NHH

Benchmarking and yardstick competition in regulation of electricity networks

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Overview

- Norwegian electricity sector
  - Regulatory model – yardstick competition
  - Performance evaluated by DEA
- DEA challenges
  - Cost assessment and data quality
  - Scope of efficiency analyses
  - Application of benchmarking results
  - Model structure and cost drivers
- Lessons to be learned

Background

- Norwegian electricity sector
  - –Competitive supply and demand for power
  - –Regulated transmission and distribution
- Present regulation is to be revised from 2007
- NVE – stated terms
  - –Strong incentives for cost efficiency
  - –Increased importance of efficiency analyses
  - –Improved conditions for beneficial investments
  - –Less complexity
  - –Lower tariffs for customers

Incentive regulation

- Incentives for efficient organization, operation, investments
  - –Revenue should be independent of the regulated company's own costs
    - Revenue = cost of the "marginal" company, given the company's "output" (volume and quality)
    - Operating income: depends also on the company's efficiency and costs
- Sufficient revenue level to attract both financial and human capital
  - –Competitive rate of return on invested capital
  - –Accept continual efficiency differences and "super-profits"

NVE proposal

- Revenue cap regulation continued
- A company's own costs should not determine its revenue
  - "Super-efficiency"
- To allow super-profits for the most efficient companies
  - "Calibration of average efficiency"

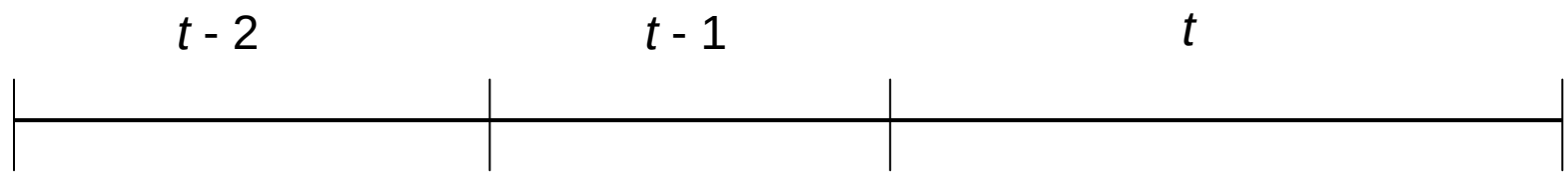
- Yardstick-competition
  - Revenue cap based on actual costs and cost norms
  - $IR = K + \rho\,(K^* - K)$

NVE proposal June 2006

- $IR_t = K_{t-2} + 0.6 \cdot (K_{t-2}^* - K_{t-2}) + JP$
  $= 0.6 \cdot K_{t-2}^* + 0.4 \cdot K_{t-2} + JP$

- *K* based on accounting values
  - Including capital costs
- K^* based on DEA
  - Cost efficiency with total accounting costs as the only input
  - Separate models for D and RS
  - ΣK^* calibrated to let average efficient companies earn normal rate of return
- Adjustment parameter (*JP*)
  - Compensates for time lag (*t*-2)
- Annual updates of *K* and *K**

Computation of cost norm



OM
DEP
*BV*r*$_{NVE}$
NL
VOLL

K_{t-2} → K_t → K_t^* → Calibrated K_t^*

DEA

$K_t^*(\text{industry}) = K_t(\text{industry})$

Time lag → *JP*

Loss of interest

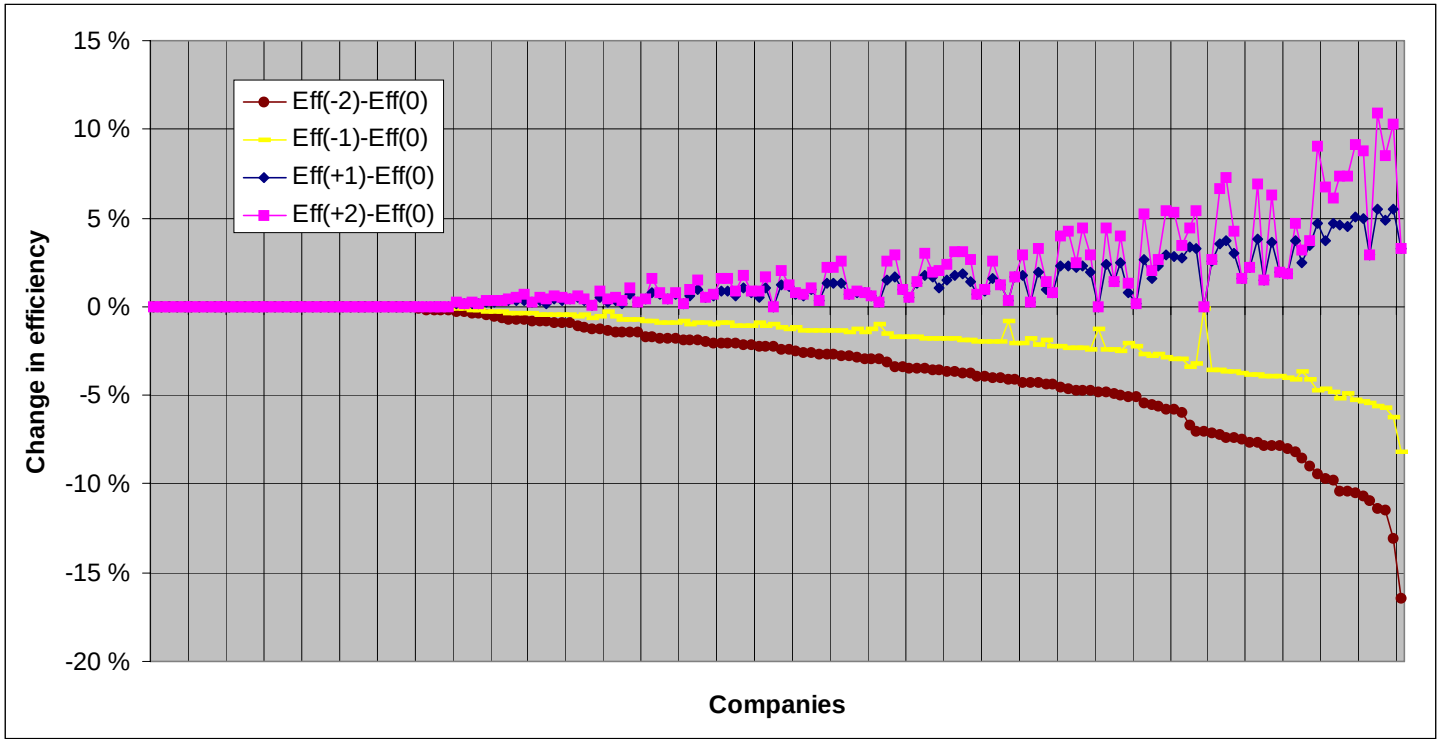
DEA - model

- CRS – constant returns to scale
- Super efficiency – modified
- Output parameters of D-model:
  - Energy except cottages, energy cottages, customers, high voltage lines, network stations, exchange, steepness, forest, wind
- Output parameters of RS-model:
  - Line lengths R and S, maximal load, exchange
    - Weighted parameters

Correctness of efficiency model

- While working on the yardstick-competition model, NVE has assumed that ”the efficiency analyses are sufficiently good to be used for regulation purposes”
- The DEA benchmarking result for a company is sensitive to
  - Model specification
  - Cost and output data
    - For the company itself and peers

Capital costs and data quality



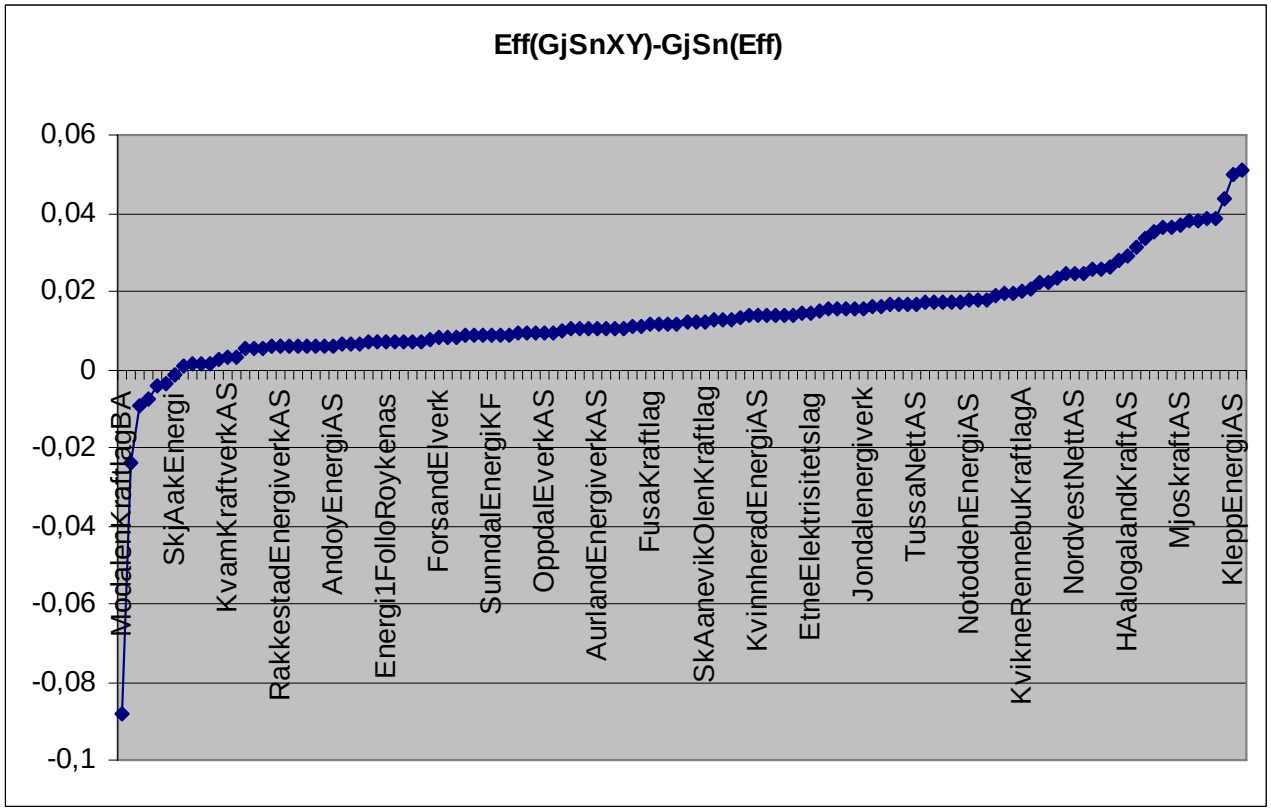
Present model for the distribution activity: Effect of changes in capital value (billion NOK) for the largest company (Viken Energinett).

NVE proposal

- *K* based on accounting values
- Reference period is mainly one year
  - I.e. the period used to determine *K*

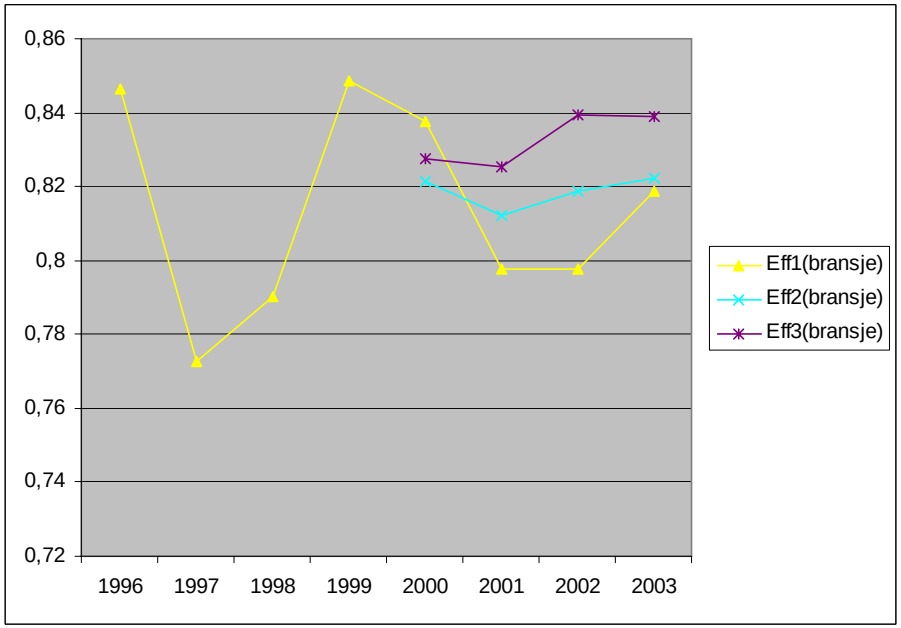
- Is the cost representative with a reference period of one year?
- Is it affected by natural cost variations?
- If the cost variations differ from one area to another, will this influence the benchmarking results?

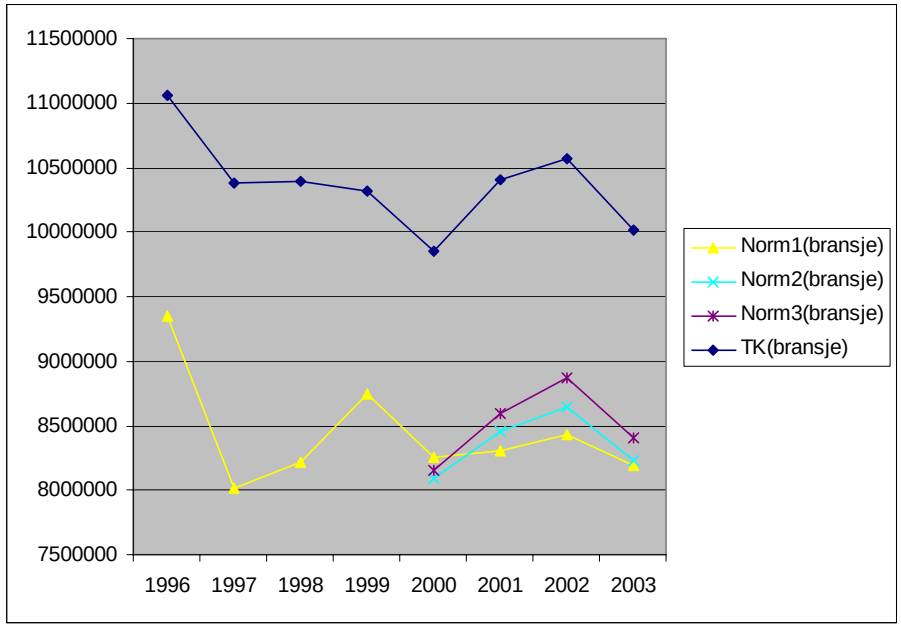
Annual data versus 5-year average



The model with annual data is stricter

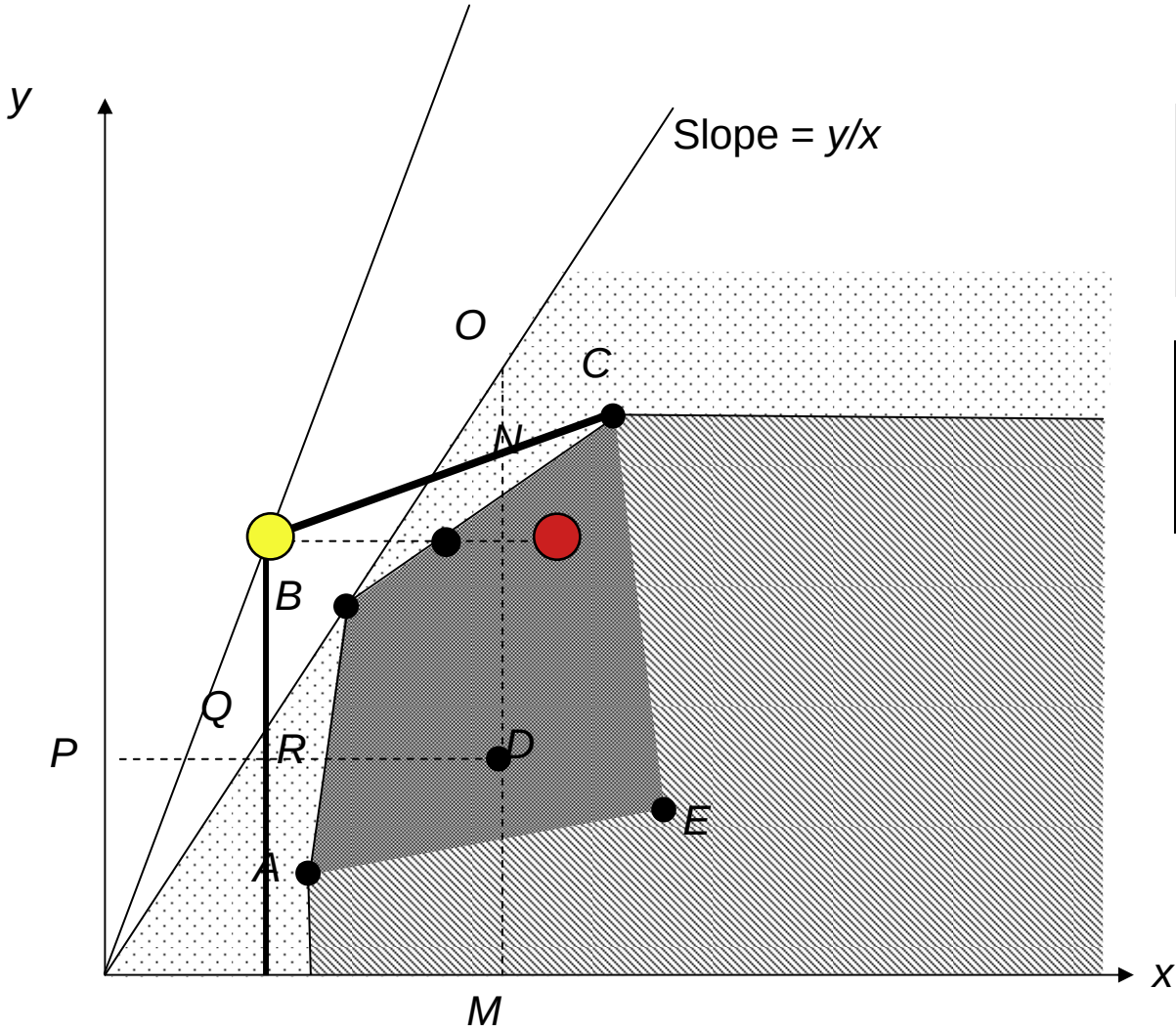
Influences efficiency and norm





- Adjusting for average efficiency will adjust total revenues, but there may be allocation issues

Effects from cost variability



”Positive” deviations change the frontier

”Negative” deviations have no effect

Convex combinations

Free disposal

Constant returns to scale

Accounting based capital costs

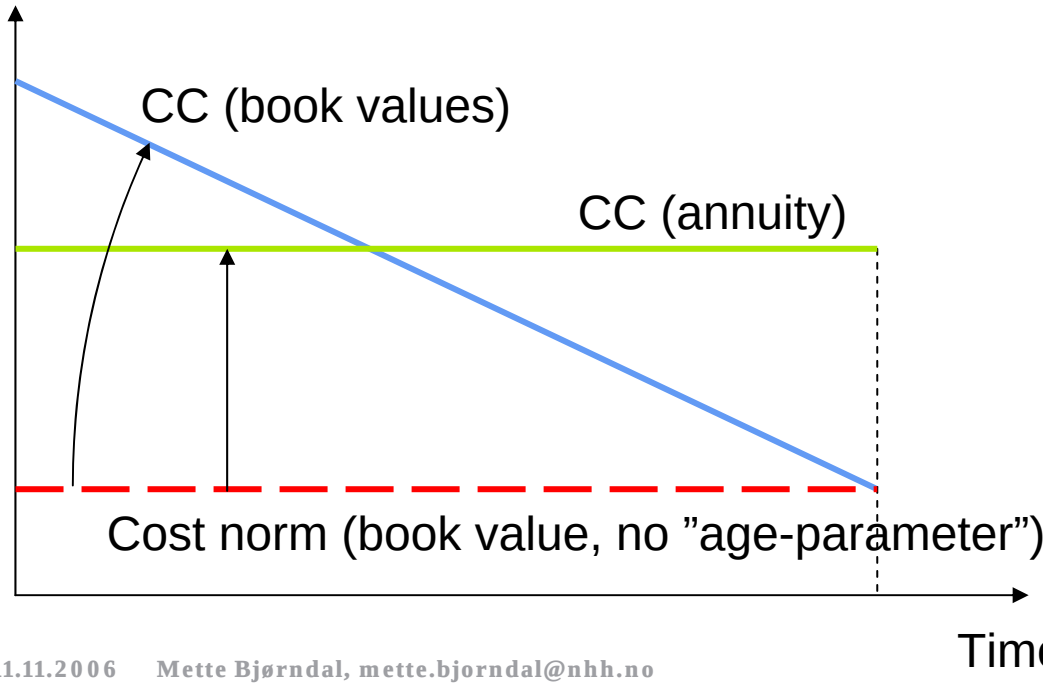
- Choice of capital base / capital cost will influence the measured efficiencies
  - –Book values versus replacement values
- Productivity relatively independent of age
  - –Accounting based costs do not reflect economic costs very well
  - –Over-estimated efficiency in old networks, under-estimated in new
- "Age-parameter"
  - –To correct for probable measurement errors in costs / inputs by adding an output (cost driver)
- Calibration of average efficiency
  - –Adjust revenues over the investment horizon

Revenue level and time profile

- Without calibration
  - Necessary to include an ”age-parameter” to obtain a sufficient revenue level over time
- With calibration
  - Whether to have an ”age-parameter” or not is a choice of time profile for the revenue

”Age-parameter”

Multiplicative calibration, no ”age-parameter”



Benchmarking units / scope

- Regulated versus non-regulated activities
  - Cost allocation
- Which tasks are to be performed under the revenue caps?
  - Ex.: Who is responsible for digging cable trenches?
  - Ex.: How are direct investment contributions to be accounted for?
- This is a major issue irrespective of the type of efficiency model

Separate models for R- and D-networks

- Companies with both network types have to allocate cost (and outputs) between the two levels
  - –Two cost groups
  - –Separable?
- Datar and Gupta (1994)
  - –Design of costing systems
  - –Trade-off
    - Specification / aggregation errors
    - Measurement errors

Relevance for DEA specification

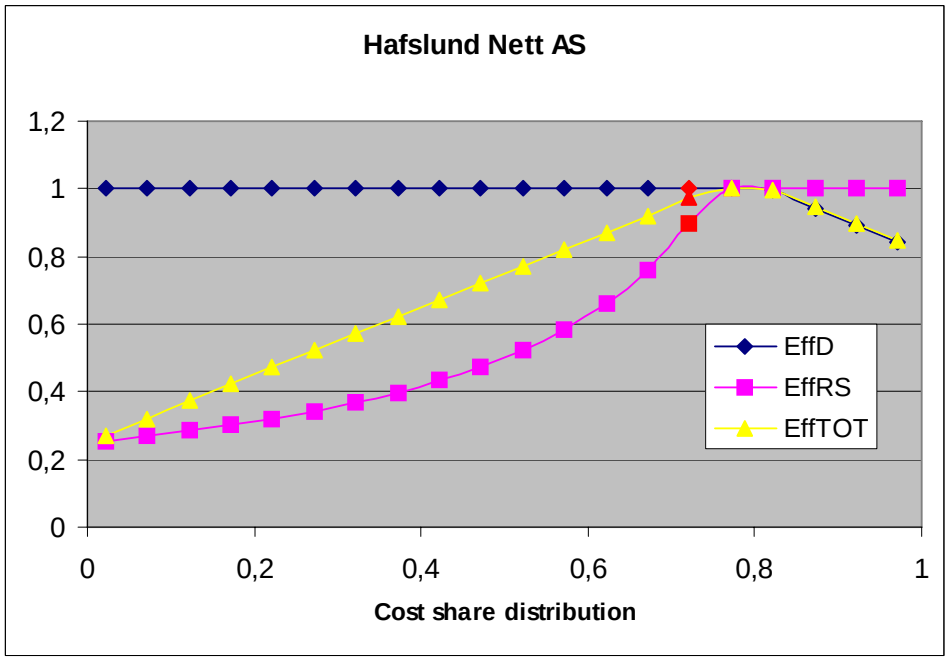
- If costs are separable
  - Should have two models
  - More information
  - Stronger discriminatory power
  - Misspecification with respect to separable activities tend to overestimate efficiency
- If not separable
  - Possibilities for opportunistic reporting
  - What are the effects assuming different DEA-implementations?

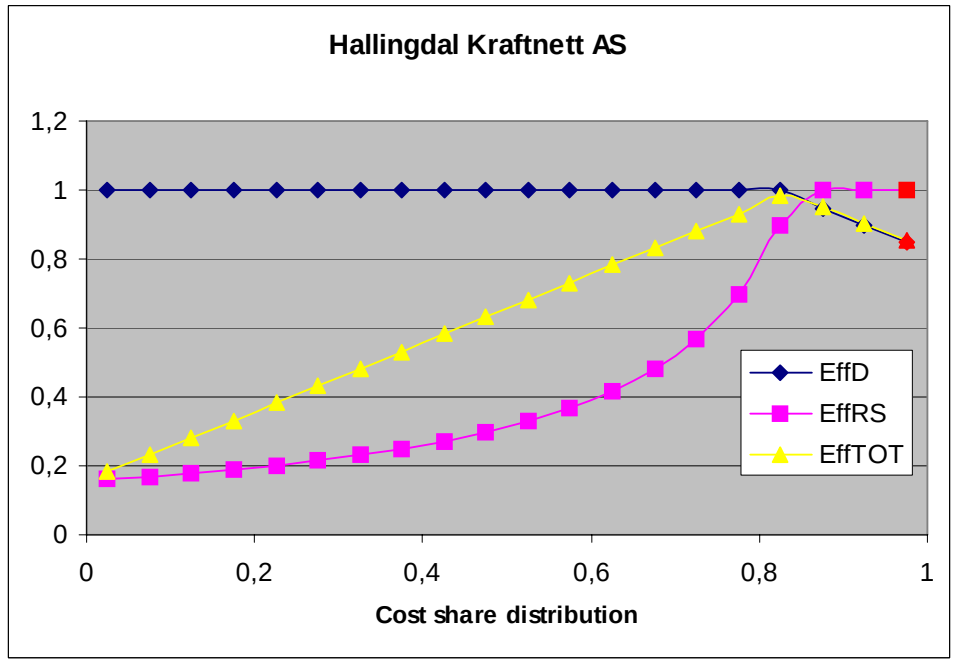
Potential for opportunistic reporting

$$Eff^{D} = \text{efficiency score from D - model}$$

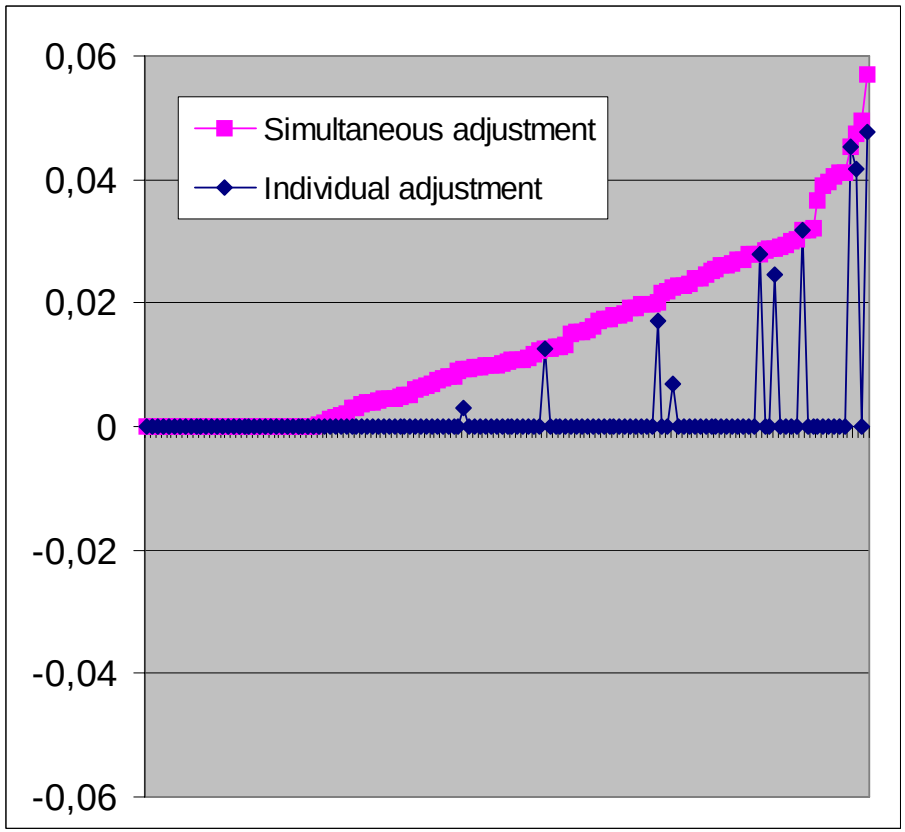
$$Eff^{R} = \text{efficiency score from R - model}$$

$$Eff^{TOT} = Eff^{D} \cdot \frac{K^{D}}{K^{D} + K^{R}} + Eff^{R} \cdot \frac{K^{R}}{K^{D} + K^{R}}$$

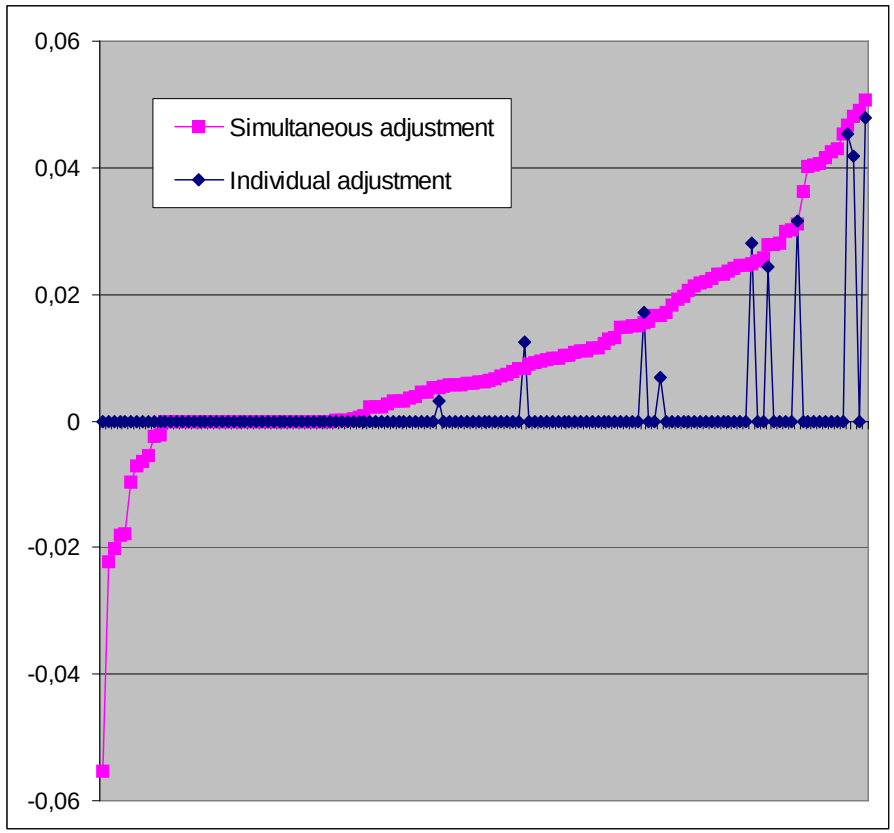




Effects of opportunistic cost allocation

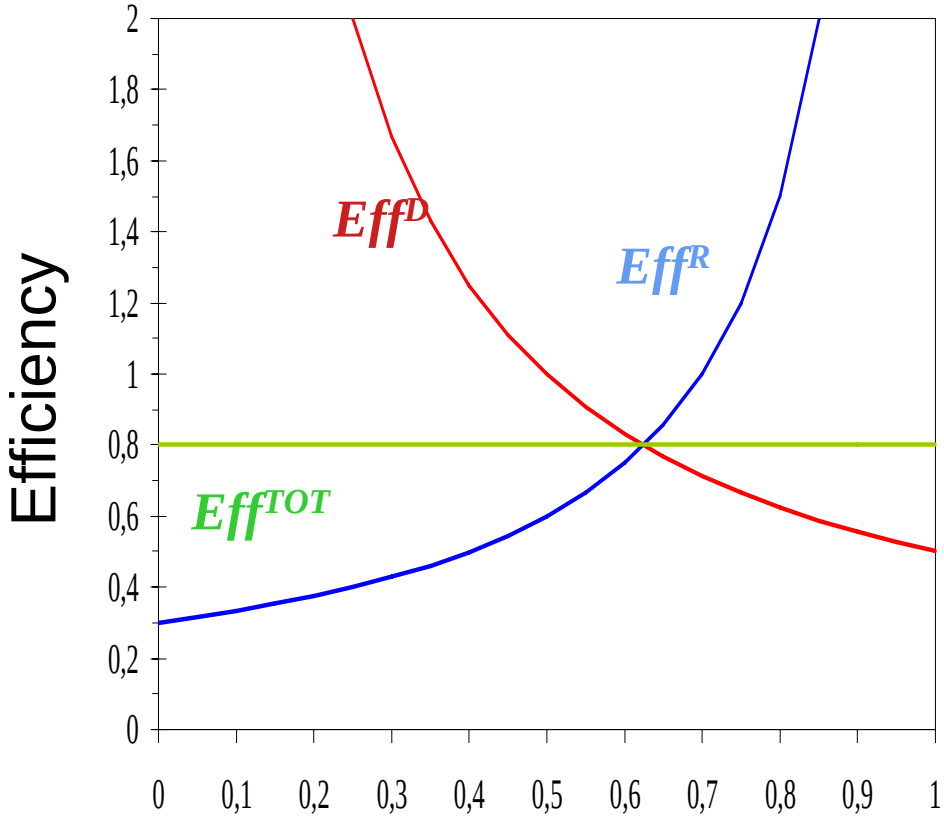


Ex post adjustment



Ex ante adjustment

Cost allocation and super-efficiency



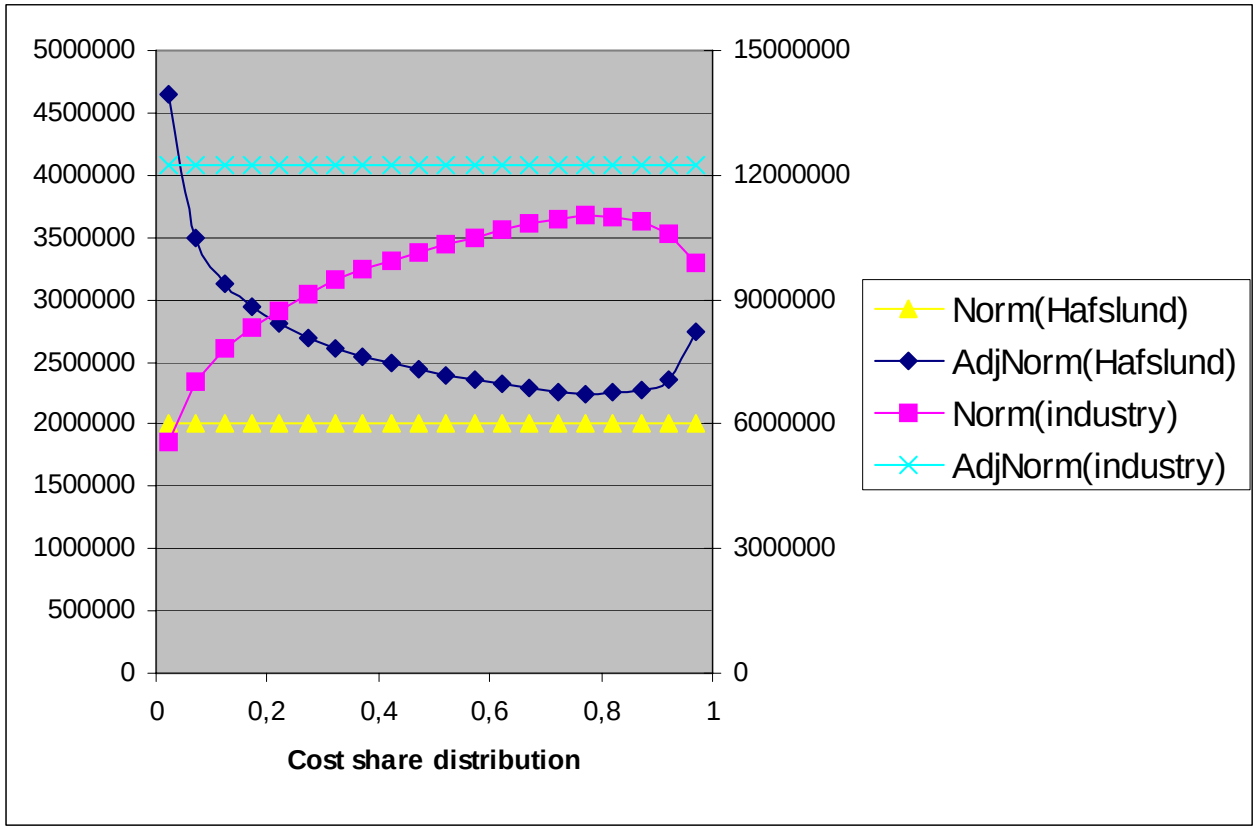
$$\alpha = \frac{K^D}{K^D + K^R}$$

- A company cannot be part of its own reference set
- Ensured by adding the constraint

$$\lambda_{j^*} = 0$$

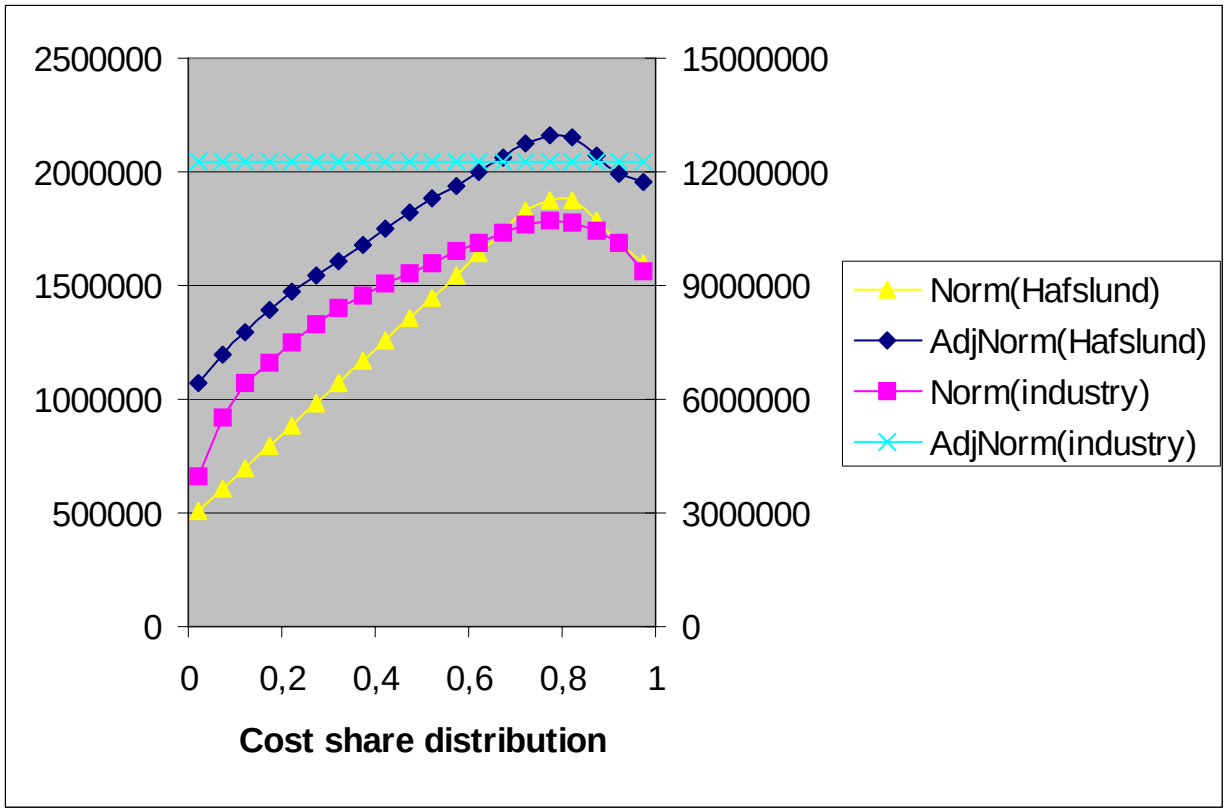
- Cannot influence its own efficiency score by reallocating costs
- HOWEVER:
- Still possible to influence the efficiency of other companies!

Effect of cost allocation



CRS model with super-efficiency

Effect of cost allocation

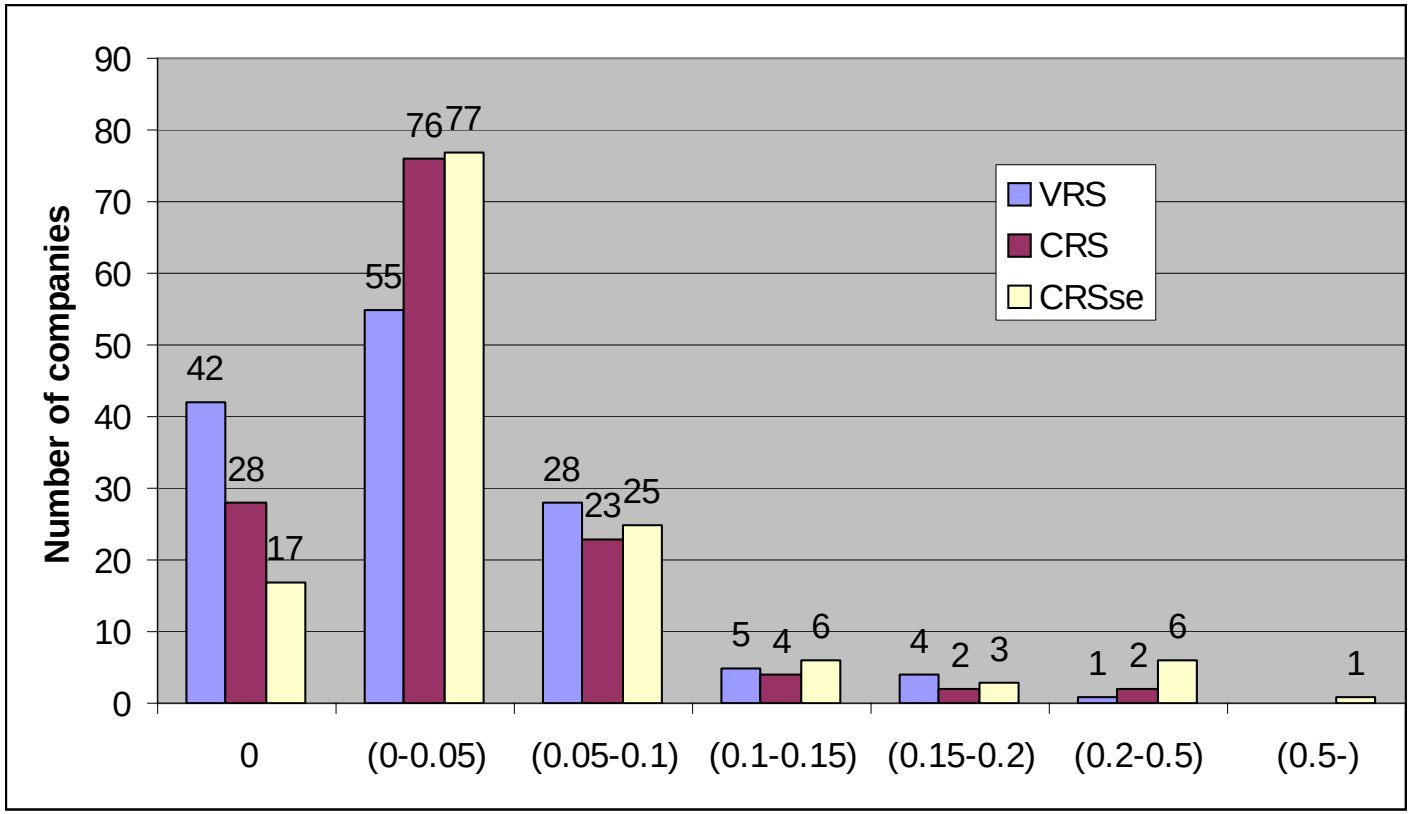


CRS model without super-efficiency

Possible solution: One model

- Advantage
  - –Removes problems related to the allocation of cost and outputs
- Disadvantage
  - –Less disaggregated efficiency measurement
    - If the cost structure is really separable, this information should be exploited in the efficiency analyses
    - If costs are separable, a combined model tends to overestimate efficiency

Combined versus separate models



The efficiency score of most companies will increase in a combined model

Representative company

- Determine the normal rate of return
- Should average efficiency be 100 %?
- How is the industry's average efficiency affected by changes in the efficiency model?

	Old model			New model (1 input, book values)				Effect of age parameter		
	NV	BV	MAX	VRS	CRS	SE	SEnve	CRS	SE	SEnve
Simple average	89 %	85 %	90 %	88 %	85 %	88 %	85 %	4 %	5 %	6 %
Weighted average	92 %	89 %	93 %	93 %	88 %	91 %	89 %	2 %	3 %	4 %
Industry norm (MNOK)				9168	8666	8948	8709	232	265	432

Average efficiency depends on the scaling factor for indices

Scaling factor	Basic model		Effect of AP	
	CRS	SE	CRS	SE
HV	88.3 %	91.2 %	0.3 %	0.4 %
TC	91.0 %	94.5 %	1.6 %	2.0 %
HV and TC	88.3 %	91.2 %	2.4 %	2.7 %
LV	87.3 %	90.3 %	0.2 %	0.4 %

Average efficiency

- Should we adjust for this?
  - The DEA model is not very strict in the first place
  - A general efficiency requirement for an inefficient industry?
- NVE has decided to adjust the efficiency results such that the industry return over time is approximately equal to the reference rate of return, r_{NVE} (NVE document 19/2005)
- How to implement this calibration?
  - General efficiency increase?
  - Normalizing the cost weighted average efficiency score to 100?

Calibration of cost norm

- Assume that the total industry cost norm measured by the DEA models is equal to ΣK^*
- Assume that the total industry cost including the normal rate of return is equal to ΣK
- One possible adjustment to the cost norms for the individual companies is:

Alt 1: Multiplicative

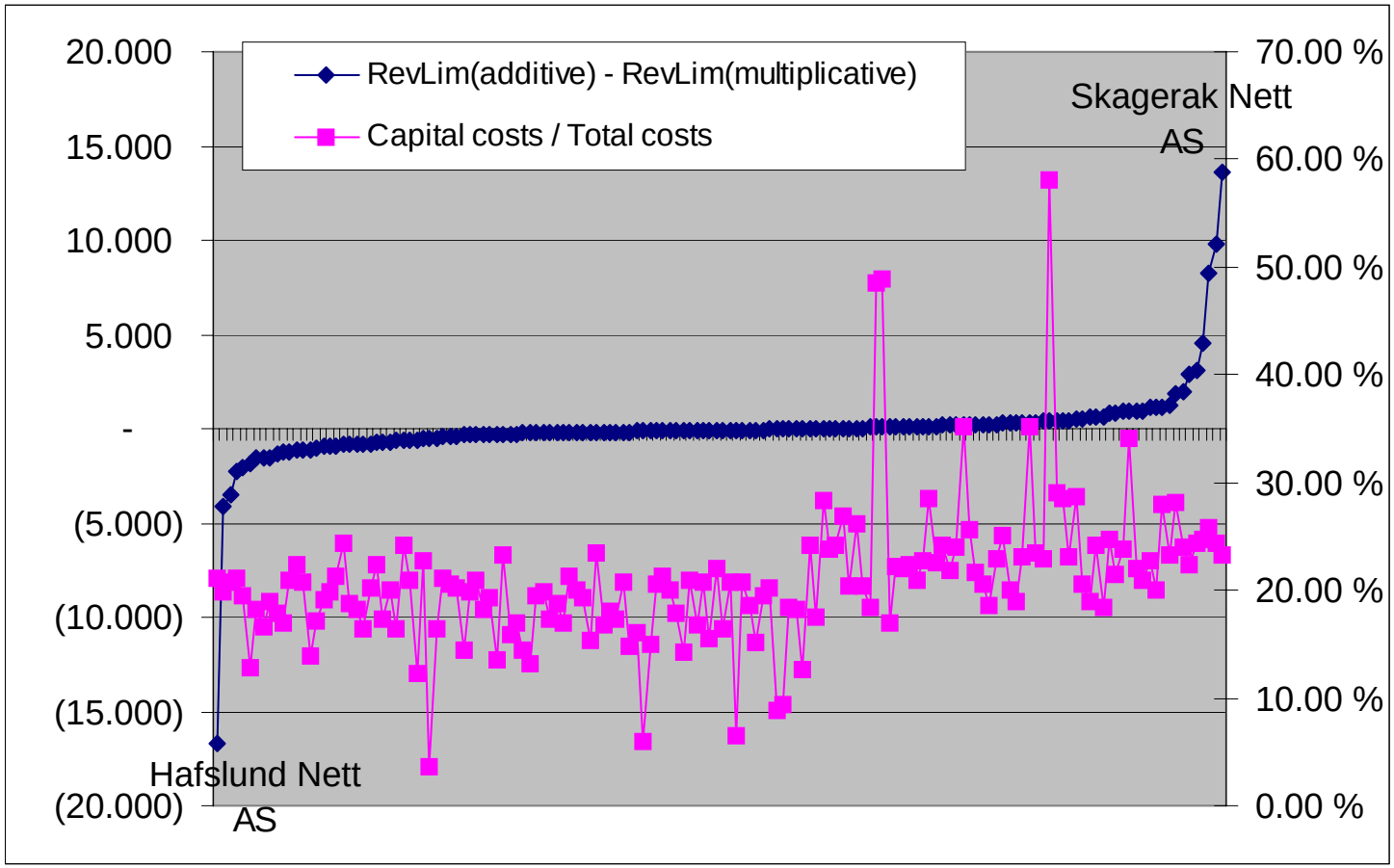
$$K^*_{i,Calibrated} = K^*_i \cdot \frac{\Sigma K}{\Sigma K^*}$$

- Another is:

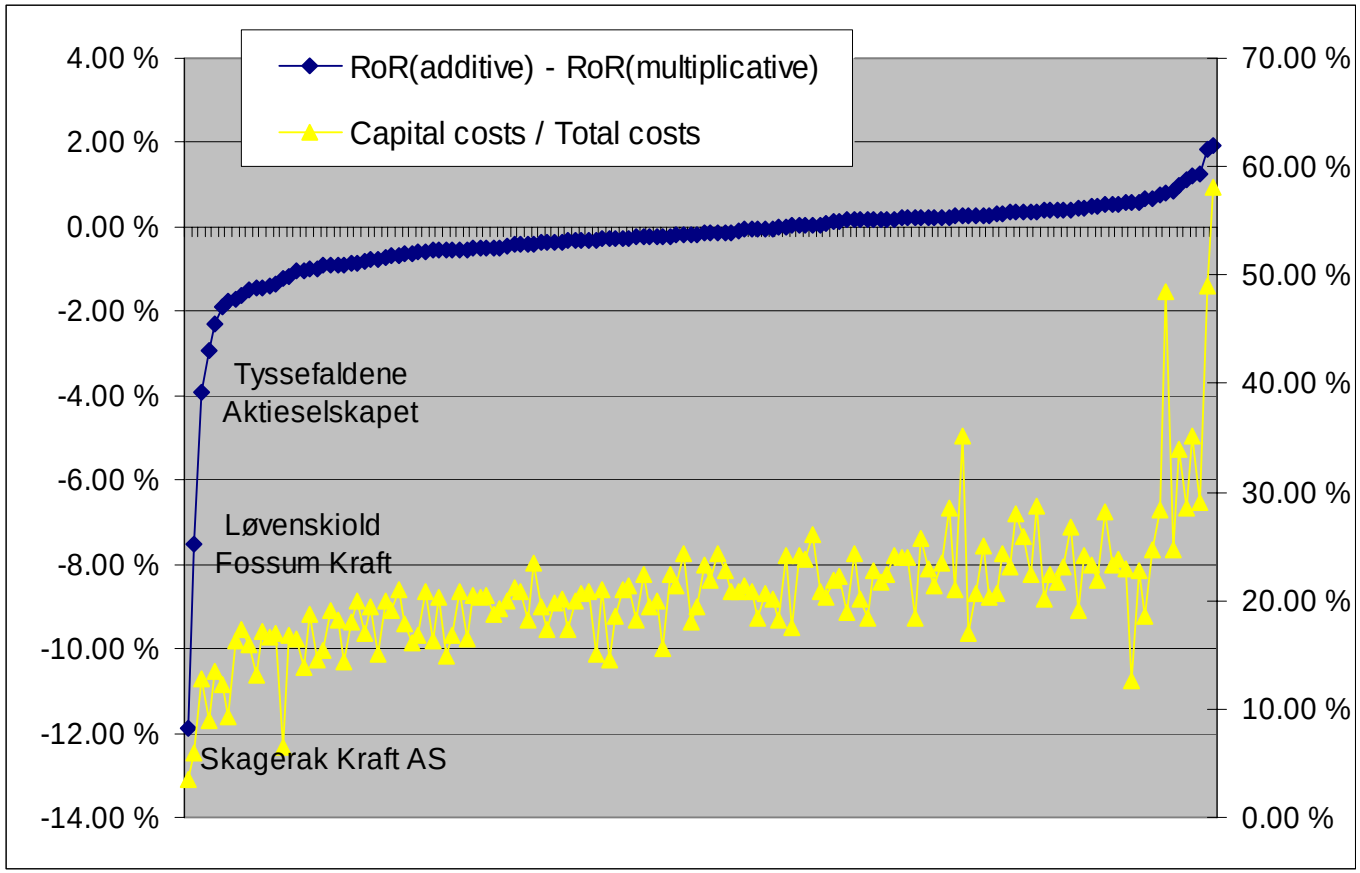
Alt 2: Additive

$$K^*_{i,Calibrated} = K^*_i + \left(\frac{\Sigma K - \Sigma K^*}{\Sigma BV} \right) \cdot BV_i$$

Additive versus multiplicative calibration



Additive versus multiplicative calibration



Suggested three step calibration NVE June 2006

1. Correct for difference between average and actual VOLL
   - Complicated
   - Necessary?
2. Find a cost-weighted DEA-result for each company
   - D and RS aggregated
   - Multiplicative
   - Most of the calibration takes place here
3. Calibration of average returns
   - Additive
   - Removes ΣJP

Calibration effects

(2006-MNOK)

	2003	2004	2005	2006
Initial revenue limit	12,362	12,359	11,972	11,945
Multiplicative calibration	1,239	1,390	1,286	1,049
Delay compensation (JP)	290	299	311	308
Additive calibration	(318)	(318)	(248)	(330)
Final revenue limit	13,574	13,730	13,321	12,973

- Additive calibration reverses effect of delay compensation (JP)
- Not correct!

Primal and dual DEA-formulation

$$\min_{\lambda} \sum_{j \neq j^*} \lambda_j x_j$$

s. t.

$$y_{rj^*} \leq \sum_{j \neq j^*} \lambda_j y_{rj} \qquad r = 1,\ldots,s$$

$$\lambda_j \geq 0 \qquad j = 1,\ldots,n$$

$$\max_{p} \sum_{r} y_{rj^*} p_{rj^*}$$

s. t.

$$\sum_{r} y_{rj} p_{rj^*} \leq x_j \qquad j \neq j^*$$

$$p_{rj^*} \geq 0$$

Find reference company with minimum costs, such that the reference company produces at least as much as the evaluated company

Find prices that maximize the company's revenues given that the costs of the other companies are within budget

Interpretation shadow price p_{rj^*}:
Indicates the increase in minimum costs given an increase in produced output y_{rj^*}
Local "unit cost"

Shadow prices, slack and investment incentives

- Example
  - Viken, CRS + SuperEff
  - Objective function = Cost norm
- Slack in all outputs except one
  - High slack-values compared to actual quantities
  - Shadow price = 0 for very large increases in output (allowable increase)
  - No increase in cost norm if output is increased

Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
Kvantum referanseselskap Lavspent	16133	0	8010	8123	1E+30
Kvantum referanseselskap Høyspent	6280	0	2665	3615	1E+30
Kvantum referanseselskap Levert energi	8656968	0	8370401	286568	1E+30
Kvantum referanseselskap Abonnenter	303312	2,73	303313	1E+30	10040
Kvantum referanseselskap ForventetKILE	25727	0	14865	10862	1E+30
Selskapets egen vekt	-1,10578E-13	-93198	0	1	0

Recommendations

- Cost must be representative
  - Reference period
  - Principles for assessing cost (economic versus accounting)
  - Data quality
- Investigate cost structures
  - Must gain knowledge about cost structures and cost groups in order to build a good model
    - Which unit to analyze
    - Responsibilities must be comparable or reflected in different outputs
    - Determine the cost drivers (outputs)
- Start early to think about data collection
- How will you use the results of the DEA analyses?
  - May need to adjust the efficiency scores