Benchmarking in Electricity Distribution and Regional Transmission Companies – Effects of Data Quality and Cost Allocations

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Background

- Norwegian electricity sector
  - Competitive supply of (and demand for) power
  - Transmission and distribution are regulated
- Present regulatory scheme
  - Limit on total revenue for each company
  - 5 year regulation period
  - Initial revenue limit based on historical costs
  - Yearly reduction in revenue cap for inefficient companies
  - Inefficiency is determined using DEA (data envelopment analysis)

New regulation period

- The regulatory scheme is to be revised from 2007
  - Increased use of norms
    - Efficiency analyses (ρ = 0.6)
  - Research Projects
    - Regulator (NVE)
    - Companies/industry (EBL)
- Our project
  - Efficiency requirements and cost pools
    - Correct?
    - Understandable?
  - Alternative norm-based model

Present DEA scheme

- Input-based, cost efficiency
- VRS
- 5 inputs, company specific factor prices
  - No. of man years / wage (NOK)
  - Goods and services (NOK) / factor price = 1
  - Power losses (MWh) / system price (NOK)
  - Capital
    - Book value (NOK) / depreciation rate + interest
    - Catalogue value (NOK) / annuity factor
  - Value of energy not delivered (NOK) / factor price = 1
- Separate models for distribution/regional networks
  - Total efficiency score = cost weighted combination of individual efficiency scores

DEA models – output factors

- Distribution network
  - Low voltage lines (km)
  - High voltage lines (km)
  - Customers (number of)
  - Energy delivered (MWh)
  - Value of energy not delivered, expected (NOK)

- Regional transmission network
  - Network size (km)
  - Transported load (MW)
  - Exchange (weighted no. of components)
  - Value of energy not delivered, expected (NOK)
  - Central grid (weighted no. of components)
- Structure is imposed through weighting of components!

Proposed revision

- Yardstick regulation
  - Yearly updates based on efficiency scores
- Formula
  - $IR_t = K_{t-2} + 0.6 \cdot (K_{t-2}^* - K_{t-2})$
- K based on accounting values, including capital costs
- K^* based on DEA
  - Cost efficiency / CRS
  - Total cost
  - Book values
  - ‘Age’ parameter?

Overview

- Data Uncertainty
  - Cost of capital
  - Effects
- Cost Allocations
  - R versus D
  - Effects
  - Super-efficiency
- Conclusions and recommendations

Capital costs

- Alternatives
  - Book values (BV = ‘bokført verdi’)
  - Replacement values (NV = ‘nyverdi’)
  - Historical costs adjusted for inflation
- Choice of capital base / capital cost will influence the measured efficiencies

Capital costs - alternatives

- Book value (BV)
  - Depreciation plan influences efficiency scores
    - Life span of equipment (choice?)
    - Age distribution of assets
  - Possible advantage: If the productivity of the equipment decreases over time, then the use of book values gives a cost estimate that is more consistent with actual operating and maintenance costs

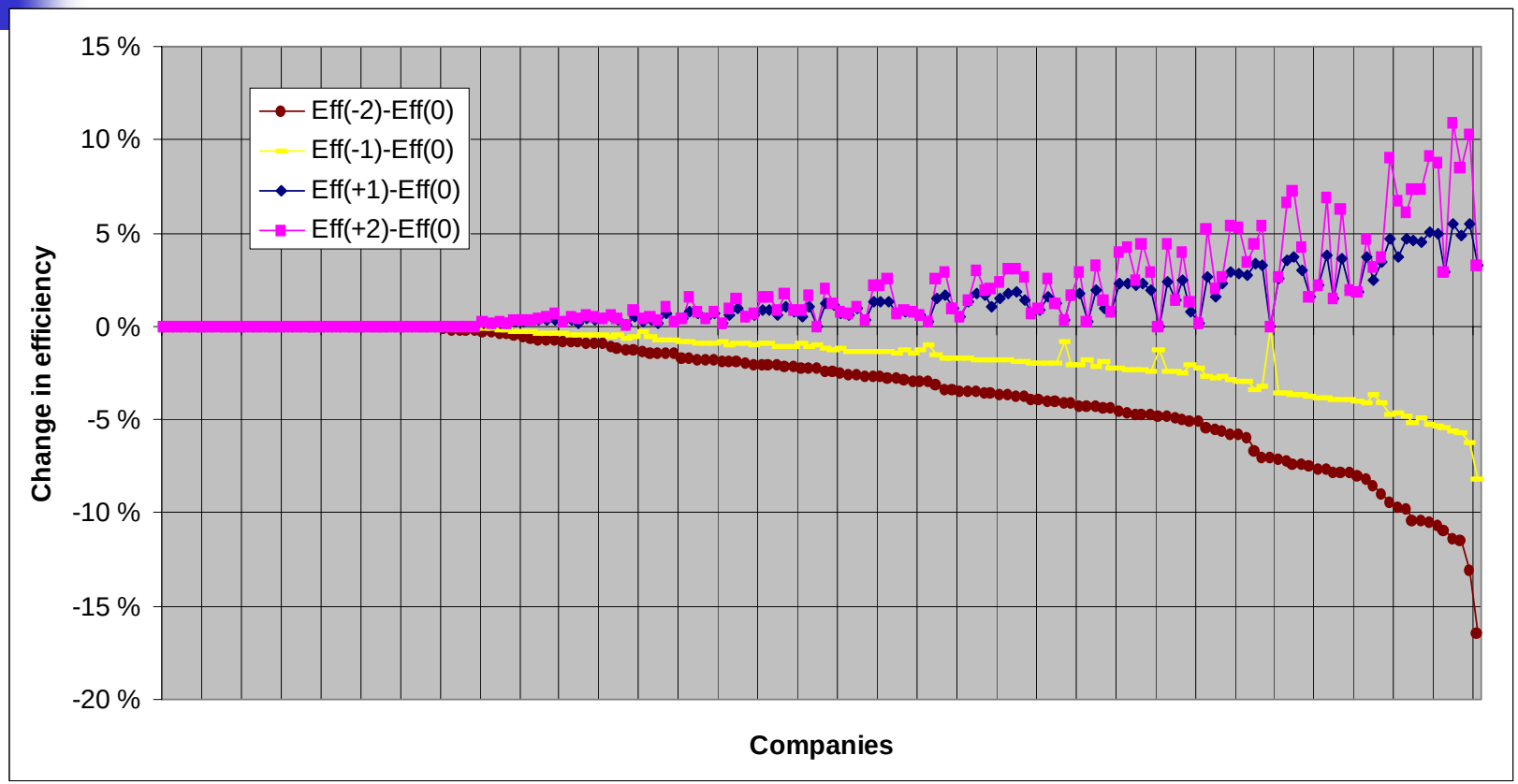
Capital costs - alternatives

- NV (‘nyverdi’)
  - Advantage: More correct if productivity of equipment is approximately constant over time
  - Uses catalogue prices of equipment
    - Price inefficiency is not measured?
  - Catalogue prices do not fully reflect local conditions
    - Climate, topography etc.
  - Does not reflect direct investment contributions by customers (‘anleggsbidrag’)

Capital costs - alternatives

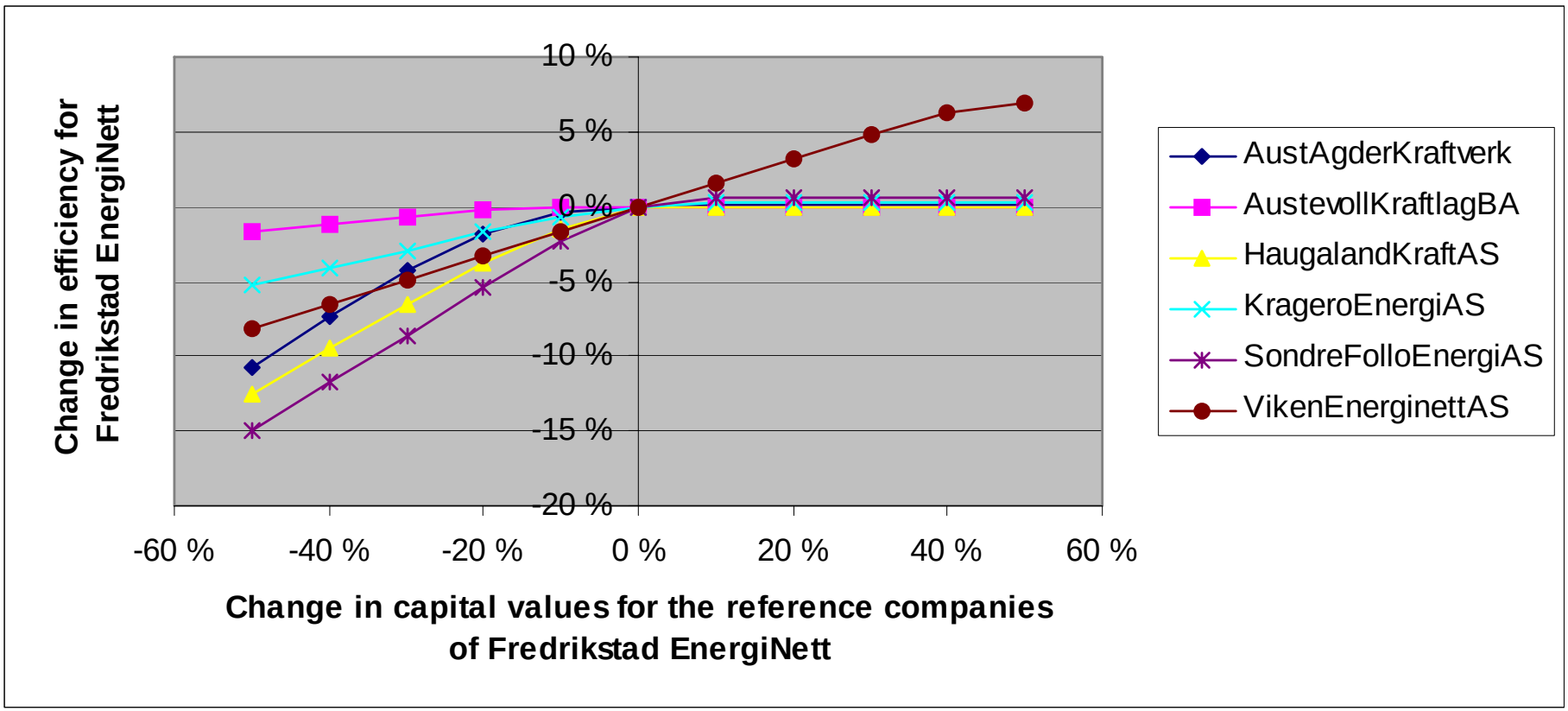
- Historical cost adjusted for inflation and direct investment contributions
  - Advantage: Takes into account price efficiency
  - But: Relative prices change over time. The method does not reflect that it is not always possible to take advantage of favorable prices
  - Consistency between efficiency measurement and the determination of revenue caps?
    - Old equipment can play a large role in the efficiency measurement even though their share of the revenue cap is very small

Capital costs – effects of data quality



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

Capital costs – effect of data quality



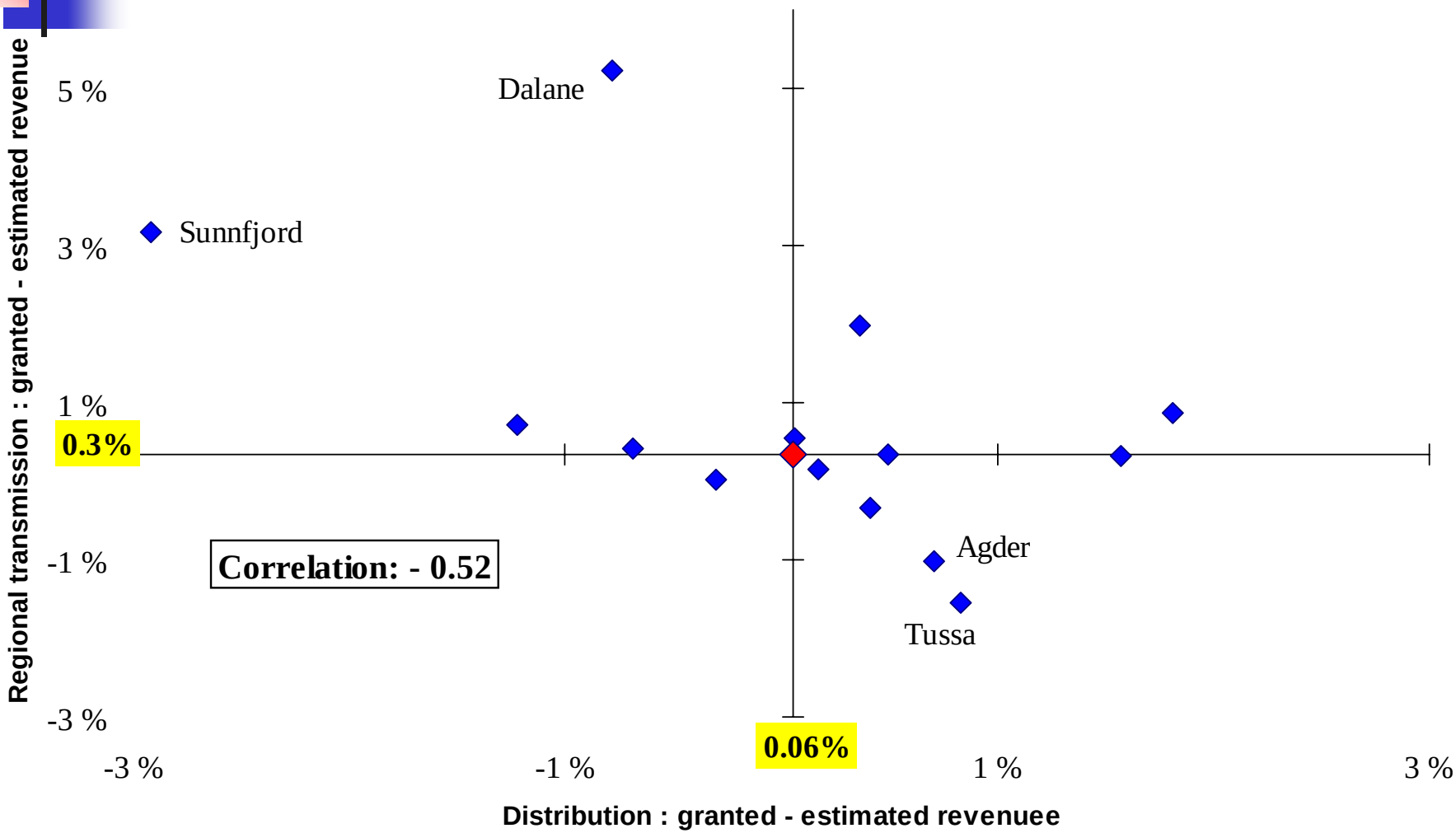
Capital costs & definition of tasks

- 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
  - Norm-model based on replacement values / real annuity
  - DEA

Three Alternative Cost Groups

Criteria	**Regional transm. / distribution**	**Customer rel. / Network rel.**	**Activities**
Divisibility	Problematic cost allocations	Possible to separate accounts	Difficult to compare between companies
Measurement errors when comparing units	Large	Some, but possible to reduce	Very large
Controllability	Not considered	Partly	Great possibilities
Information value	Very low	Medium	Potentially high

Cost Allocation – R vs D



Separate LP-models

$$\underset{\lambda^k}{\text{Minimize}} \frac{\sum_j \lambda^k_j x^k_j}{x^k_{j^*}}$$

subject to

$$y^k_{rj^*} \le \sum_j \lambda^k_j y^k_{rj} \qquad r = 1,\ldots,s^k$$

$$\lambda^k_j \ge 0 \qquad j = 1,\ldots,n$$

$$\sum_j \lambda^k_j = 1$$

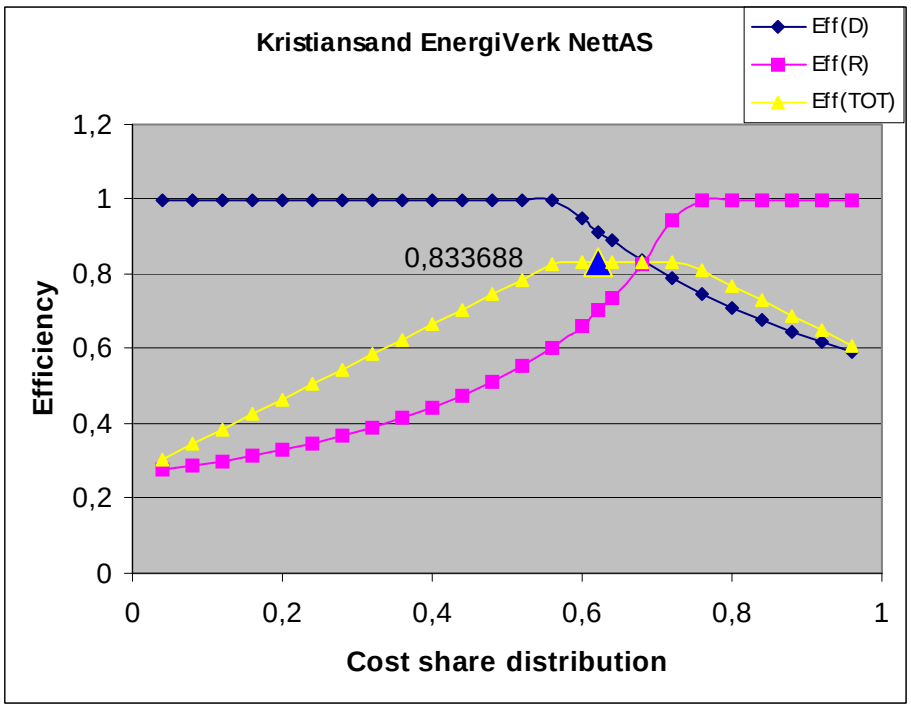
$$k \in \{D, R\}$$

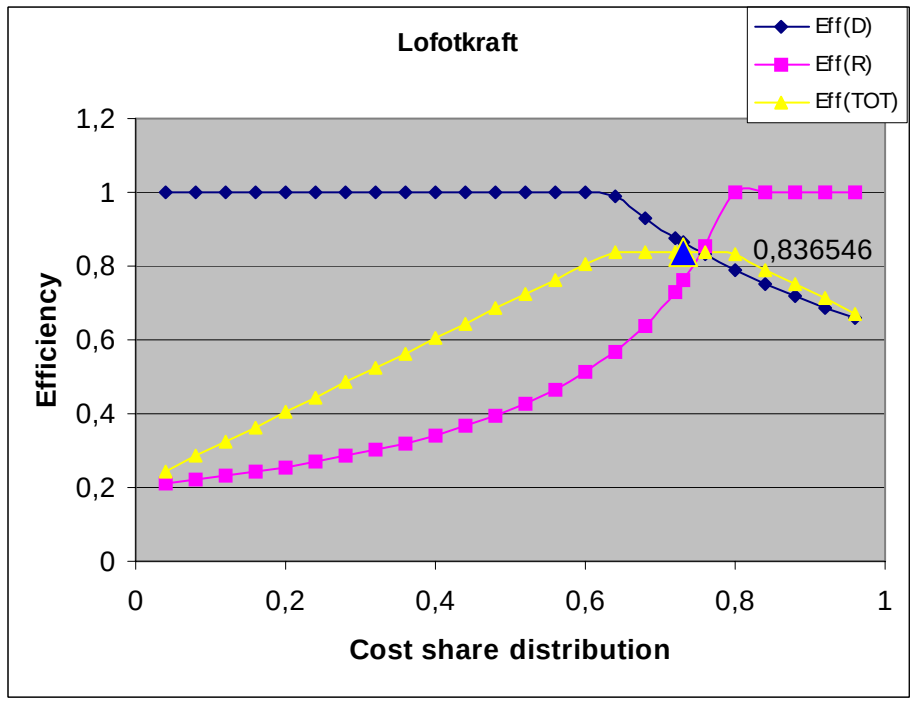
Combined DEA-efficiency

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

Is it possible to influence the efficiency scores by reallocating costs?

Cost allocation and efficiency





Examples: Model with aggregated inputs, CRS

Finding the ”optimal” cost allocation

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

$$= \frac{\sum_j \lambda_j^D x_j^D}{x_{j^*}^D} \cdot \frac{x_{j^*}^D}{x_{j^*}^D + x_{j^*}^R} + \frac{\sum_j \lambda_j^R x_j^R}{x_{j^*}^R} \cdot \frac{x_{j^*}^R}{x_{j^*}^D + x_{j^*}^R}$$

$$= \frac{\sum_j \lambda_j^D x_j^D + \sum_j \lambda_j^R x_j^R}{x_{j^*}^D + x_{j^*}^R}$$

$$= \frac{\lambda_{j^*}^D x_{j^*}^D + \lambda_{j^*}^R x_{j^*}^R + \sum_{j \neq j^*} \lambda_j^D x_j^D + \sum_{j \neq j^*} \lambda_j^R x_j^R}{x_{j^*}^D + x_{j^*}^R}$$

$\lambda_{j^*}^D > \lambda_{j^*}^R \Rightarrow$ Shift costs from R to D

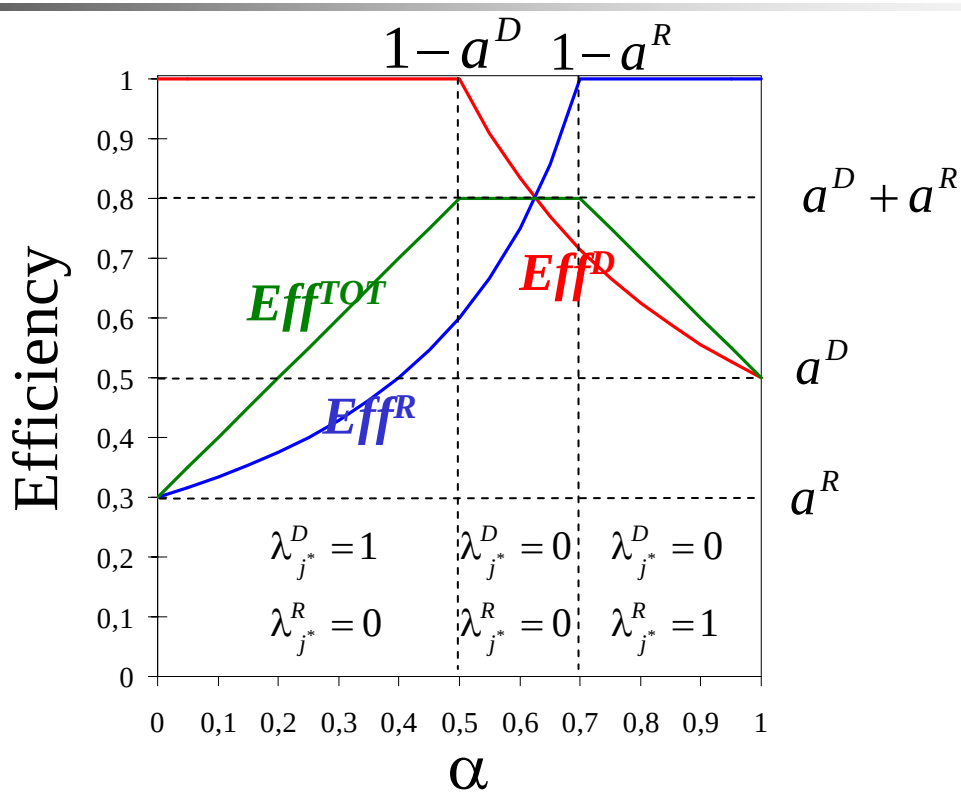
$\lambda_{j^*}^D < \lambda_{j^*}^R \Rightarrow$ Shift costs from D to R

Possible cases

$\lambda_{j^*}^D$	$\lambda_{j^*}^R$	Eff^D	Eff^R	Eff^{TOT}
1	1	1	1	1
0	0	$\frac{\sum_{j\neq j^*}\lambda_j^D x_j^D}{\alpha x_{j^*}^{TOT}} = \frac{a^D}{\alpha}$	$\frac{\sum_{j\neq j^*}\lambda_j^R x_j^R}{(1-\alpha) x_{j^*}^{TOT}} = \frac{a^R}{1-\alpha}$	$a^D + a^R$
1	0	1	$\frac{\sum_{j\neq j^*}\lambda_j^R x_j^R}{(1-\alpha) x_{j^*}^{TOT}} = \frac{a^R}{1-\alpha}$	$\alpha + a^R$
0	1	$\frac{\sum_{j\neq j^*}\lambda_j^D x_j^D}{\alpha x_{j^*}^{TOT}} = \frac{a^D}{\alpha}$	1	$a^D + 1 - \alpha$

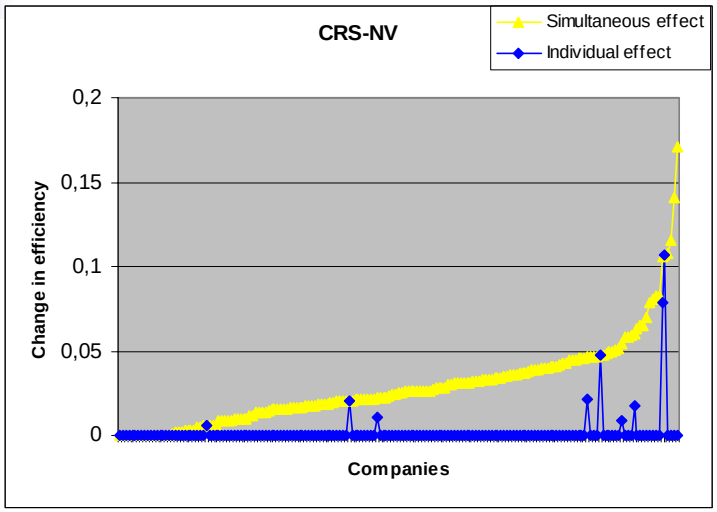
α = share of cost allocated to distribution network

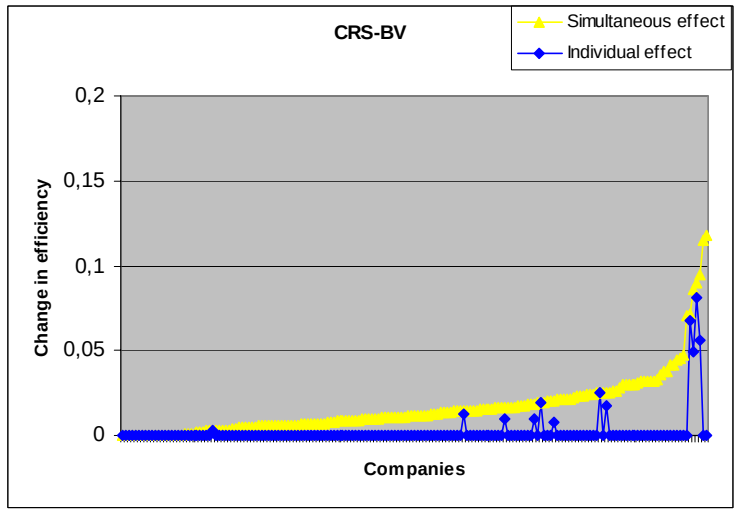
Exact relationship

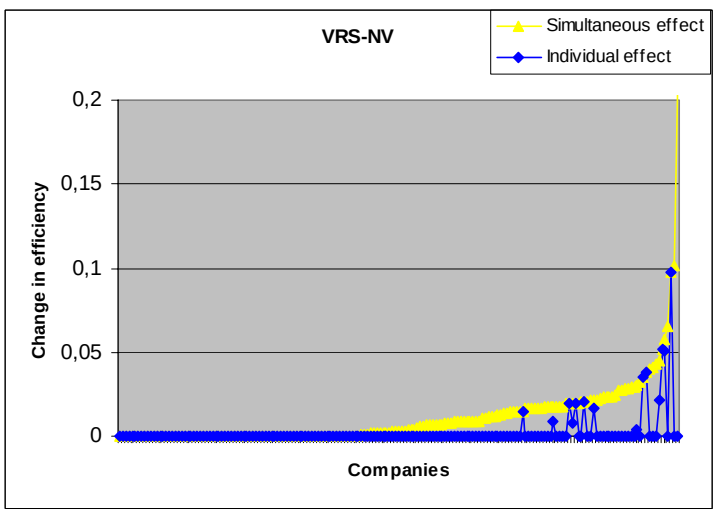


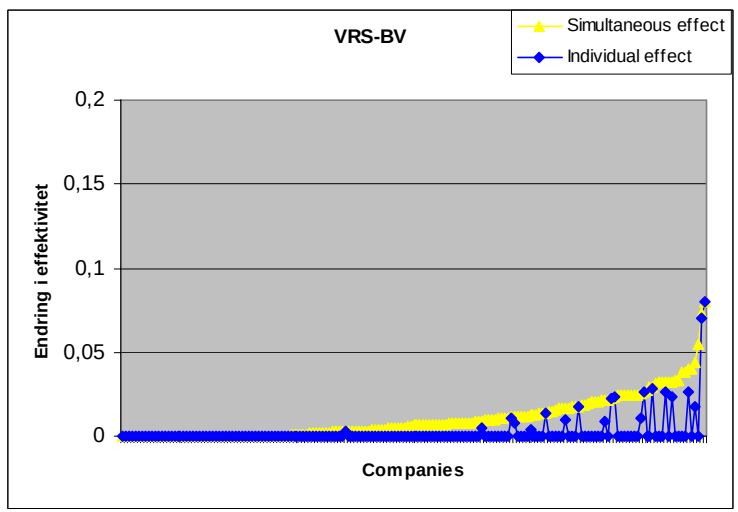
- Shifting 1% of the costs causes *Eff*^{TOT} to change by ±1%, or remain the same!
- A company can increase its *Eff*^{TOT} by shifting costs from an inefficient to an efficient activity!

Reallocation of costs - effects









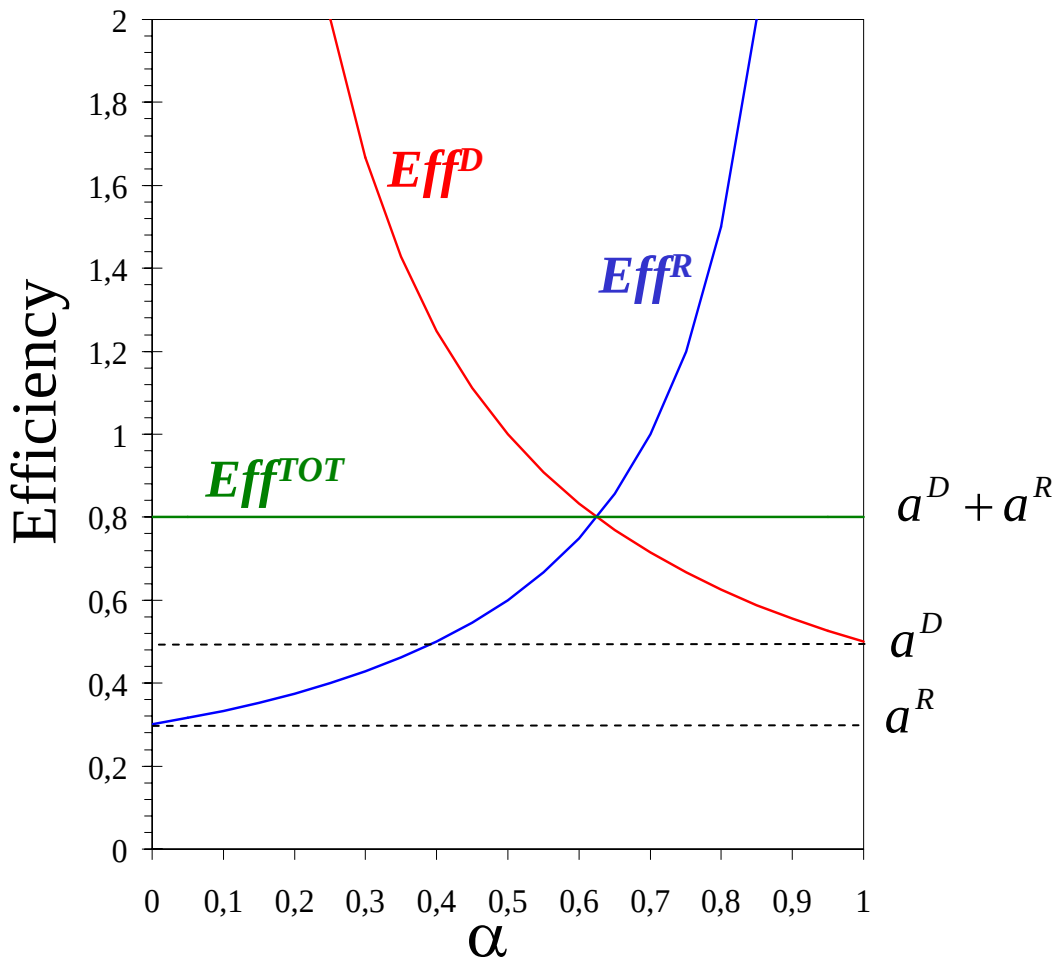
Super-efficiency

- Companies cannot be part of their own reference set
- Ensured by adding the constraint

$$\lambda^{k}_{j^*} = 0$$

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

Super-efficiency



Conclusions

- The DEA-model is
  - NOT simple to understand and interpret
  - NOT necessarily correct
  - NOT robust with respect to measurement errors

- Corrections or development of supplementary models require knowledge about the underlying cost structure!

Recommendations

- Start cautiously
  - Share data and models
  - Make sure the efficiency model is good enough
- Major challenges
  - Capital costs / Replacement values / Age parameter
  - ”Geography factor”
  - Definition of tasks
  - Quality