Implementing Super-Efficiency in the Regulation of Electricity Networks

Endre Bjørndal Mette Bjørndal Thore Johnsen
NHH

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Norges Handelshøyskole
Norwegian School of Economics and Business Administration

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 right 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"

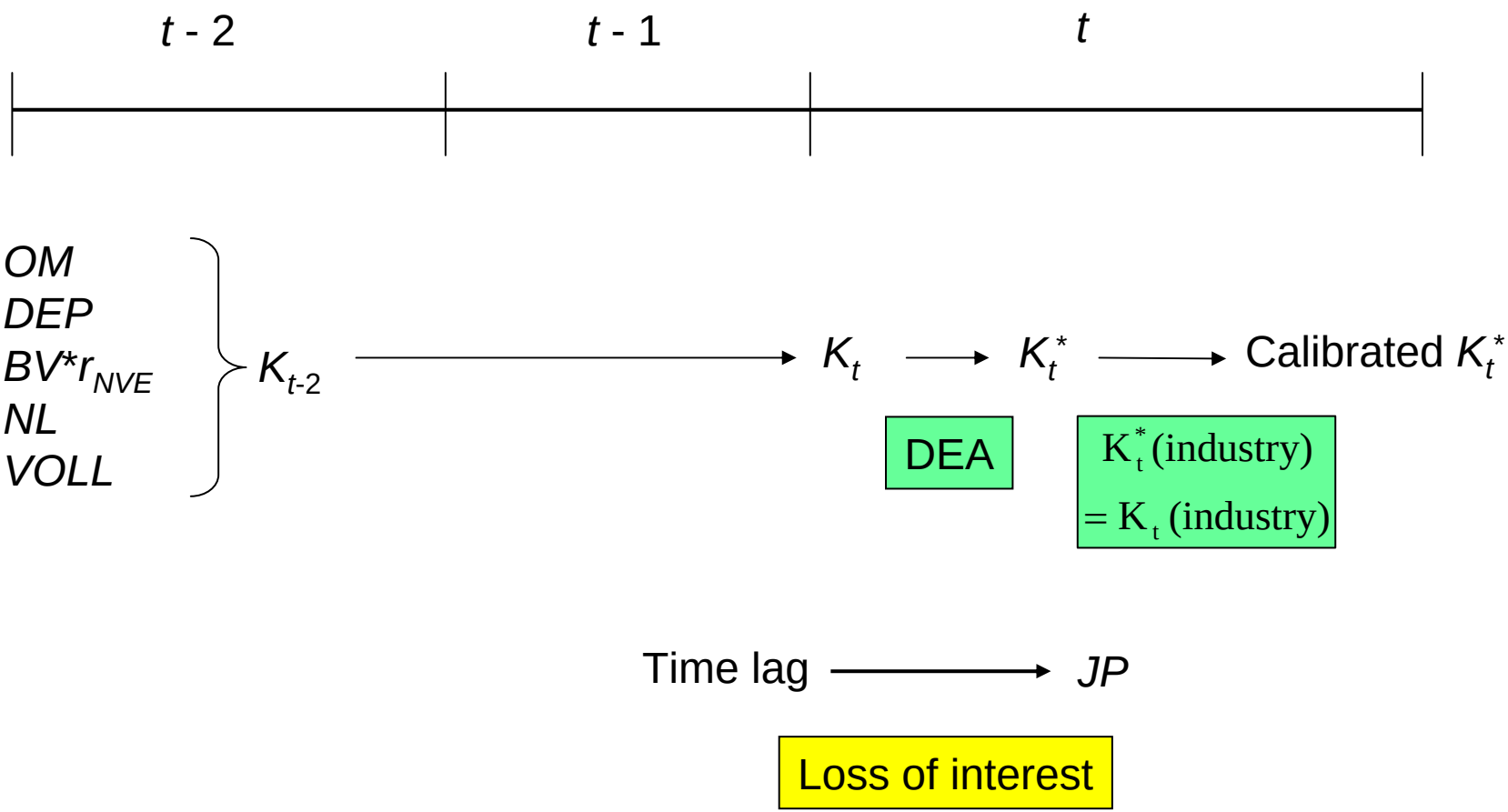
- Yardstick-competition
  - Revenue cap based on actual costs and cost norms
  - $IR = K + \rho\,(K^* - K)$

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 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



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

DEA model – primal and dual

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

s. t.

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

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

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

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

s. t.

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

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

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

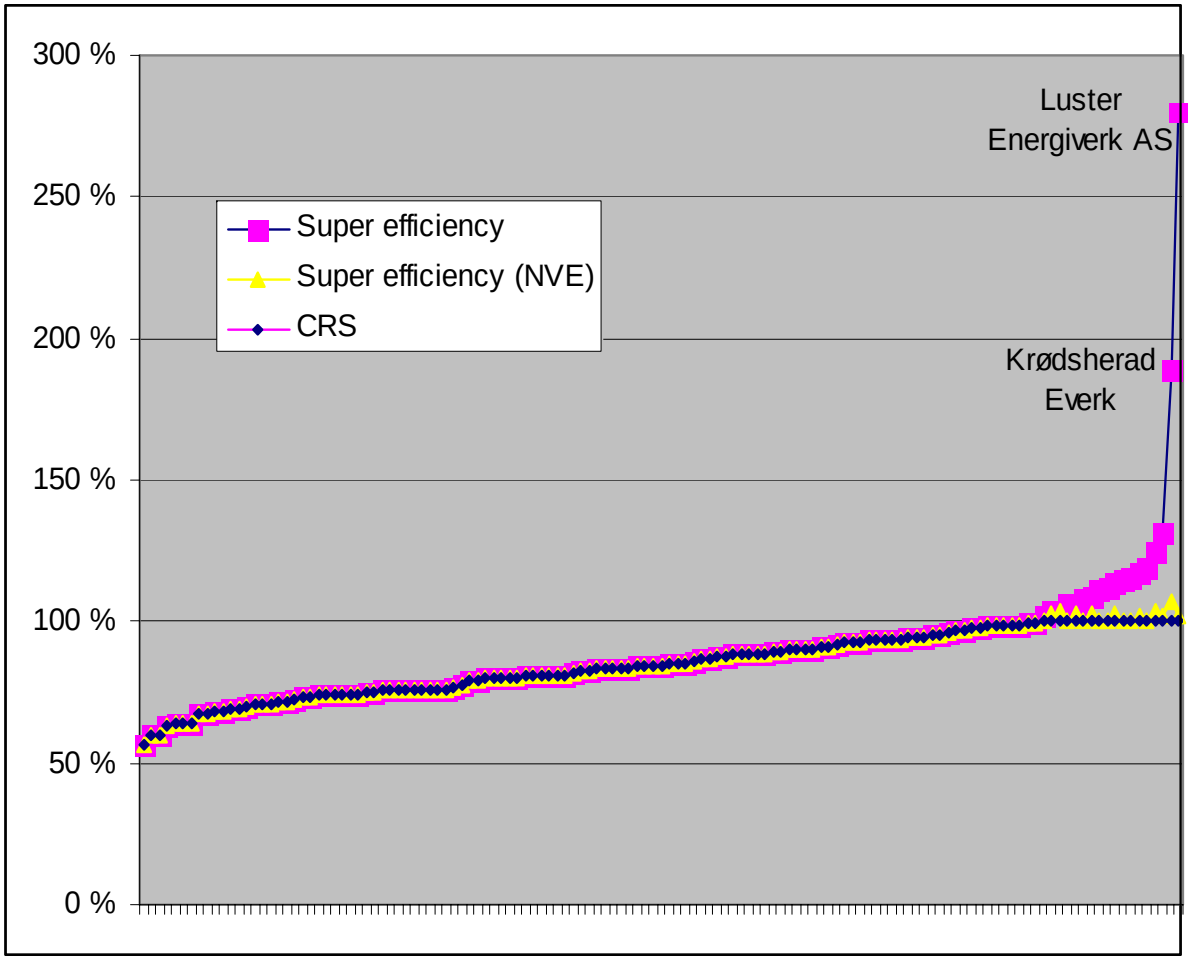
Interpretation shadow price p_{rj^*}:
Indicates the increase in minimum costs given an increase in produced output y_{rj^*}
Local "unit cost"

Super efficiency & outliers

- Super efficient companies are not necessarily efficient
  - Outliers in the data set
- NVE proposal for remedy
  - For a super efficient company, its own data for the previous year (*t - 3*) are added to the data set
  - A company may be evaluated relative to its own performance the previous year
  - If output has not changed, an upper bound for the measured efficiency will be:

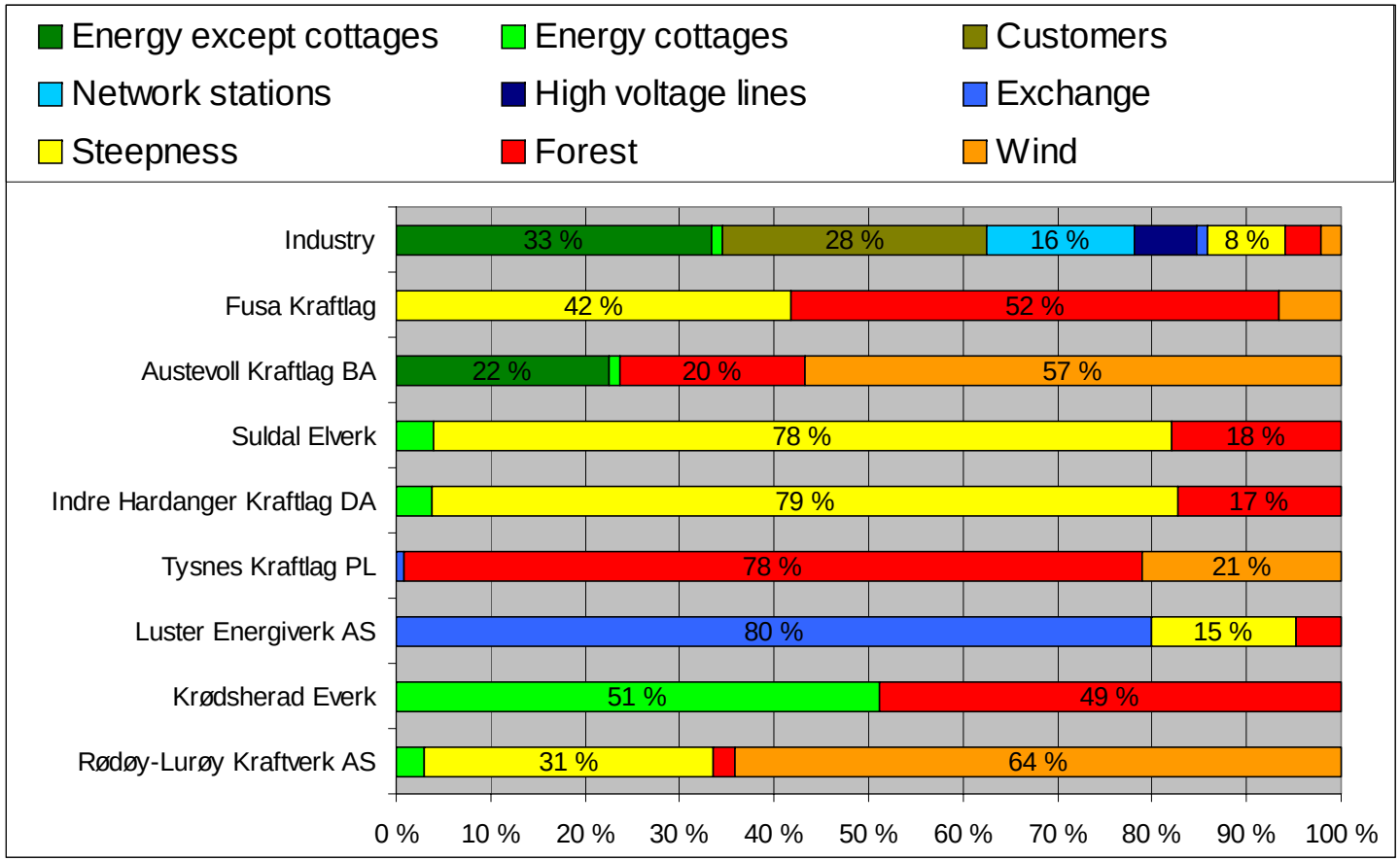
$$E_{i,t} \leq \frac{K_{i,t-1}}{K_{i,t}}$$

Super efficiency
(Distribution companies, 2004)



	CRS	Super eff.	NVE
Min	56 %	56 %	56 %
Max	100 %	280 %	107 %
# >100%	0	18	10

Decomposition of cost norms



- For many companies, most of their cost norm is based on ”non-essential” output factors

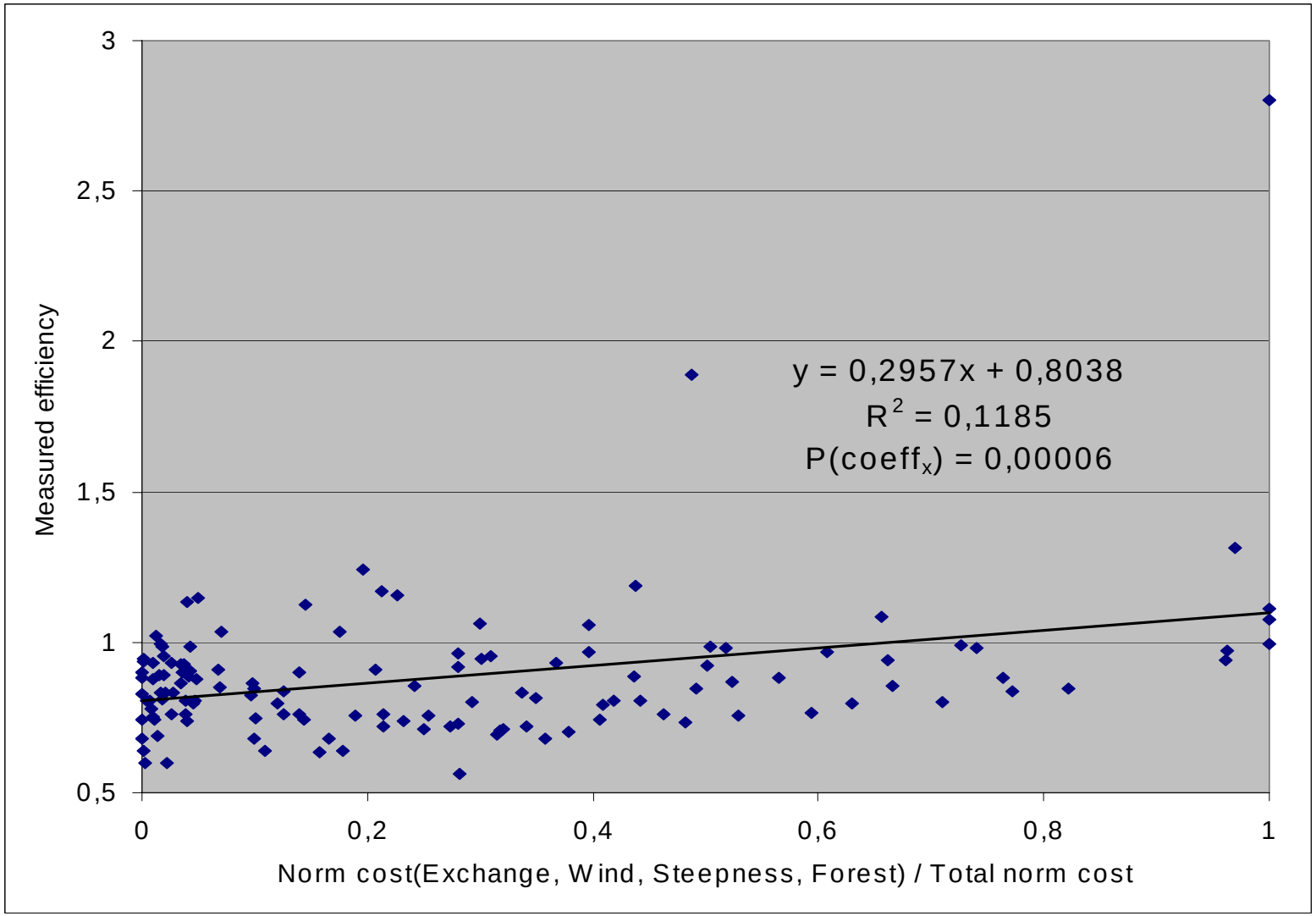
Example

(Tysnes Kraftlag AL, Eff = 99.5%)

Output	Price	Slack
Customers	0	2050
Energy except cottages	0	39204
Energy cottages	0	10439
Network stations	0	156
High voltage lines	0	116
Exchange	2.39	0
Forest	1.52	0
Steepness	0	284
Wind	554.86	0

- The revenue limit of this company will be independent of #customers and delivered energy
- Reasonable?

Efficiency or extreme output weights?



NVE proposal – incentive effects

- Example
  - Luster Energiverk
  - Distribution
- Actual costs of 16 MNOK in 2004
- Efficiency analysis for the determination of the 2006 revenue limit
  - Eff(CRS) = 100%
    - K* = 16 MNOK
  - Eff(CRS w/super efficiency) = 280%
    - K* = 45 MNOK = 16 + 29

Effect of cost reduction

(reduction of 1 MNOK from 2006)

- Model with super efficiency:

t	2006	2007	2008	2009	2010
ΔK_t	-1	-1	-1	-1	-1
ΔK_{t-2}	0	0	-1	-1	-1
ΔK^*_{t-2}	0	0	0	0	0
ΔIR_t	0	0	-0,4	-0,4	-0,4
ΔR_t	+1	+1	+0,6	+0,6	+0,6

Owners are allowed to keep 60% of cost reduction for ever

- NVE model:

t	2006	2007	2008	2009	2010
ΔK_t	-1	-1	-1	-1	-1
ΔK_{t-2}	0	0	-1	-1	-1
ΔK^*_{t-2}	0	0	0	-1	-1
ΔIR_t	0	0	-0,4	-1	-1
ΔR_t	+1	+1	+0,6	0	0

Owners are allowed to keep (part of) cost reduction for three years

Effect of cost increase

(increase of 29 MNOK from 2006)

- Model with super efficiency:

t	2006	2007	2008	2009	2010
ΔK_t	+29	+29	+29	+29	+29
ΔK_{t-2}	0	0	+29	+29	+29
ΔK^*_{t-2}	0	0	0	0	0
ΔIR_t	0	0	+11,6	+11,6	+11,6
ΔR_t	-29	-29	-17,4	-17,4	-17,4

Increased payoff to other input factors

Loss for capital owners

- NVE model:

t	2006	2007	2008	2009	2010
ΔK_t	+29	+29	+29	+29	+29
ΔK_{t-2}	0	0	+29	+29	+29
ΔK^*_{t-2}	0	0	0	+29	+29
ΔIR_t	0	0	+11,6	+29	+29
ΔR_t	-29	-29	-17,4	0	0

Increased payoff to other input factors

Loss for capital owners

Average efficiency

- 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?

Accounting based capital costs

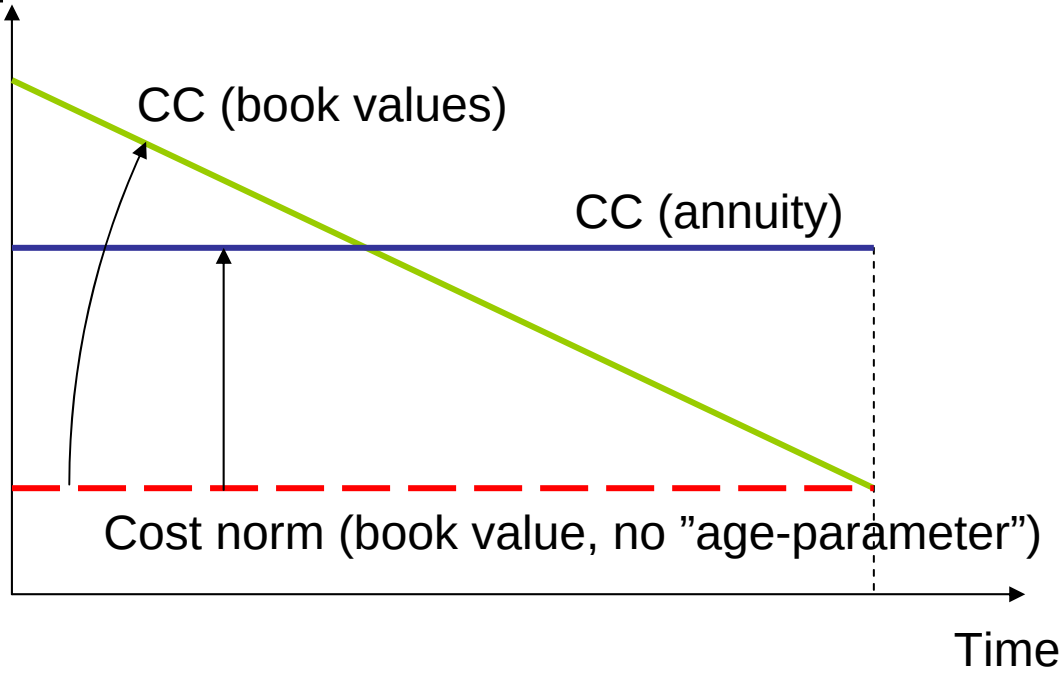
- Choice of capital base / capital cost will influence the measured efficiencies
  - Book values versus replacement values
- Productivity relatively independent of age
  - Accounting based costs do not reflect economic costs very well
  - Over-estimated efficiency in old networks, under-estimated in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

Calibration: 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”



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

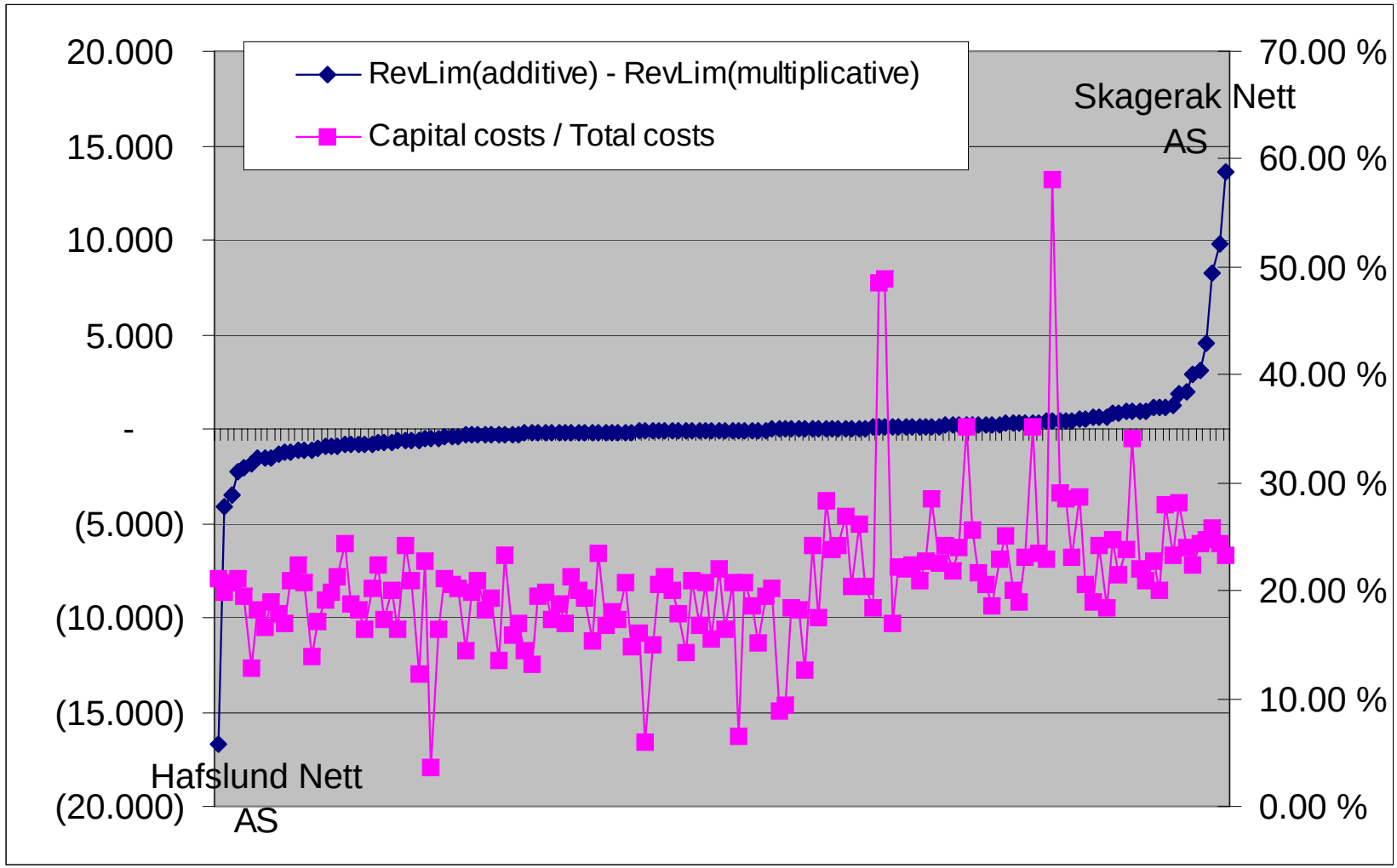
$$K^*_{i,Calibrated} = K^*_i \cdot \frac{\Sigma K}{\Sigma K^*}$$

- Another is:

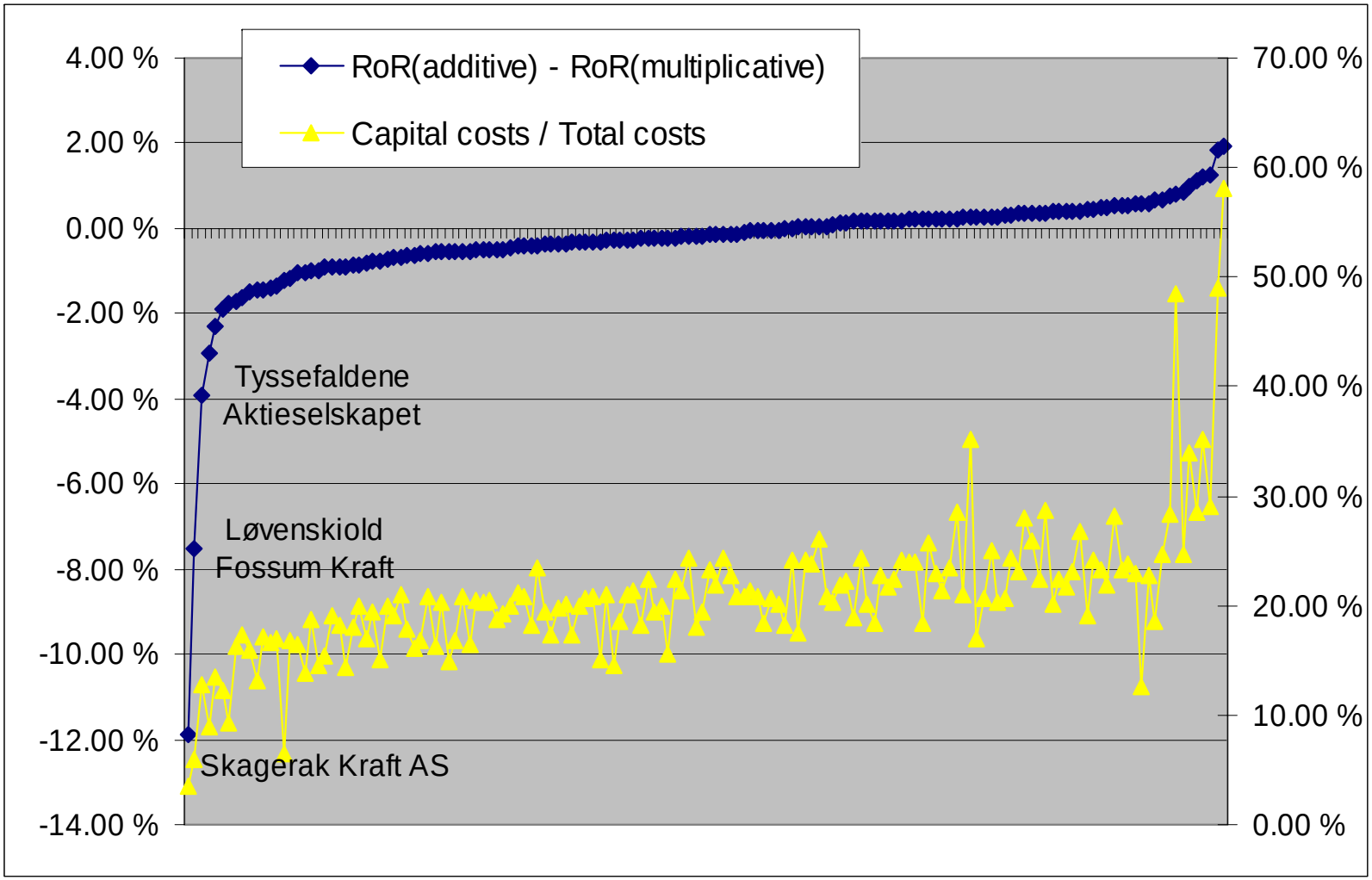
Alt 2: Additive

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

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

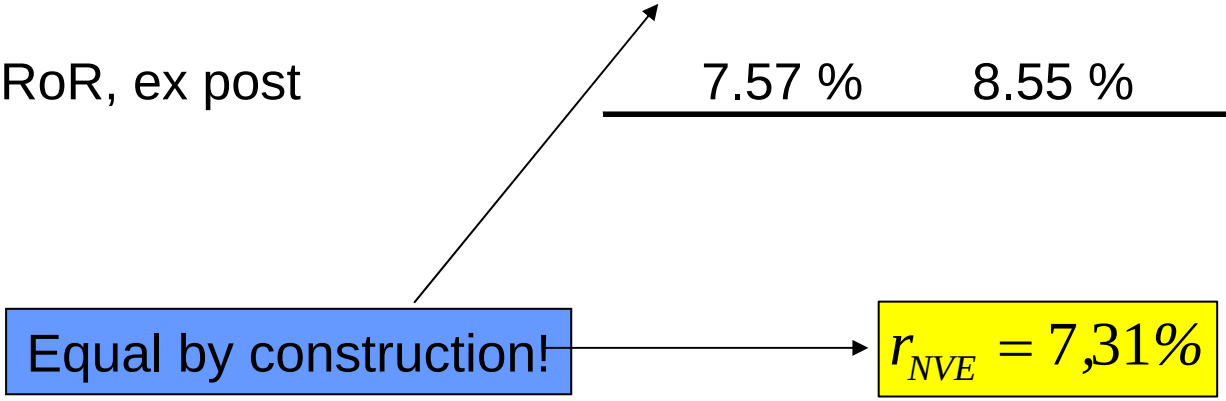
(2006-MNOK)

	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!

Calibration effects

	2003	2004	2005	2006
RoR, initial revenue limit	4.38 %	3.91 %	3.91 %	4.66 %
Multiplicative calibration	3.00 %	3.45 %	3.24 %	2.71 %
	7.38 %	7.36 %	7.15 %	7.37 %
Delay compensation (JP)	0.70 %	0.74 %	0.78 %	0.80 %
Additive calibration	-0.77 %	-0.79 %	-0.62 %	-0.85 %
RoR, final revenue limit	7.31 %	7.31 %	7.31 %	7.31 %
RoR, ex post	7.57 %	8.55 %	N/A	N/A



Alternative calibration

1. Find the efficiency ratio E_i from solving the DEA-model
2. Compute $K_i^* = K_i^t \cdot E_i$ where K_i^t is the cost basis to be used in the revenue cap calculation
3. Calibrate K_i^* based on one of the alternatives
   - Multiplicative
   - Additive (wrt *BV*)

   $$\left.\begin{array}{l}\text{Multiplicative}\\ \text{Additive (wrt } BV\text{)}\end{array}\right\} \Rightarrow \sum_i K^*_{i,Calibrated} = \sum_i K_i^t$$
4. The revenue cap is equal to

$$IR_i = \rho \cdot K^*_{i,Calibrated} + \left(1-\rho\right) \cdot K_i^t + JP_i^t$$

Conclusions

- Super efficiency
  - Proposed variant gives weak incentives for cost reductions
  - Cost norm is not independent of actual costs
  - Can outliers be handled in a different manner?
    - Weight restrictions á la Wong & Beasley (1990)
- Calibration
  - Important
  - Ensures sufficient profitability for the entire industry
  - Choice of method matters
    - Incentive effects
    - Time profile of revenues