

# Productivity and deregulation of Norwegian electricity distribution utilities

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# Overview

- Background
- Norwegian regulation regime
- Cost Malmquist
- Bootstrap
- Model specification
- Data
- Results
- Conclusion

# Background

- Electricity distribution & transmission is natural monopoly
- Production and supply is not
- Norwegian Energy Act of 1990, in force from 1991
  - Competition in supply
  - Regulation in distribution & transmission
- Mainly public ownership
- Kittelsen (1994) suggested DEA-based Yardstick competition for regulating distribution
- Førsvund and Kittelsen (1998 /1994) found productivity growth around 1.5% for average unit 83-89.
- Prices are capped directly in new regime, but has productivity improved as expected?

# Regulation regime for distribution ( $\leq 22\text{kV}$ )

- Rate of return regulation 1993-1996
- RPI-X Revenue cap from 1997-2001
  - Common X: 1.5% p.a., supported by Malmquist analysis
  - Individual X, 0 - 3% p.a.
    - based on DEA potential in 94/95 data, cost minimizing VRS model
    - Best of replacement and book value capital models
    - Up to 38% of inefficiency to be eliminated in 5 years
  - ROR interval 2% - 15% as safety measure
- Revised RPI-X 2002-2006
  - Cost of energy not supplied (CENS/KILE), incentives for quality and investments
  - Cost base updated
  - ROR ceiling increased to 20%

# Cost Malmquist index

$$P^s = \{(\mathbf{x}, \mathbf{y}) \mid \mathbf{x} \text{ can produce } \mathbf{y} \text{ at time } s\}$$

$$\bar{P}^s = \{(\mathbf{x}, \mathbf{y}) \mid (g\mathbf{x}, g\mathbf{y}) \hat{=} P^s\}$$

$$c_t(\mathbf{y}, \mathbf{w}) = \underset{\mathbf{x}}{\text{Min}} \sum_{i=1}^m \hat{a}_i w_i x_i : (\mathbf{x}, \mathbf{y}) \hat{=} \bar{P}^t$$

$$OE_t = OE_t(\mathbf{x}^t, \mathbf{y}^t, \mathbf{w}^t) = \frac{c_t(\mathbf{y}^t, \mathbf{w}^t)}{\sum_{i=1}^m \hat{a}_i w_i^t x_i^t}$$

$$MC_s(\mathbf{x}^t, \mathbf{y}^t, \mathbf{x}^u, \mathbf{y}^u, \mathbf{w}^s) = \frac{OE_s(\mathbf{x}^u, \mathbf{y}^u, \mathbf{w}^s)}{OE_s(\mathbf{x}^t, \mathbf{y}^t, \mathbf{w}^s)} = \frac{c_s(\mathbf{y}^u, \mathbf{w}^s) / \sum_{i=1}^m \hat{a}_i w_i^s x_i^u}{c_s(\mathbf{y}^t, \mathbf{w}^s) / \sum_{i=1}^m \hat{a}_i w_i^s x_i^t}$$

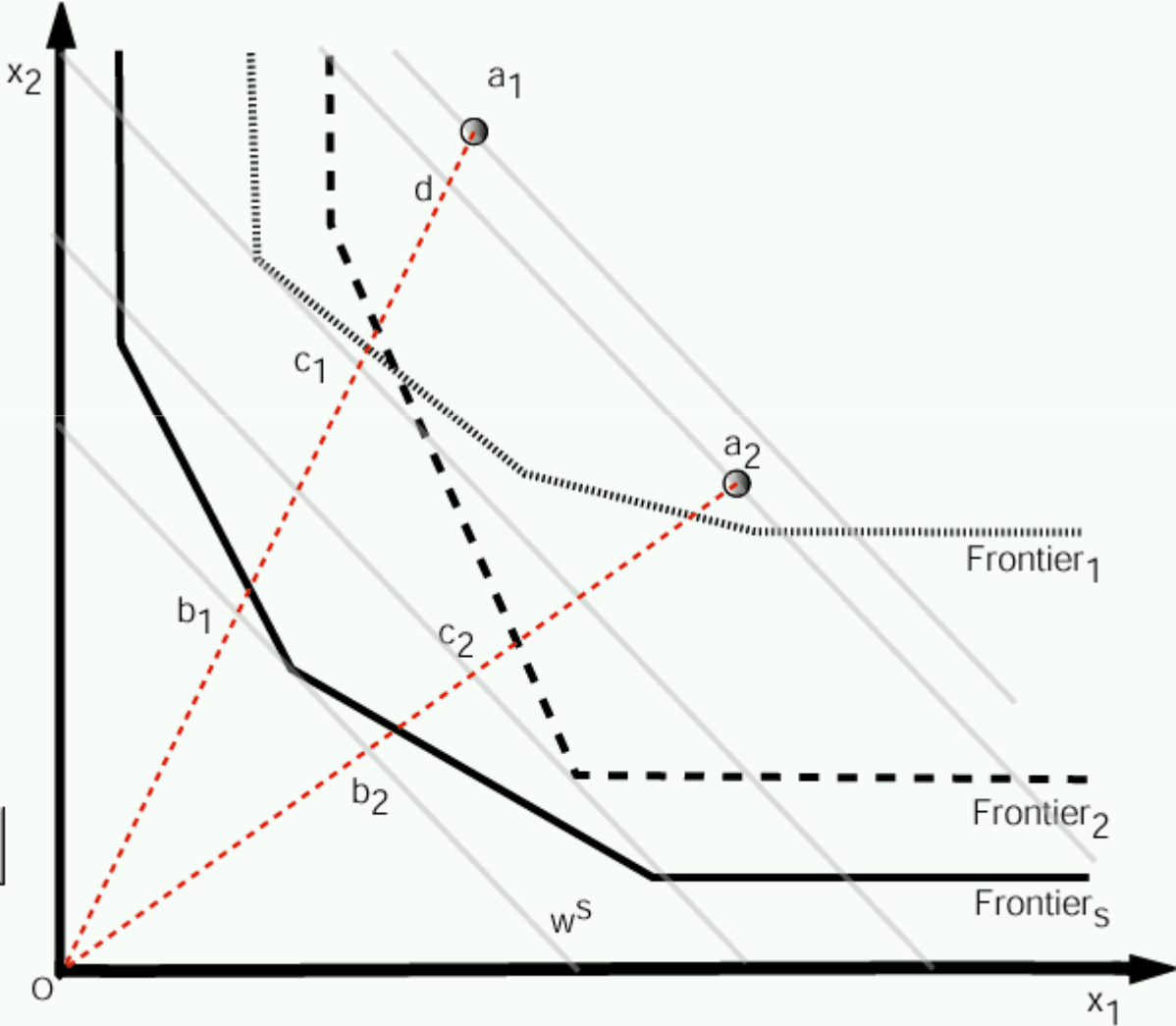
# Decomposition

$$\begin{aligned}
 & MC_s(\mathbf{x}^t, \mathbf{y}^t, \mathbf{x}^u, \mathbf{y}^u, \mathbf{w}^s) \\
 &= \frac{OE_u(\mathbf{x}^u, \mathbf{y}^u, \mathbf{w}^s)}{OE_t(\mathbf{x}^t, \mathbf{y}^t, \mathbf{w}^s)} \quad g \quad \frac{OE_s(\mathbf{x}^u, \mathbf{y}^u, \mathbf{w}^s)/OE_u(\mathbf{x}^u, \mathbf{y}^u, \mathbf{w}^s)}{OE_s(\mathbf{x}^t, \mathbf{y}^t, \mathbf{w}^s)/OE_t(\mathbf{x}^t, \mathbf{y}^t, \mathbf{w}^s)} \\
 &= \frac{c_u(\mathbf{y}^u, \mathbf{w}^s) / \overset{\circ}{\mathbf{a}}_{i \hat{M}} w_i^s x_i^u}{c_t(\mathbf{y}^t, \mathbf{w}^s) / \overset{\circ}{\mathbf{a}}_{i \hat{M}} w_i^s x_i^t} \quad g \quad \frac{c_s(\mathbf{y}^u, \mathbf{w}^s) / c_u(\mathbf{y}^u, \mathbf{w}^s)}{c_s(\mathbf{y}^t, \mathbf{w}^s) / c_t(\mathbf{y}^t, \mathbf{w}^s)} \\
 &= CEC_{u,t}(\mathbf{x}^t, \mathbf{y}^t, \mathbf{x}^u, \mathbf{y}^u, \mathbf{w}^s) \quad g \quad CFC_{s,u,t}(\mathbf{y}^u, \mathbf{y}^t, \mathbf{w}^s)
 \end{aligned}$$

# Index estimation

- $P^t$  estimated with DEA (Farrell, CCR, BCC)
- Homogenous envelopment even when VRS technology
- Circularity (Berg et al.) ensured by fixed reference
  - Pooled frontier fixed reference set  $\hat{P}^s = \bigcup_t \hat{P}^t$
  - Average (over time) fixed input prices
- Average unit as Structural measure (Farrell, Førsund & Hjalmarsson)
- Bootstrap confidence intervals and bias estimates (Simar & Wilson)
  - Homogenous bootstrap, Gaussian kernel
  - No time dependencies (univariate kernel)

# Cost Malmquist





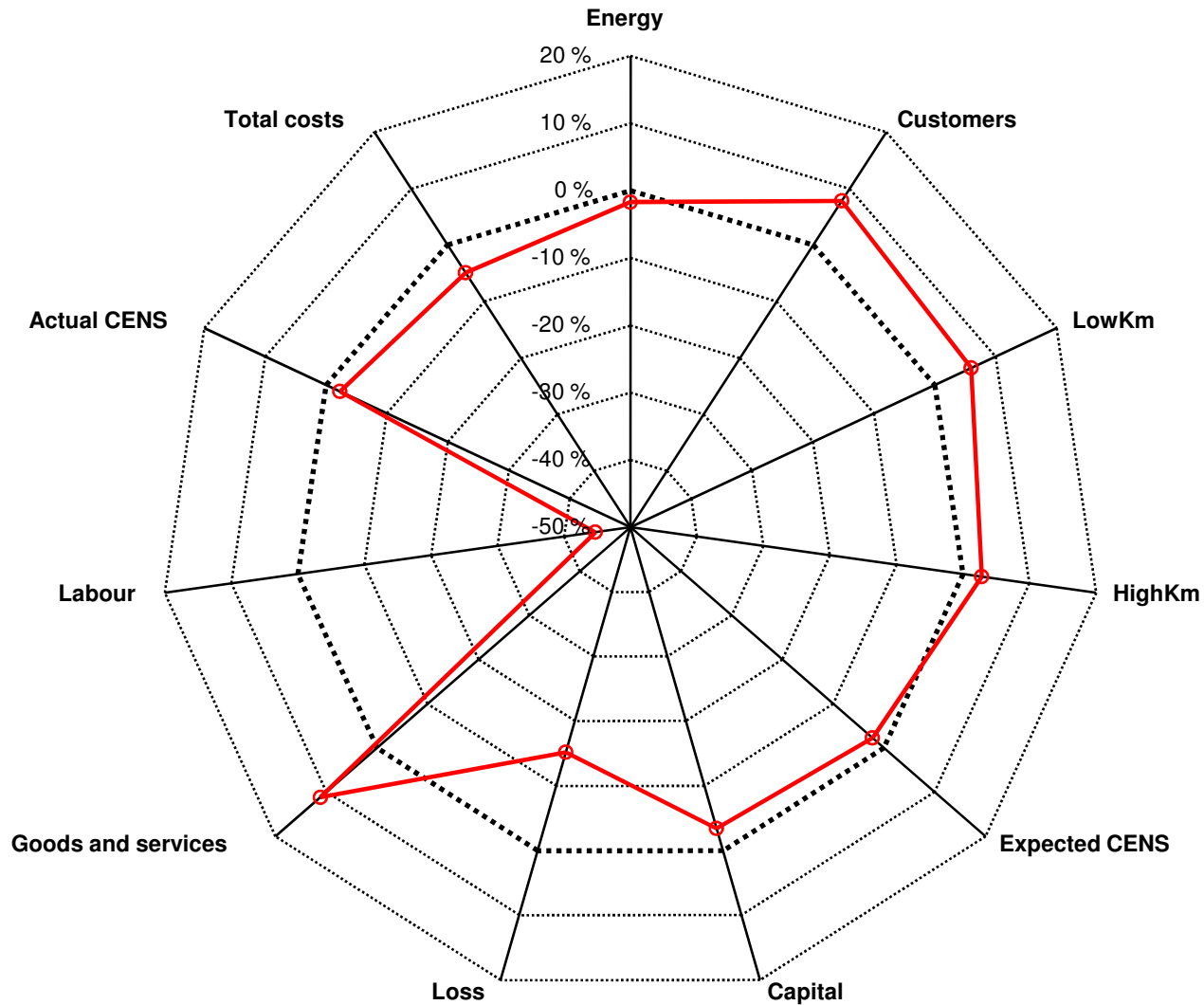
# Data

- Inputs
  - Capital, book value -- priced at depreciation plus interest
  - Loss, priced at pool -- price plus 20 NOK/MWh)
  - Goods and services -- price = 1
  - Labour -- priced at labour cost divided by man years
  - Actual CENS, outages as valuated in subpopulations -- price = 1
- Outputs
  - Energy
  - Customers
  - Low Voltage km lines,  $\leq 1$  kV
  - High Voltage km lines,  $> 1$  kV
  - Expected CENS, partly predicted from regression on exogenous variables
- 1292 observations from 8 years 1996-2004

# Data

Year	Total distribution of energy in Norway in GWh	Sample			Panel		
		Number of utilities	Energy distribution in sample in GWh	- Share of total	Number of utilities	Energy distribution in panel in GWh	- Share of total
1996	66 994	191	64 882	96.8%	98	19 729	29.4%
1997	65 468	184	63 397	96.8%	98	19 458	29.7%
1998	68 612	181	66 322	96.7%	98	20 264	29.5%
1999	70 417	168	68 384	97.1%	98	20 174	28.6%
2000	70 744	155	67 461	95.4%	98	20 390	28.8%
2001	72 747	142	72 226	99.3%	98	21 260	29.2%
2002	70 474	142	69 962	99.3%	98	20 816	29.5%
2003	64 472	129	63 765	98.9%	98	20 171	31.3%
Sum	549 928	1 292	536 399	97.5%	784	162 264	29.5%

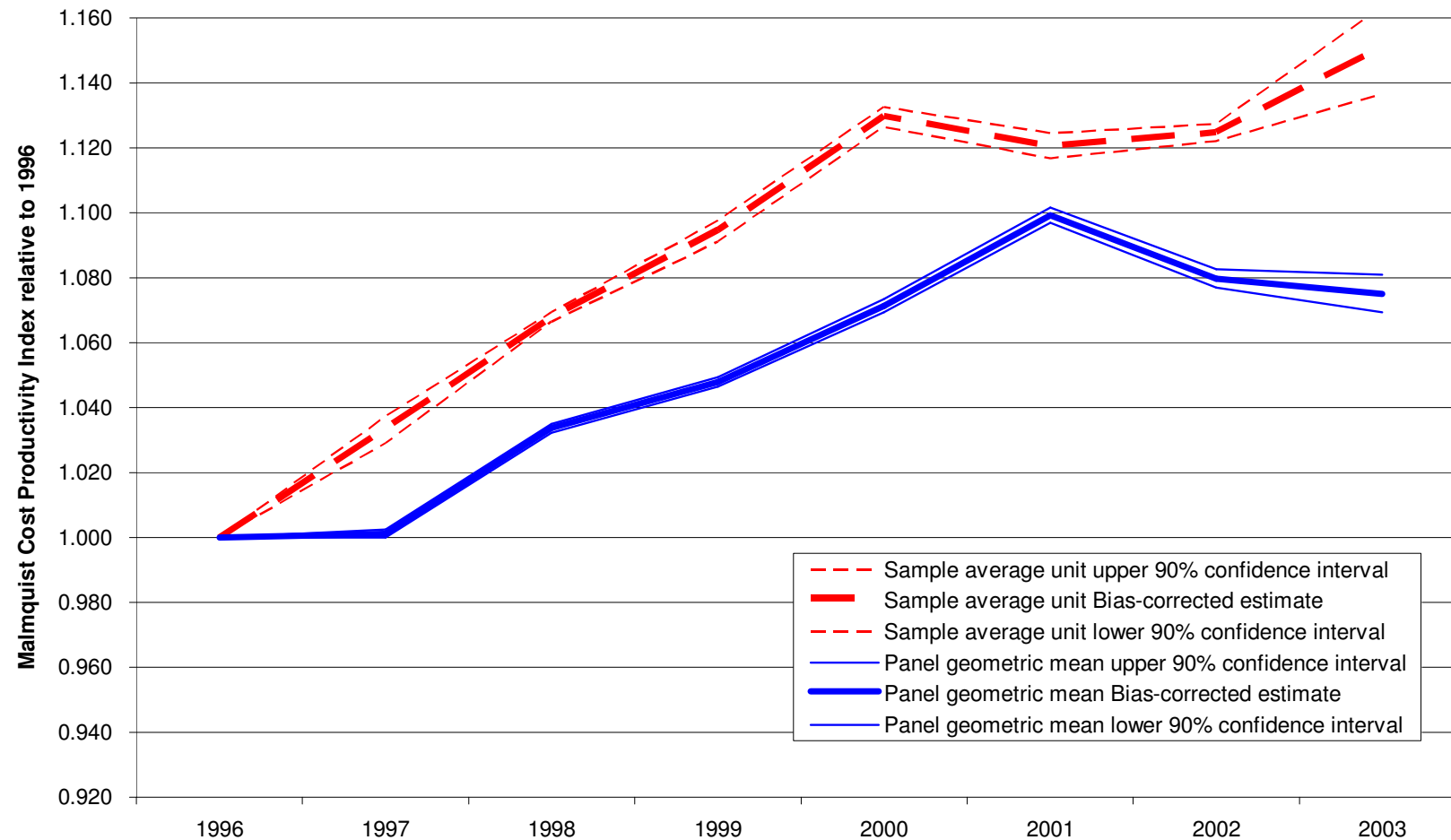
# Change in variables 96-03



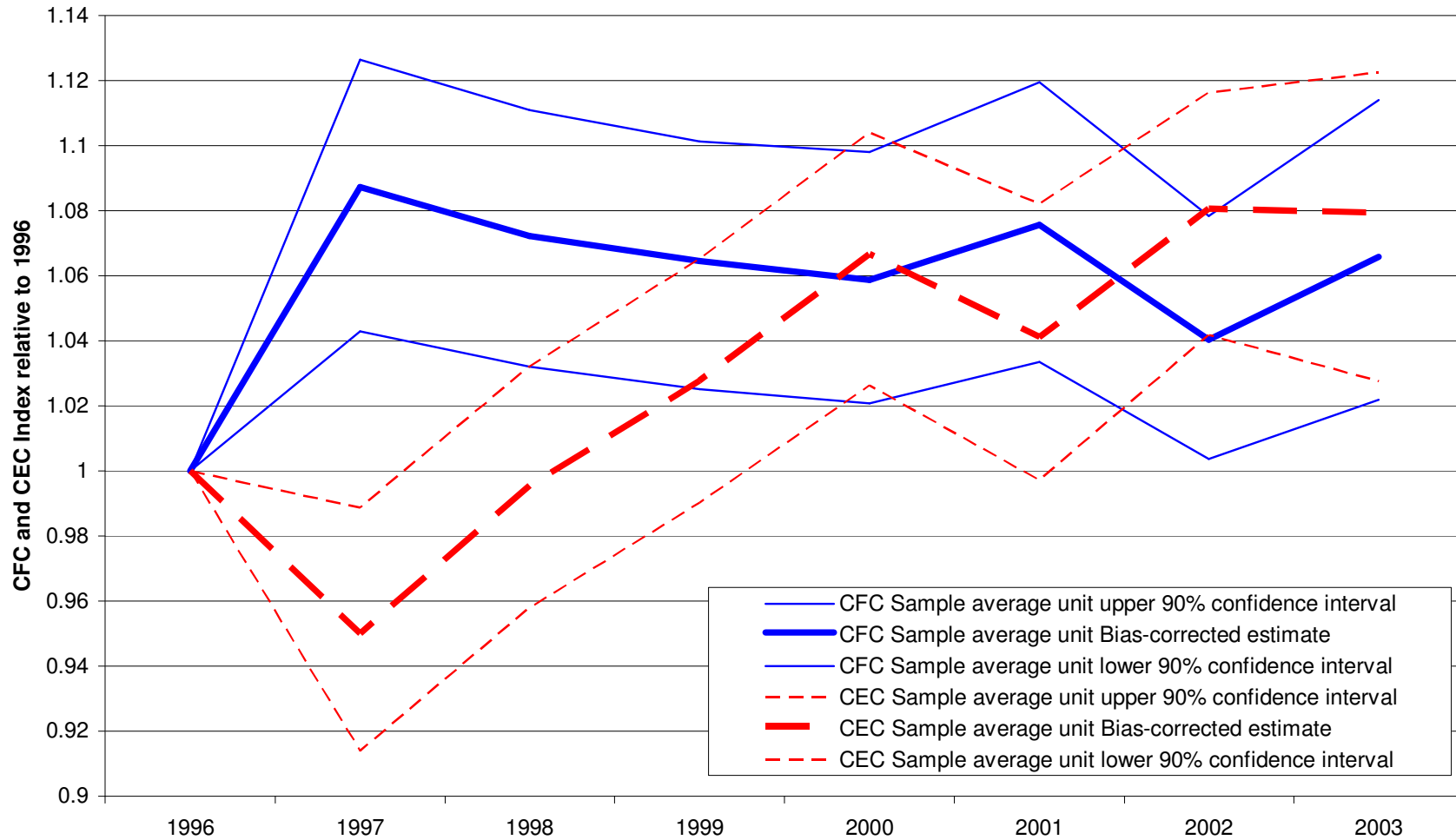
# Year to year change MC Average unit

	1996	1997	1998	1999	2000	2001	2002	2003
1996	1.000	1.033	1.068	1.095	1.130	1.122	1.126	1.154
1997		1.000	1.033	1.060	1.094	1.086	1.089	1.117
1998			1.000	1.025	1.058	1.051	1.054	1.081
1999				1.000	1.032	1.025	1.028	1.054
2000					1.000	0.993	0.996	1.021
2001						1.000	1.003	1.028
2002							1.000	1.025
2003								1.000

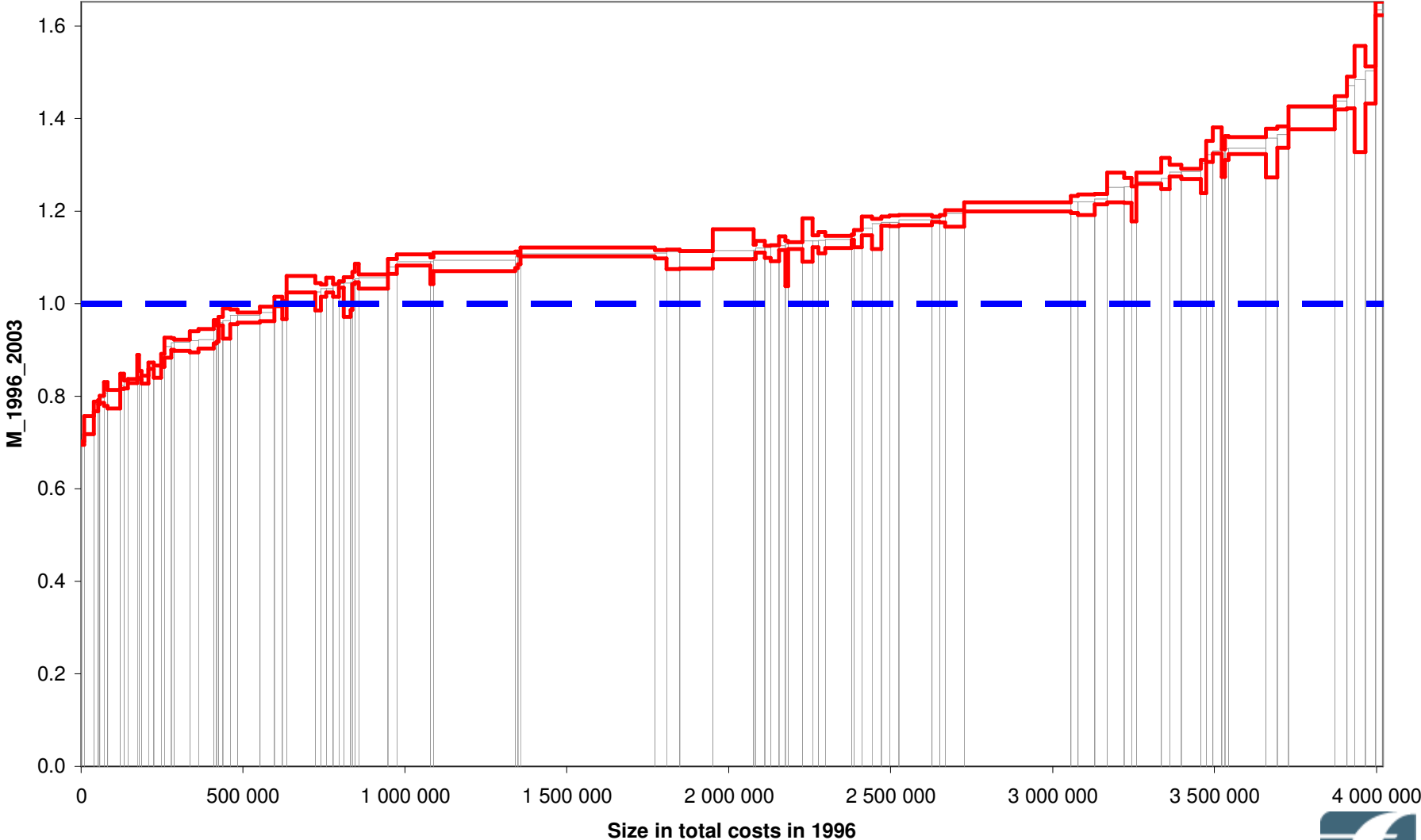
# Main results Average Unit and Geomean panel units



# Decomposition results Average Unit



# Individual units MC\_96\_03



# Conclusions

- Considerable improvement in productivity, 2.1% p.a.
- Weaker in 2001-2002 than previously
  - New regulatory requirements?
  - Diminishing returns?
  - Apprehensive pause?
- Merging firms not in panel have higher and earlier growth
  - Selection bias or economies of scale and scope?
- Average unit as robust measure of industry performance
- Cost Malmquist robust
  - Depends only partially on frontier position
  - In Pooled reference version, reference envelopment stable
  - Bootstrap bias-correction does not improve MSE
    - Confidence intervals still nice to have
- Decomposition not robust
  - Sensitive to annual frontier estimate, and therefore outliers