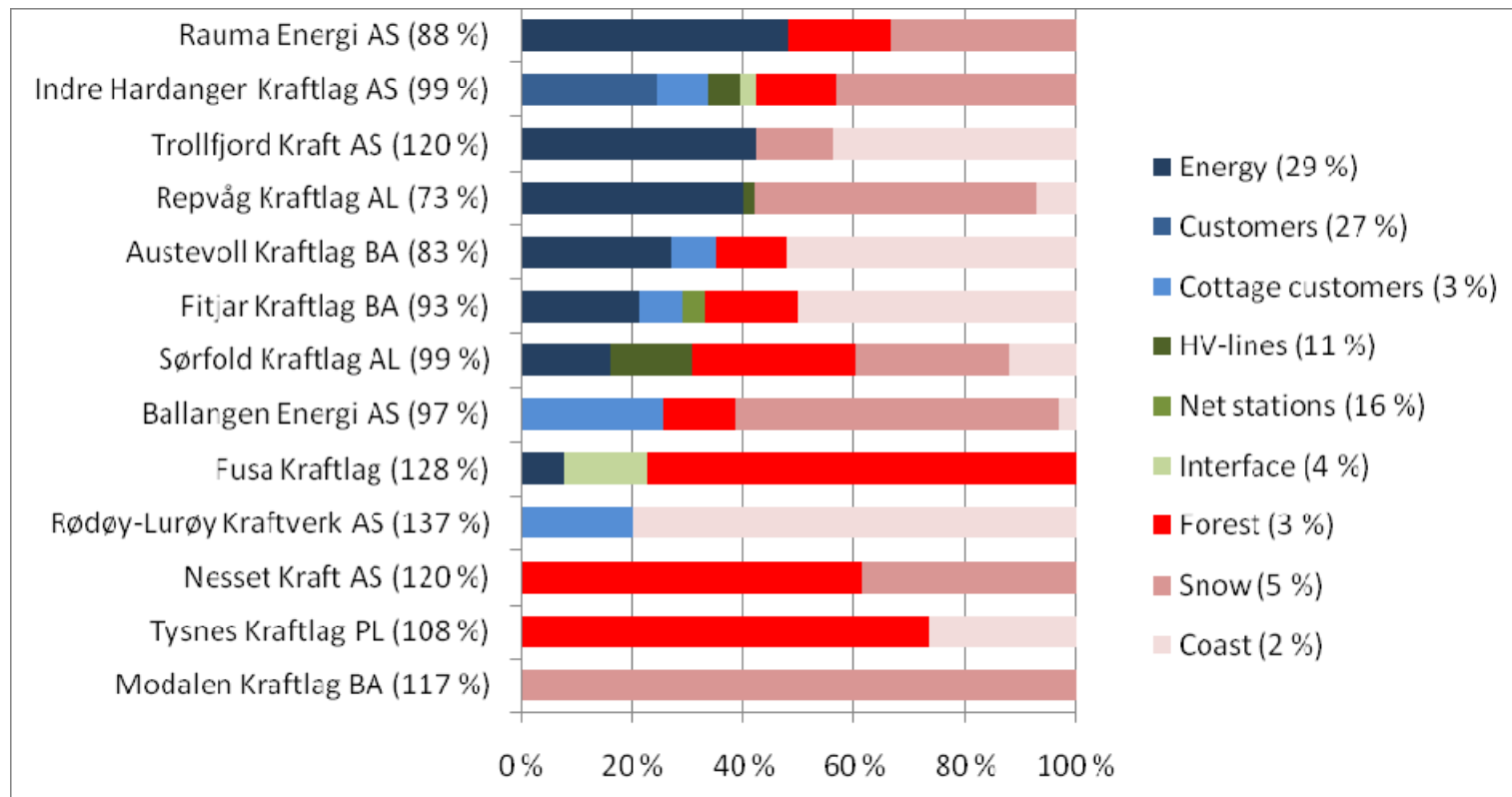
	Average (NOK)		Max (NOK)		No. of zeros	
	2005	2006	2005	2006	2005	2006
Energy	21	32	93	92	68	48
Customers	605	510	2 343	2 671	73	82
Cottage customers	1 531	1 165	7 848	7 264	67	69
HV-lines	4 864	8 735	32 457	44 683	88	63
Network stations	15 979	12 896	45 769	52 548	50	59
Interface	1 174	1 300	7 032	7 701	69	51
Forest	29 284	28 184	222 056	215 491	44	57
Snow	18 445	24 193	109 824	123 595	73	58
Coast	22 847	22 700	148 469	165 919	82	81

*) The forest, snow and coast variables have been rescaled in order to make them easier to interpret.

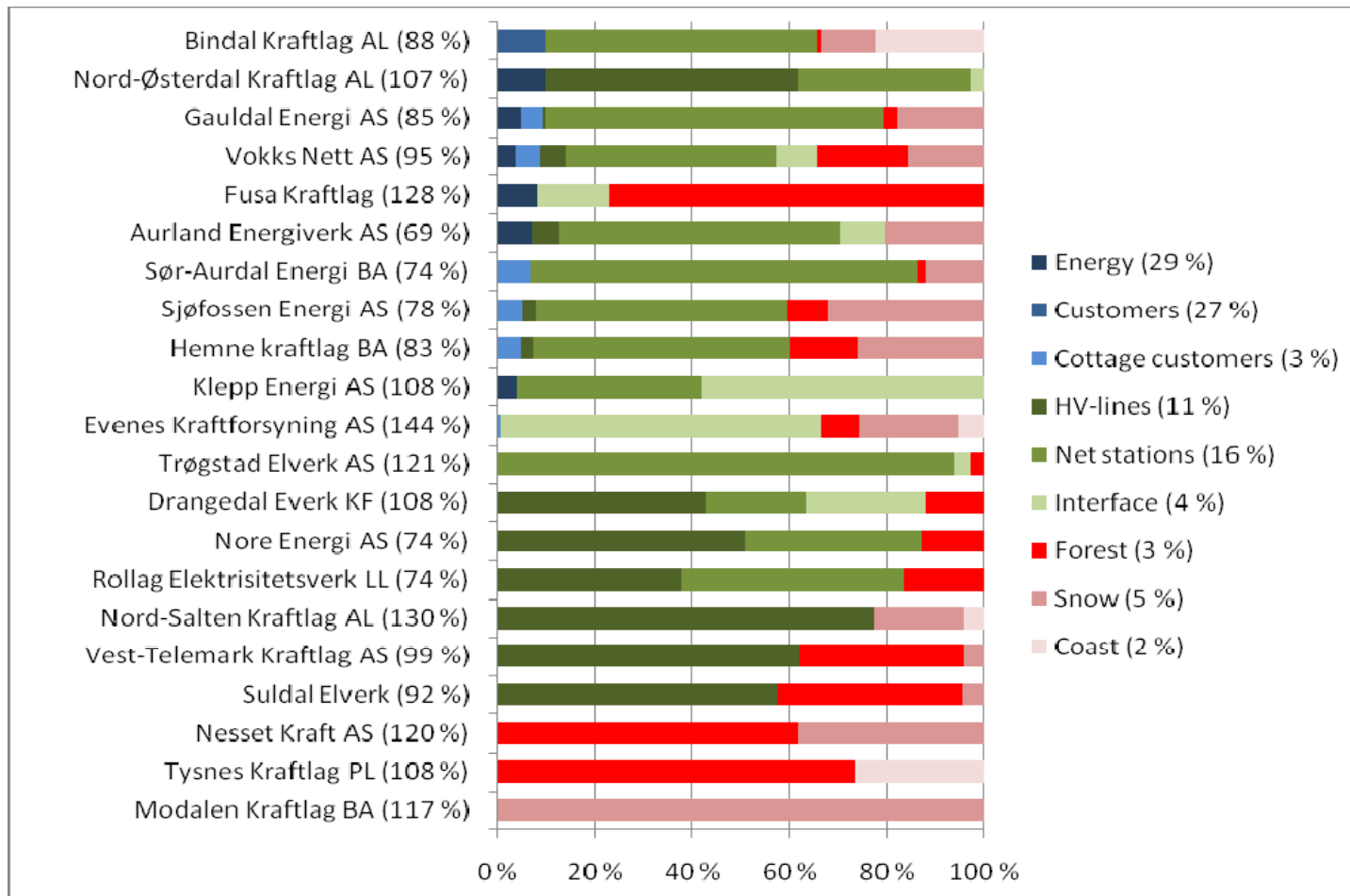
Virtual weights



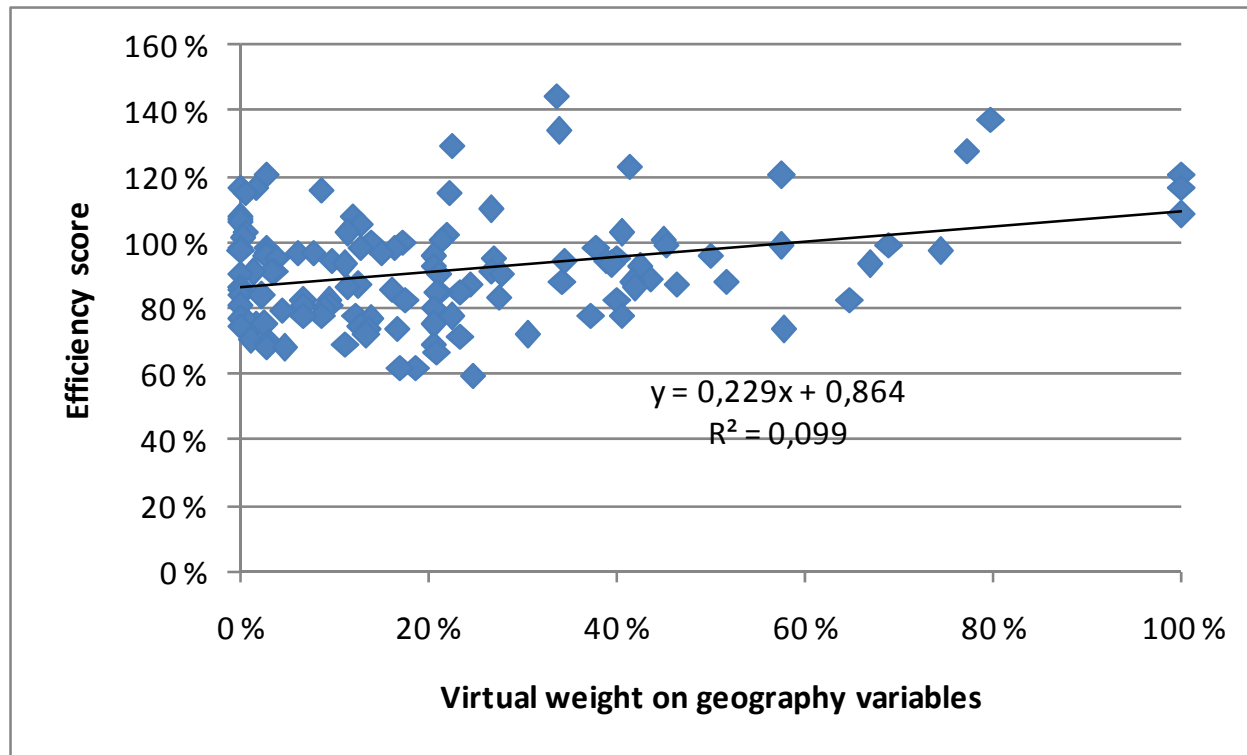
Geography weight > 50 %



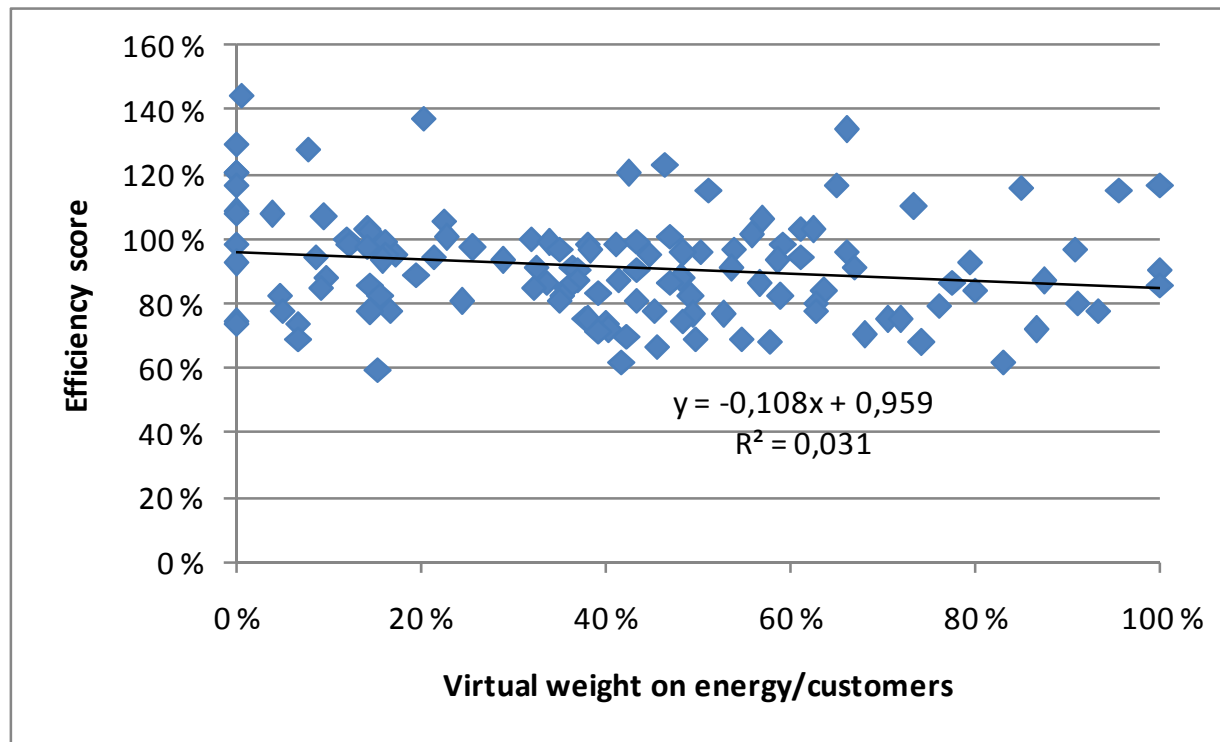
Energy / customer weight < 10 %



Efficiency score vs geography weight



Efficiency score vs weight of energy / customers



Proposed relative restrictions NVE (2007)

Restriction(s)	Involved variables	Mathematical formulation
VR1 / VR2	HV-lines versus net stations	$0.952p_{NS} \leq p_{HV} \leq 8.572p_{NS}$
VR3 / VR4	Interface versus net stations	$0.02304p_{NS} \leq p_{Int} \leq 0.20738p_{NS}$
VR5 / VR6	Customers versus cottage customers	$1/3p_{Cust} \leq p_{CCust} \leq 3p_{Cust}$
VR7 / VR8	Net stations versus customers	$1.618p_{Cust} \leq p_{NS} \leq 58.252p_{Cust}$
VR9	Forest versus HV-lines	$p_{Forest} \leq 0.04p_{HV}$
VR10	Snow versus HV-lines	$p_{Snow} \leq 0.0053p_{HV}$
VR11	Coast versus HV-lines	$p_{Coast} \leq 36.364p_{HV}$

Example – snow fall

- Proposed restriction

$$p_{Snow} 757 / 2 \leq 2 p_{HV}$$

- Adjustments
 - Maximal snow fall = 752 mm / year
 - Average share of HV-lines through air \approx 50 %
 - Wrong to adjust for this, weights represent marginal effects!

Example – snow fall

- Better to normalize the output parameter
 - Interpretation of new parameter: number of kilometers of “difficult” HV-lines
- Revised weight restriction

$$p_{Snow} \leq 2p_{HV}$$

Example – HV-lines versus network stations

- Proposal based on investment costs
 - Ratio between average investment costs
 - 419' NOK / 146' NOK = 2.87
 - Same life span?
- Interval $[1/3, 3]$ gives the restriction

$$0,952p_{NS} \leq p_{HV} \leq 8,572p_{NS}$$

Relative restrictions - issues

- Assumes implicitly that outputs can be substituted
 - Reasonable in all cases?
 - E.g. network stations versus customers
- The DEA model is not complete
 - Important output parameters have been omitted
 - E.g. low voltage lines
 - Evaluation of ratios between included variables cannot be based on their own costs!

Virtual weight restrictions

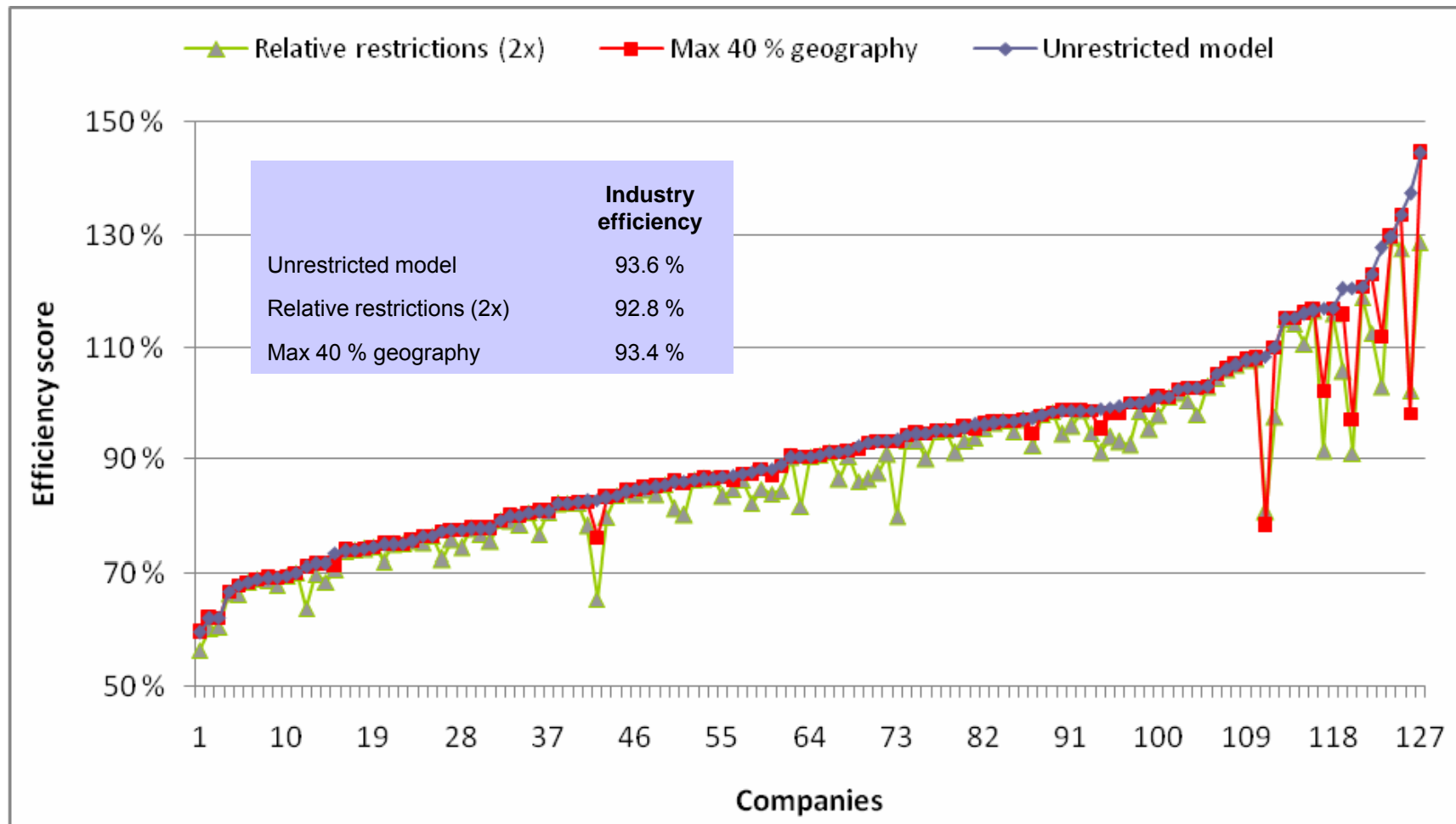
- Upper bound for the geography variables

$$\frac{p_{Forest} \cdot y_{Forest,j^*} + p_{Snow} \cdot y_{Snow,j^*} + p_{Coast} \cdot y_{Coast,j^*}}{\sum_r p_r \cdot y_{rj^*}} \leq \alpha$$

- Lower bound for energy / customers

$$\frac{p_{Energy} \cdot y_{Energy,j^*} + p_{Cust} \cdot y_{Cust,j^*} + p_{CCust} \cdot y_{CCust,j^*}}{\sum_r p_r \cdot y_{rj^*}} \geq \beta$$

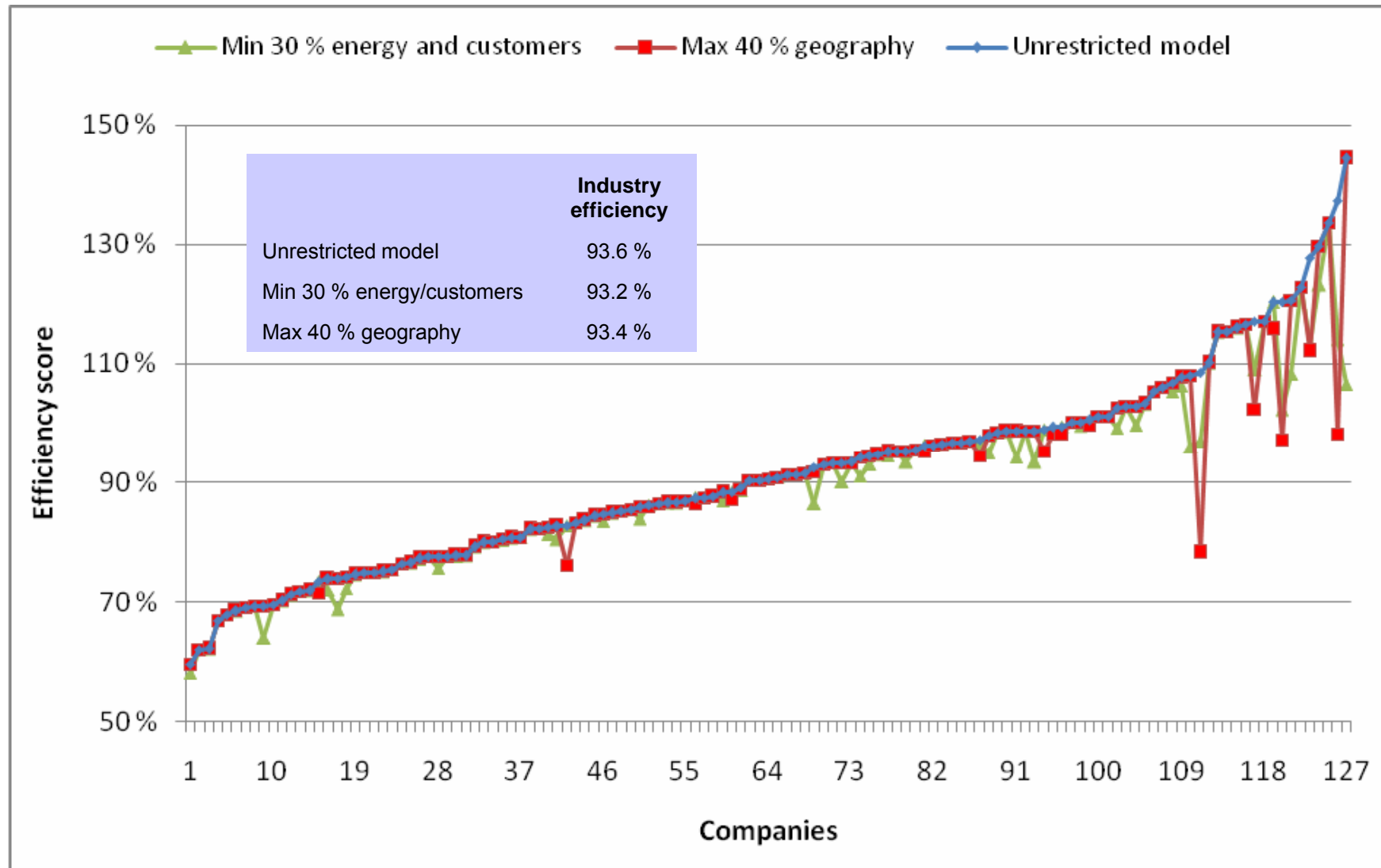
Relative versus virtual restrictions – geography variables



Sensitivity analysis – virtual restriction

		Maximum geography share										
		0 %	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %	100 %
Industry efficiency		89,8 %	91,8 %	92,8 %	93,2 %	93,4 %	93,5 %	93,6 %	93,6 %	93,6 %	93,6 %	93,6 %
No. of affected comp.		115	80	58	35	26	13	9	6	3	3	0
Average reduction		9,7	8,4	6,9	6,8	5,8	7,7	6,4	5,4	5,0	2,0	-
Reduction in %-points	Over 50	2	1	1	0	0	0	0	0	0	0	0
	25 - 50	8	6	4	3	2	1	0	0	0	0	0
	10 - 25	29	12	4	4	3	4	3	1	0	0	0
	5 - 10	22	19	13	1	1	0	2	2	2	0	0
	0 - 5	54	42	36	27	20	8	4	3	1	3	0
	No change	12	47	69	92	101	114	118	121	124	124	127
Corr(Eff, VirtualGeography)		-	-0,21	-0,08	0,05	0,12	0,17	0,22	0,25	0,29	0,30	0,32
Corr(Eff, PhysicalGeography)		-0,43	-0,30	-0,16	-0,05	0,02	0,06	0,10	0,13	0,14	0,15	0,16

Lower bound for energy / customers



Restrictions wrt customer weights

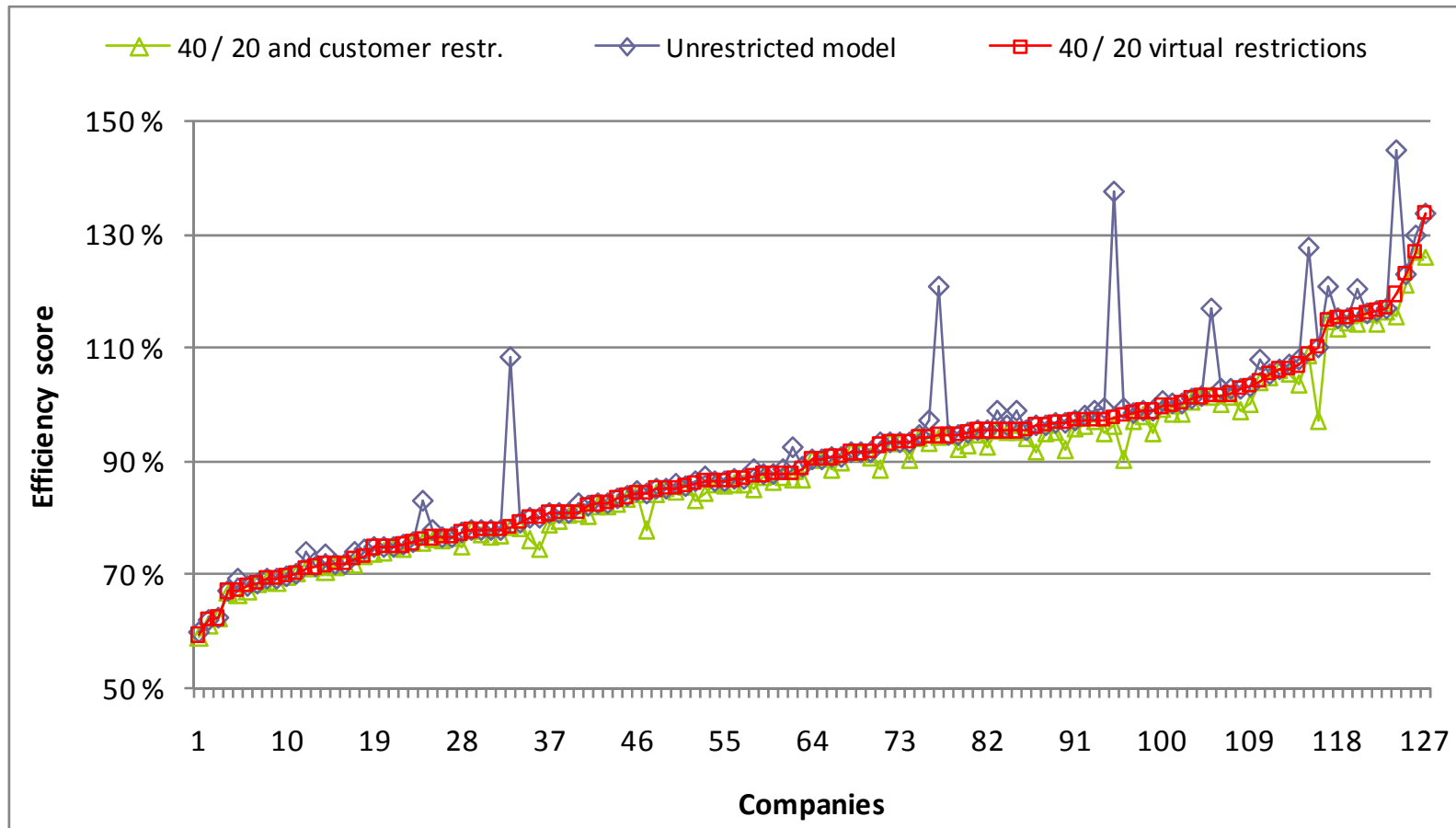
- NVE proposal

$$\frac{1}{3} p_{Cust} \leq p_{CCust} \leq 3p_{Cust}$$

- Lower absolute bound based on direct cost per customer

$$p_{Cust}, p_{CCust} \geq 380$$

Combined effects



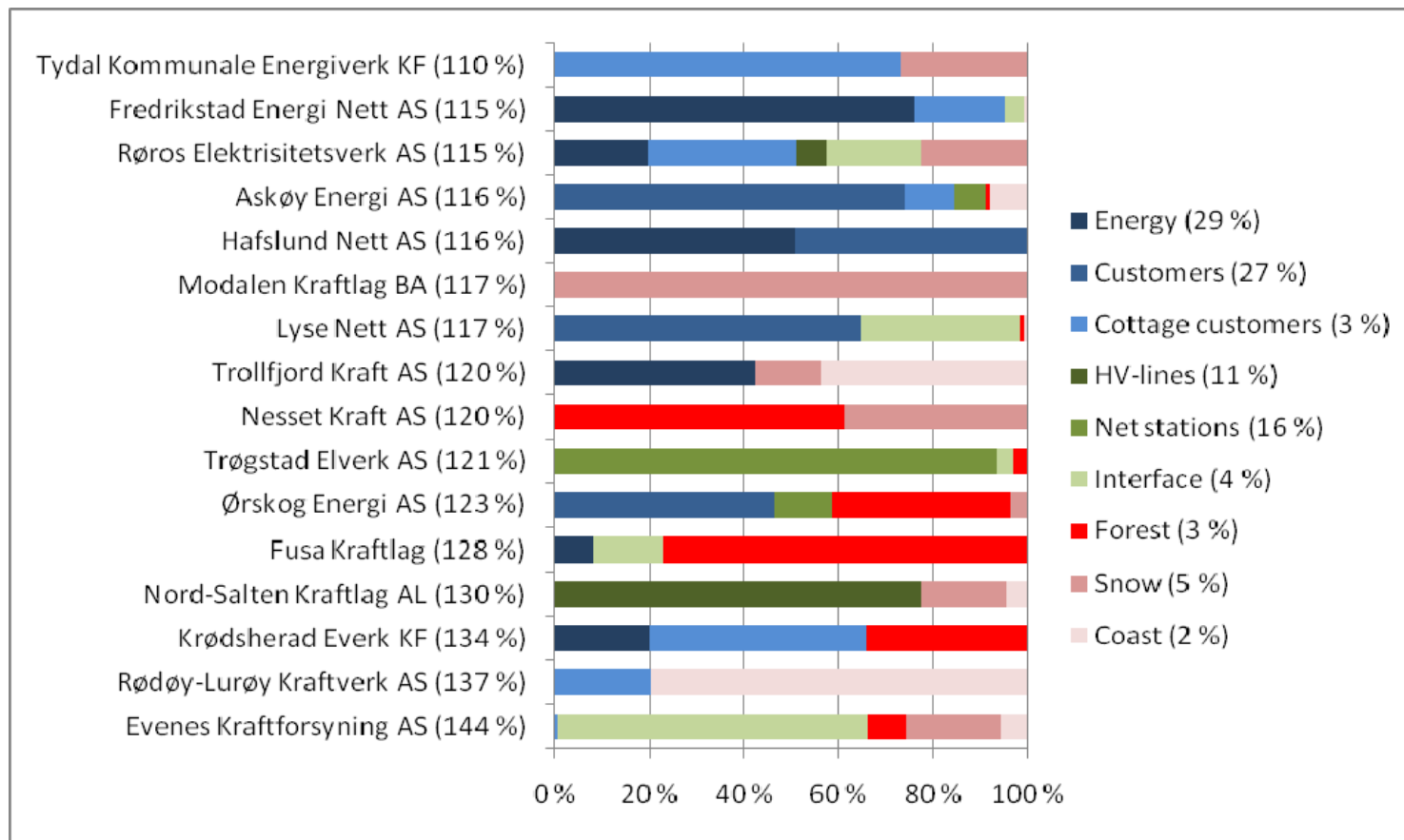
Conclusions

- Price restrictions at a detailed level are problematic in a non-complete DEA model
 - An output parameter may be explaining the effect of omitted variables
 - Difficult to specify meaningful bounds on included variables
- Virtual proportional restrictions at an aggregated level
 - Ease of interpretation
 - Keep sufficient weight flexibility
 - Target companies that are compensated too much from the introduction of environmental variables

Descriptive statistics, 2006

	TotEx	Energy	Customers	Cottage customers	Network HV-lines	stations	Interface	Forest	Snow	Coast
Average	80 699	541 232	18 902	2 115	757	947	1 145	7 143	161 046	5
Std. dev.	167 628	1 539 025	53 582	3 451	1 295	1 814	5 440	14 741	259 314	9
Percentiles										
25 %	16 942	57 766	2 194	464	180	210	0	974	37 085	0
50 %	28 227	130 181	4 728	1 017	311	341	0	2 530	84 747	1
75 %	63 362	332 342	10 327	1 993	741	863	283	6 987	160 821	5
100 %	1 378 964	14 823 496	515 884	25 298	8 438	13 294	46 189	97 290	1 547 997	49

Efficiency score > 110 %



Sensitivity analysis – relative restrictions

		Maximum geography weights relative to HV-weight						
		0x	1x	2x	3x	4x	5x	Unrestr.
Industry efficiency		89,8 %	91,5 %	92,4 %	92,8 %	93,0 %	93,2 %	93,6 %
No. of affected comp.		115	103	91	81	79	78	0
Average reduction		9,7	6,9	5,0	3,7	2,7	2,3	-
Reduction in %-points	Over 50	2	1	0	0	0	0	0
	25 - 50	8	4	4	0	0	0	0
	10 - 25	29	15	7	7	6	3	0
	5 - 10	22	22	14	6	3	5	0
	0 - 5	54	61	66	68	70	70	0
	No change	12	24	36	46	48	49	127
Corr(Eff, VirtualGeography)		-	-0,15	-0,02	0,10	0,17	0,20	0,32
Corr(Eff, PhysicalGeography)		-0,43	-0,24	-0,10	0,00	0,05	0,07	0,16