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Benchmarking
Electricity Distribution Networks

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Overview

- Background to benchmarking
- Methods and applications
- Strategic behaviour
- Lessons

(Incentive) Regulation - History

- Regulation of licensing, obligation to serve, pricing, reliability, safety, theft, etc. date back to early years of the industry (House of Commons, 1882)

- First (incentive) regulations - UK
  - In 1855 - Sliding scale in the Sheffield Gas Act for Sheffield Company, a town gas supplier
  - A similar plan in 1893 for the electricity industry

- Canada - In 1887 - Cost-At-Service plan for Consumers’ Gas Company of Toronto
- US – Sliding scale scheme in Boston Plan of 1906 for price of gas (Schmidt, 2000)

Incentive Regulation

- Renewed interest after liberalisation
- Efficiency improvement – through penalty/reward

- **Benchmarking** – as a tool for incentive regulation
  - Information asymmetry
  - Mimic market mechanisms / non-intervention

- Incentives are strong and work

- But, concerns about unintended consequences, e.g.
  - Fairness
  - Investments
  - Quality of service
  - Innovation
  - Security etc.

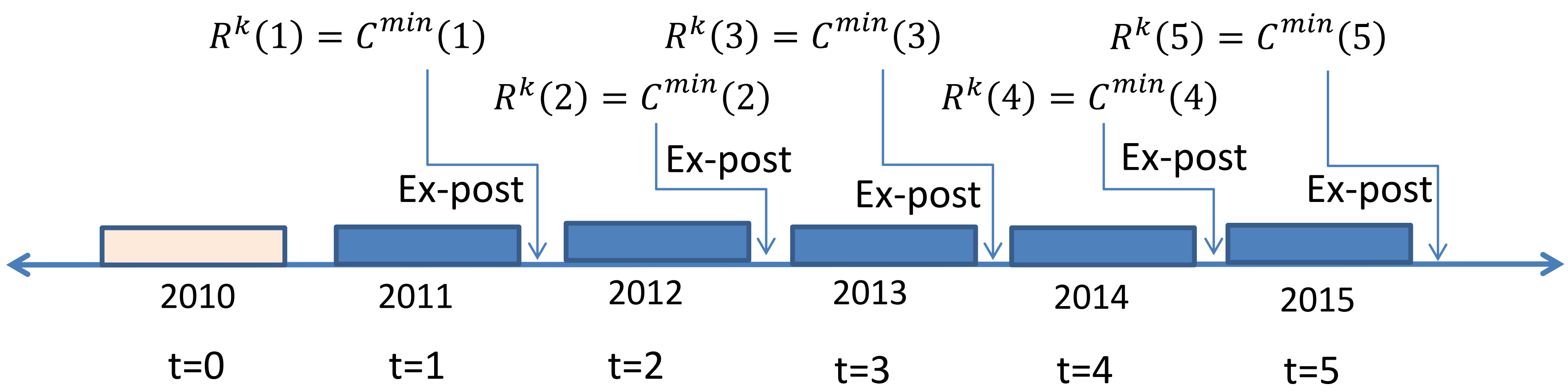
Yardstick Incentive Regulation and Benchmarking

- Under this incentive scheme, firms' allowed revenues relies on the performance of other comparable firms
  - Tries to mimic a competitive market where firms' survival depend on the efficiency/cost of their rivals

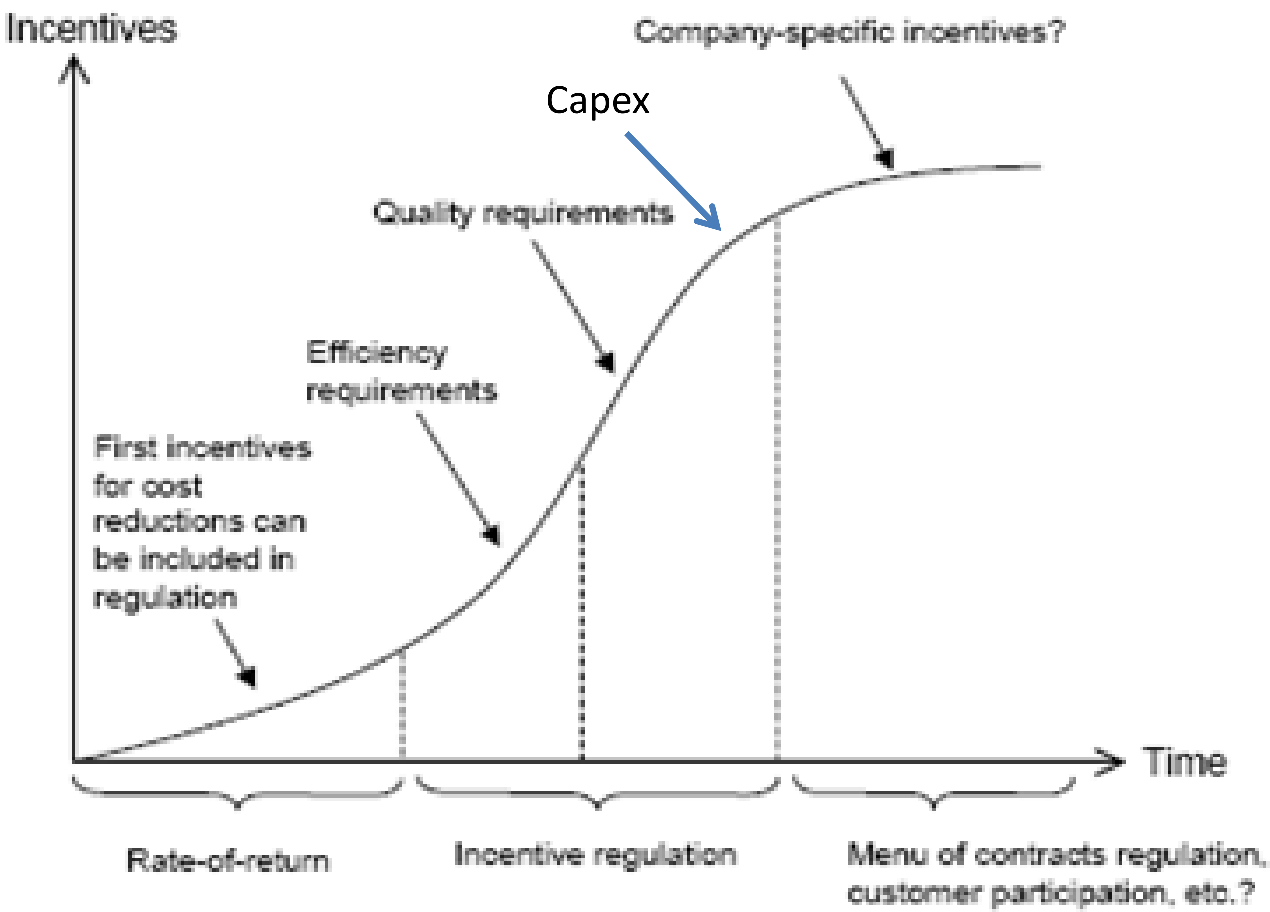
- Instead of using an ex-ante prediction of firms' cost, the regulator uses the real data of other firms to estimate the "true" costs

- Allowed revenues/prices not linked to their own costs. This provides incentives to minimize cost.

The Dynamics in Yardstick Competition



Evolution of Regulation & Benchmarking



Source: Viljainen (2005)

Uses of Benchmarking

- **Academic research**
  - We do efficiency / productivity analysis to try new techniques, investigate features of the sector, and suggest new approaches

- **Regulators**
  - Direct input in IR benchmarking
  - Informing incentive regulation more broadly

- **Self benchmarking** –
  - Firms benchmarking themselves

- **Third parties**
  - To inform, and name and shame

Benchmarking Methods

Benchmarking Methods

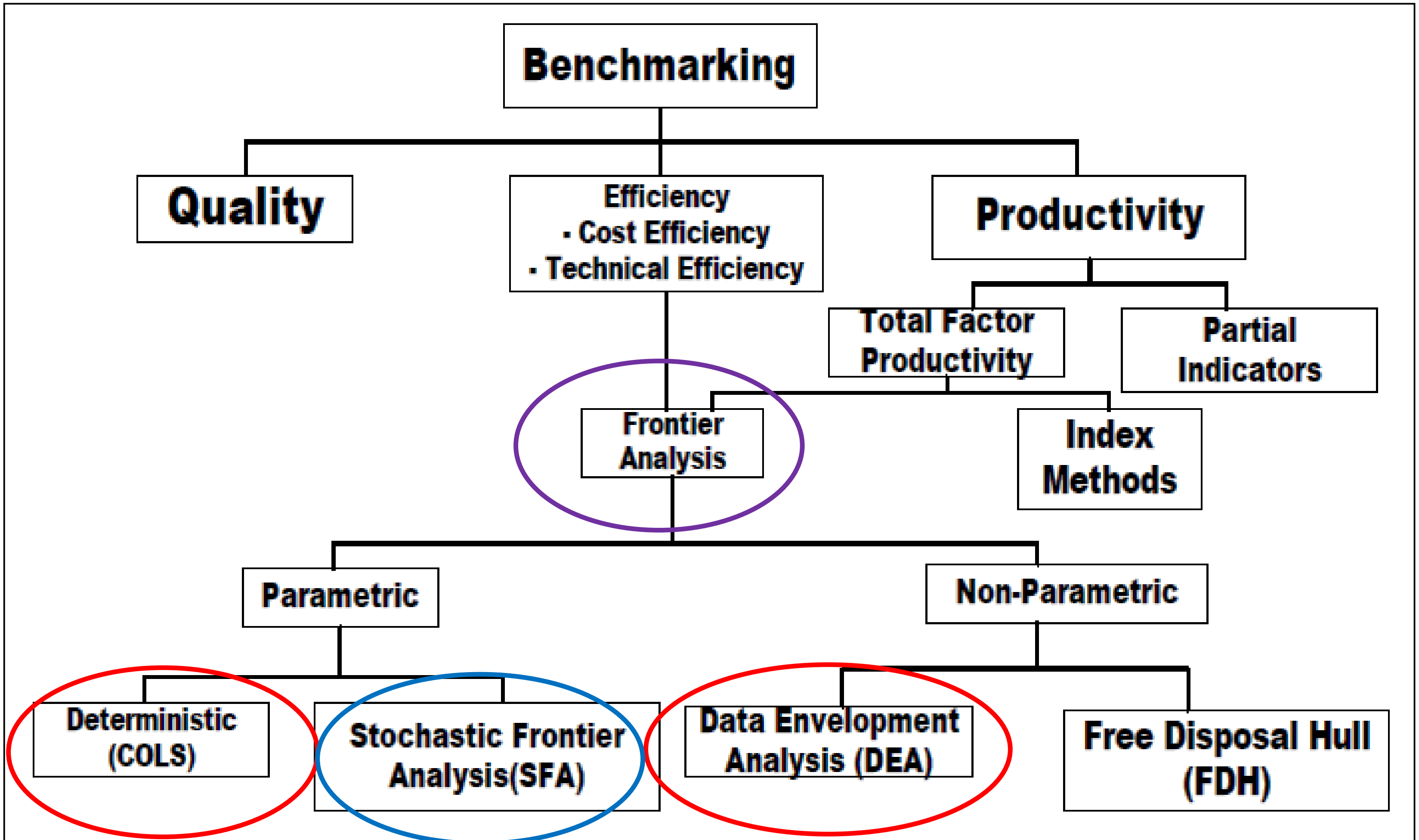


Figure 1. Benchmarking approaches

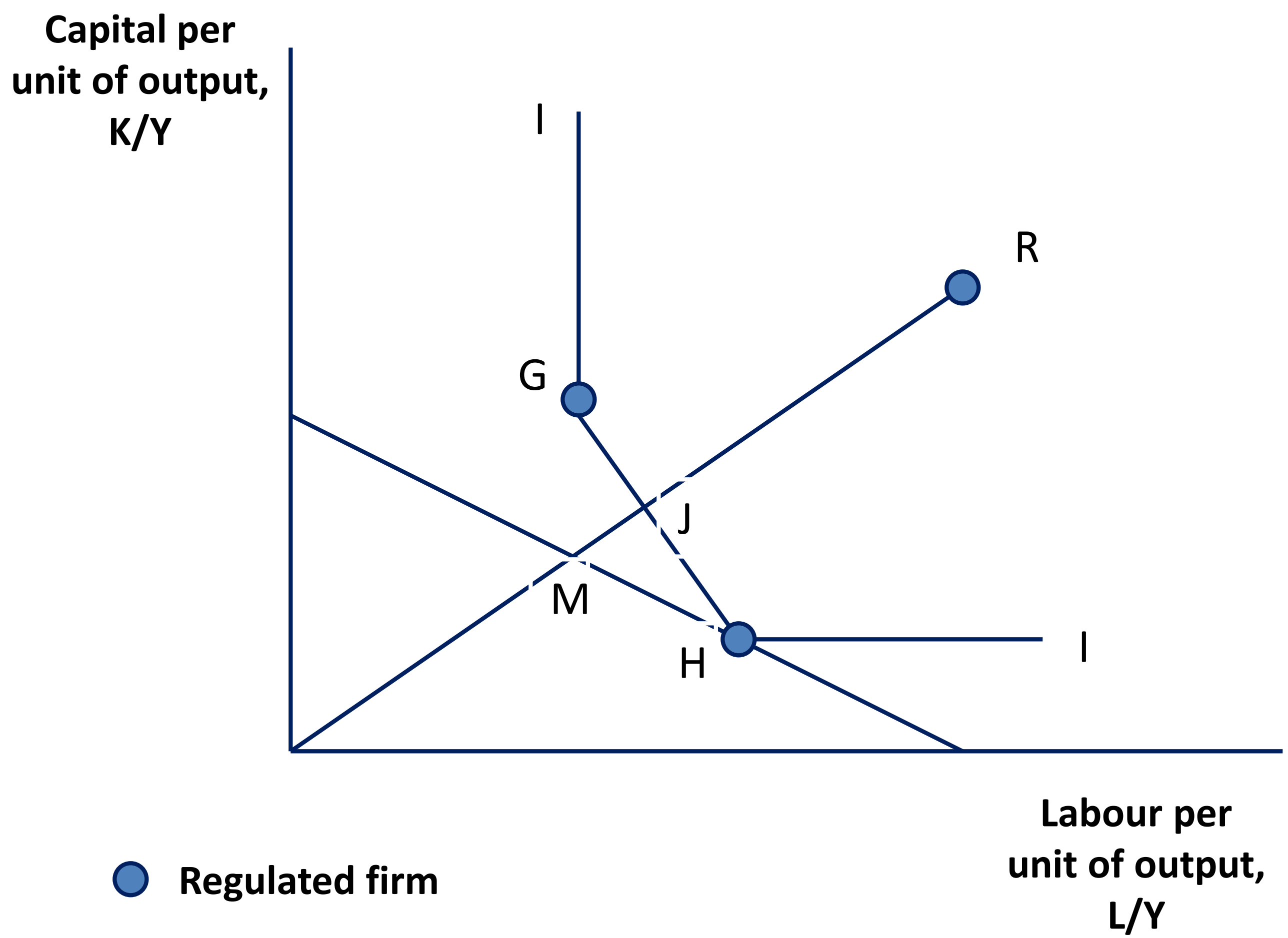
Source: Khetrapal and Thakur (2014)

Measuring Firms' X-Factors: DEA and SFA Methods

- F**rontier/benchmarking** models are mathematical/statistical techniques that compare each firm with <u>fully efficient</u> firms
- The efficient cost of each firm is <u>not</u> directly observed, but inferred from the data using frontier techniques

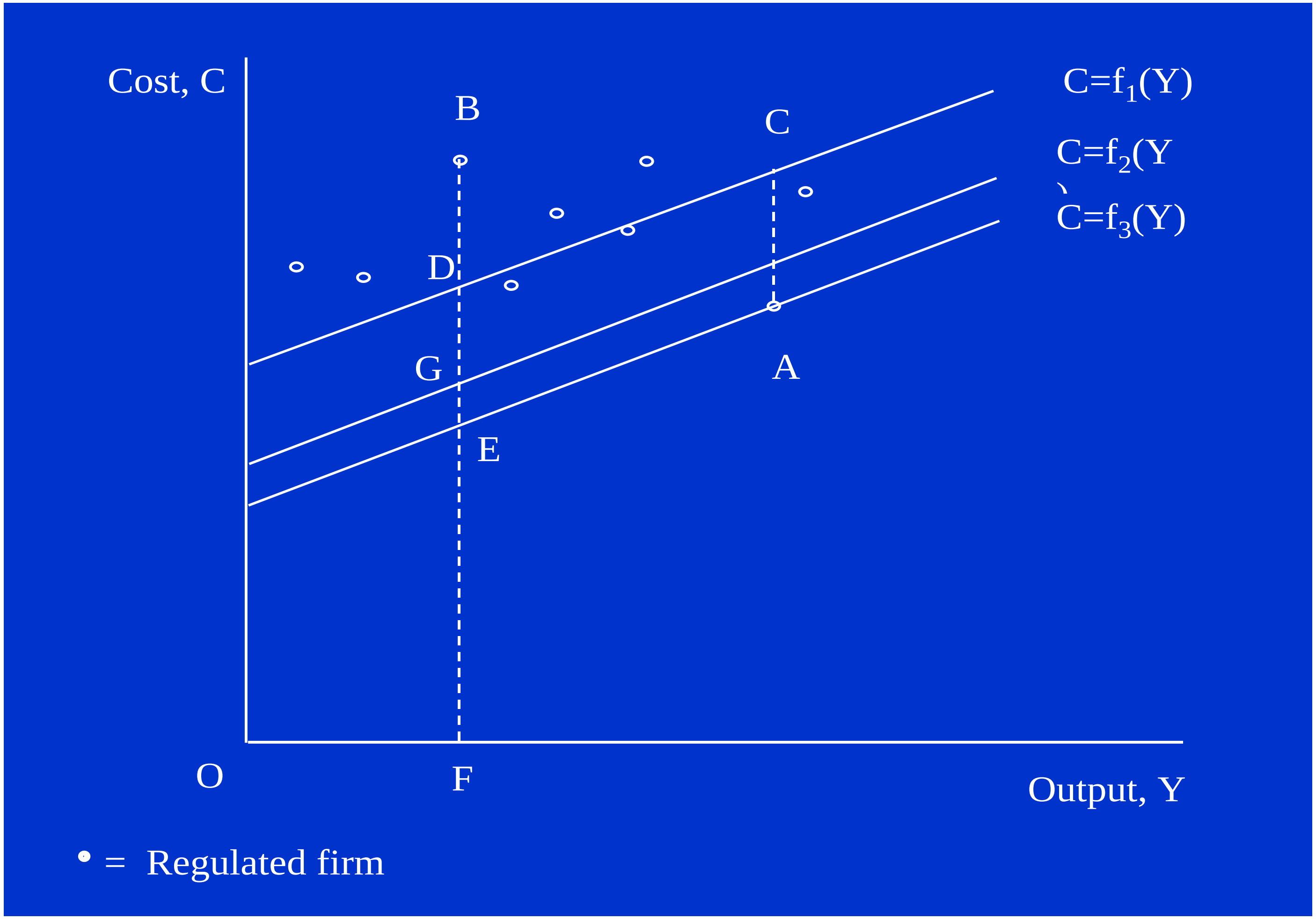
- **Frontier techniques**
  - Engineering-based techniques
  - Statistical-based techniques
- **Statistical-based frontier techniques**
  - Non-parametric but deterministic techniques (e.g. DEA)
  - Parametric and stochastic techniques (e.g. SFA)
  - "In-between" approaches, e.g. stochastic DEA, StonED, semi-parametric models, random coefficient models, latent class models, etc.

DEA in Practice



Firm R: Techn. eff.= OJ/OR Alloc. eff.= OM/OJ Tot. econ. eff.=OM/OR

Econometric Techniques



SFA efficiency score of B, approximately = GF/BF

COLS efficiency of B = FE / FB

Reference Model - Sweden

- Several critical parameters derived from hyperbolic tangent functions based on customer density and 5 constants to resemble empirical data

- Paras dependent on customer density:

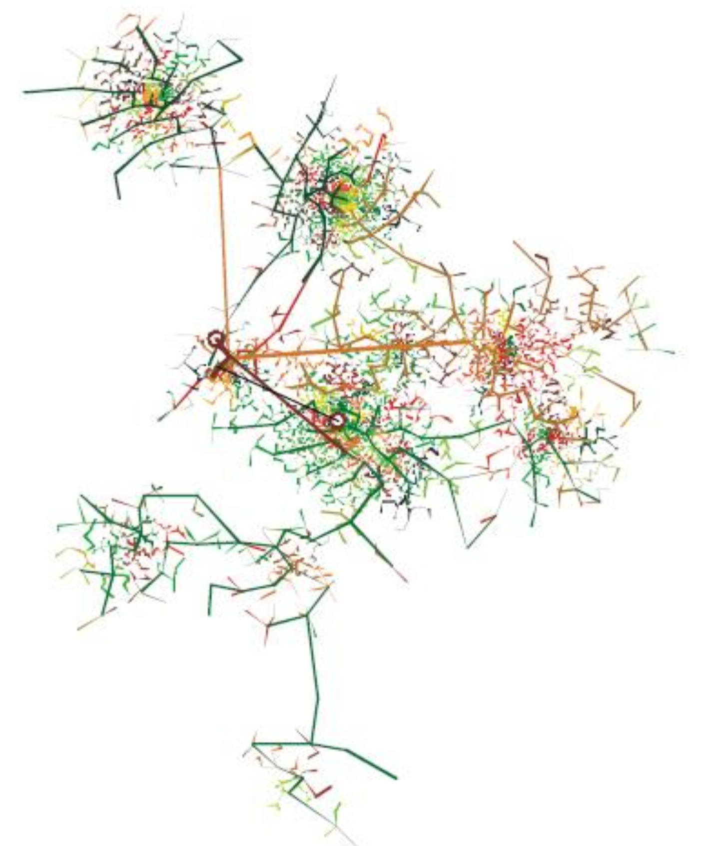
  - (1) Lines, (2) Back-up lines, (3) Back-up transformers, (4) Cost of land for transformers, (5) Geometrical adjustment, (6) Energy losses, (7) Interruption cost, (8) Expected interruption cost

$$\mathrm{ModTanh}(x) = (k_1 + k_2 * \tanh(k_3$$

- For each parameter at each voltage level, functions are estimated using “reference values”

–x density (meters of line/customer)

–*k0, …, k4* constants



Source: Larsson (2004)

Engineering-Based vs. Statistical-Based Techniques

Statistical-based / real data techniques

	Deterministic	Stochastic
Parametric	Corrected Ordinary Least Squares (COLS)	Stochastic Frontier Analysis (SFA)
Non-parametric	Data Envelopment Analysis (DEA)	Stochastic Data Envelopment Analysis (SDEA)

Source: Cossent (2013)

Engineering-based/ non-real data techniques

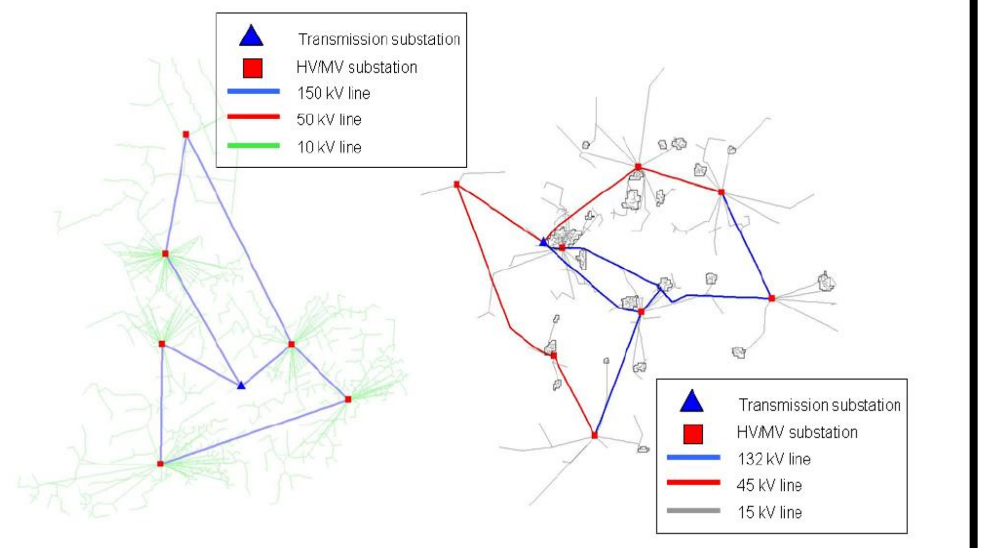


Figure 4-11: Examples of geographical representation of the outputs of RNMs

Source: Cossent (2013)

Reference/Norm models

Table 1: Some European regulation regimes and cost function methodologies for electricity DSOs

Code	Country	Regulation	Benchmark
AT	Austria	Revenue cap	DEA-SFA, best-off
BE	Belgium	Revenue cap	DEA
CH	Switzerland	Cost recovery	Ad hoc
DE	Germany	Revenue cap	DEA-SFA best-off
DK	Denmark	Revenue cap	COLS-MOLS
ES	Spain	Revenue cap	Engineering
FI	Finland	Revenue cap	DEA w. SFA back-up
FR	France	Cost recovery	Ad hoc
GB	Great Britain	Revenue cap	COLS and Ad hoc
GR	Greece	Cost recovery	Ad hoc
HU	Hungary	Price cap	Ad hoc
IRL	Ireland	Price cap	Ad hoc
NL	Netherlands	Yardstick comp	DEA-OLS-MOLS
NO	Norway	Yardstick comp	DEA
SE	Sverige	Revenue cap	Engineering and DEA

Source: Benchmarking and regulation, Per J. Agrella, Peter Bogetoftb,
Preprint submitted to DEA Journal November 14, 2012

Benchmarking – Evaluation Criteria

- Model variables
- Efficient comparators
- Consistency of results
- Quality of service
- Sufficient investments
- Long-term innovation
- Uncertainty
- Transparency

Consistency Conditions for Frontier Models

Mutual-consistency conditions	1. Efficiency scores obtained with different methods should have similar distributional properties (mean, dispersion, etc.)
	2. Different methods should provide a similar ranking of firms
	3. Different methods should identify the same best and worst firms
Consistent-with-reality conditions	4. All approaches should be stable over time
	5. Efficiency scores should be consistent with the actual market conditions
	6. Inefficiencies obtained with frontier methods should be consistent with other methods such as finantial ratios

Table 4-2: Consistency conditions for frontier benchmarking methods (Bauer et al., 1998)

Source: Cossent (2013, p. 81)

DNO Benchmarking: Example - Norway

Example: Yardstick Regulation in Norway

- The Norwegian regulator (NVE) uses a **frontier approach** to compute firms' reference costs**:**

  Reference cost = efficient cost = $\boldsymbol{C^*}$

- NVE uses DEA to compute an Efficiency Index ($E \leq 1$) for each firm, measuring firm's relative performance:

$$\boldsymbol{C^* = C \cdot E}$$

- Allowed revenues are computed as:

$$\boldsymbol{R = bC^* + (1-b)\,C = bC \cdot E + (1-b)\,C}$$

  Thus:

$$\boldsymbol{dR = bC \cdot dE}$$

- An "unfair" efficiency measure has financial consequences for the firms

BM Example – Norway (1)

Input	Output
❖ **Totex** ○ O&M ○ CENS - Cost of energy not supplied ○ Interest on capital ○ Depreciation ○ Cost of network energy los	❖ No. of customers ❖ Leisure homes ❖ Energy delivered ❖ HV lines ❖ Network stations ❖ Forest ❖ Snow ❖ Wind / coast

BM Example – Norway (2)

Second Stage	Incentive Power
Efficiency scores = *b1*Island connections* *b2*Transmission interfaces* *b3*Distributed generation*	*Revenue cap =* *Cost Norm*p + Cost Base*(1-p)*

Some Issues in Benchmarking

Regulator’s Background and BM Approach

- IR/BM as an “economic” programme, not a financial or engineering exercise

- But, the regulator’s institutional background matters

  - LAC and Sweden: Engineering ➔ norm/reference models

  - UK: Financial, accounting, auditing ➔ BM as support

  - Norway: Economics ➔ “Sotex” benchmarking

- Example - Norm model vs. DEA in Chile

Strategic Behaviour in Benchmarking

- **Method -** e.g. parametric vs. non-parametric
- **Model -** specification

- **Inputs -** which
- **Outputs -** which
- **Variables –** definitions, e.g. Opex

- **Accounting rules -** e.g. asset depreciation period

- **Contextual variables -** e.g. geography, weather, density, features of service area

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Survey: What Did Regulators Say?

Jamasb, Nilesen, Pollitt (2003)

Costs

- ❖ Shifting assets/costs between gas and power (Netherl.)
- ❖ Including customer contributions in RAB (Netherl., Ireland)
- ❖ Shifting assets/costs from S to D (Netherlands, UK)
- ❖ Shifting assets/costs from G to D (Norway)
- ❖ Definition of OPEX and accounting rules - e.g. depr. (UK)

Outputs

- ❖ Circuit vs. route network length (Netherlands)
- ❖ No. of customers vs. no. of meters (Denmark)
- ❖ Uniqueness “comparators are inherently different” (Ireland)
- ❖ Relative weights of output variables (UK)

Mergers

- ❖ Split into several firms and then back (Netherlands)

Other Strategic Behaviour

- Mergers
- R&D cutbacks to improve short term performance
- Court cases and appeals
- Information overload

Strategic Behaviour

The CEO of a distribution utility:

"In the technical studies, both sides cheat - everyone does this. If you didn't cheat then you would be stuck with the superintendent's numbers which aren't fair. … But the superintendence has poor people who don't like to do much work, so it works out. When Chilectra delivers information they use a freight truck. The guys in the regulator's office get depressed when it comes."

Di Tella and Dyck (2001)

"Every four years, you feel you are going to war."

Alejandro Jadresic, former Minister of Energy of Chile

Lessons for Regulators

- Determination of costs at unbundling is crucial (audits, technical studies, adjustments)
- Compare cost patterns in review vs. non-review periods
- Conduct sensitivity analysis of benchmarking models
- But, can motivate desirable behaviour (e.g. mergers)
- *Transparency – Cheap and helpful!*

Proof of effective benchmarking is in the outcome

Lessons for Utilities

- Examine the effect of regulator's choice of method, variables, X-factors for your firm
- Determine effect of possible gaming by other firms on your revenues
- Evaluate benefits and losses of M&A strategies of own and competitors
- Do your own benchmarking!

Thank you!

Benchmarking and Economic Principles

Criteria for Regulatory Benchmarking

❖ **Benchmarking should:**

- Be based on sound economic principles
- Seek to identify the most relevant frontier
- Make firms in sample suitable comparators

- Should send the right longer term signals and avoid uncertainty
- Economic Incentives are strong, so minimise the potential for gaming by firms

- Should be credible, predictable, and sustainable

Some Economic Principles

- Economic principles imply that appropriate costs and their trade-offs are taken into account
  - i.e. identified, valued, and incorporated
- Use controllable costs
- This includes external costs
- This separates a 'private/business' benchmarking from 'public' benchmarking
  - Mind the gap

==> Opex + Quality + NT losses

Identify the Frontier

- The frontier affects the measured relative efficiency of all less efficient firms, so:
- Seek the economically correct frontier
- Practical considerations should not come at the expense of economic properties of the model
- Create level playing field in the benchmarking model and data
  - i.e. compare 'like-with-like'
- Adjustments and discretions should be applied at later stages

Non-Technical Losses

- Cause significant external costs
- Lead to energy waste
- Eliminate use of economic / environmental policy instruments

- Lead to pressure for developing costly and sensitive generation sources
- Cause tax revenue losses to the government

- So what appropriate value for NT losses?

==> Appropriate valuation should reflect all of the above

Quality of Sevice

- They cause significant external costs

- May lead to not optimal solutions

- So what appropriate value for quality?

==> Appropriate valuation should reflect all of the above

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Benchmarking Model

- Controllable or non-controllable
- Describe production function or cause inefficiency

- 2nd. stage analysis should be the preserve of the non-controllable sources of inefficiency
- Use regulatory discretion at end stage

- Any given country's sample of firms contains a degree of heterogeneity
- Consider the effect of unobserved heterogeneity

Other Comments – Overall methodology

Outputs

- Network length is suitable for mature networks (not suitable for rapidly changing networks)
- Network expansion efforts in Brazil different from slow organic network growth
- In particular if they represent a source of short/mid term heterogeneity among the firms in the sample
- In addition, the variable can, in this context, offer some scope for gaming

Internal consistency (Benchmarking and X Factor)

- Model design should be followed through

Benchmarking: Art or Science (1)

The crucial balancing act

- Limits to theory as guide
- Limits to science as solution to issues

- Overly technical and quick implementation attempts not so successful in the past
- Successful and more technical methods have evolved over time as the regulators and firms gain confidence

Benchmarking: Art or Science (2)

- Benchmarking as the art of creating a platform for communication
  - Should intend to facilitate the price control process
  - Discretion to be applied with care
  - Regulation focus beginning to move to other pressing and emerging priorities

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Thank you!

Reference Costs and Allowed Revenues

- **Average approach**: firm k´s revenues is computed using the average (per unit) costs of the remainder k-1 firms

$$R^k(t) = \frac{1}{K-1}\sum_{h\neq k} C^h(t)$$

- **Frontier approach**: firm k´s revenues relies on the most efficient firm or the firm with lower (per unit) costs

$$R^k(t) = min\{C^h(t)|h \neq k\}$$

- "Fair" treatment implies comparing firms with similar features (network length, density, etc.)
- Productivity gains are observed, not predicted!

See Agrell and Bogetoft (2013)

Frontier/benchmarking models

- Efficient costs are often computed using **frontier / benchmarking** models:
  - Use mathematical/statistical techniques that compare each observation (firm) with best-practice

- Also used in other regulation, e.g. to compute the firm/industry productivity factors in RPI-X regulation:

$$R^k(t) = C^k(0) \cdot [1 + RPI(t) - x(t) - x^k(t)]$$

- Firm productivity factor $x^k(t)$ is often obtained using **frontier/benchmarking** models
- The industry productivity factor x(t) is often measured using **total factor productivity indexes**

Computing Industry X-factor: TFP Index

- Total factor productivity (TFP) can be defined as the ratio between an output index (Y) and an input index (X)

$$TFP = \frac{Y}{X}$$

  - The TFP index is H(1) in outputs and H(-1) in inputs (∑weights=1)
  - TFP and competetiveness

$$AC = \frac{C}{Y} = \frac{w \cdot X}{Y} = \frac{w}{Y/X} = \frac{w}{TFP}$$

- TFP **growth** is the growth in all outputs not explained by the growth of all inputs

$$\Delta lnPTF = \Delta lnY - \Delta lnX$$

Non-Parametric DEA Models

Model with CRS:

$$\min \theta_0$$

$$s.t.$$

$$\theta_0 \cdot x_{i_0} - \sum_{j=1}^{n} \lambda_j \cdot x_{ij} \geq 0; \quad \forall i$$

$$-y_{r_0} + \sum_{j=1}^{n} \lambda_j \cdot y_{rj} \geq 0; \quad \forall r$$

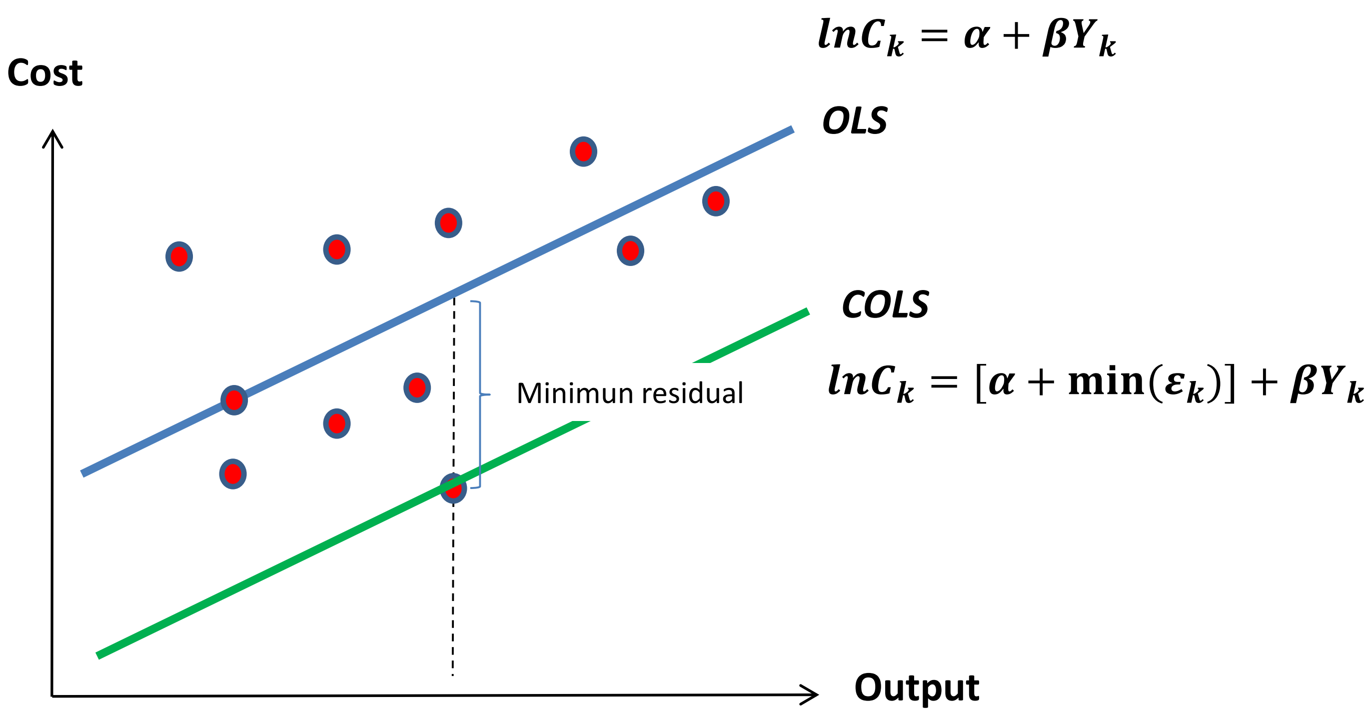
$$\lambda_j \geq 0 \quad \forall j$$

With VRS:

$$\sum_{j=1}^{n} \lambda_j = 1; \quad \forall j$$

- **Advantages:**
  - There is standard (free) software that allows you to implement a DEA analysis
  - It can be used with very few firms
  - It allows for several outputs and inputs
  - It does not impose restrictions on the technology
  - Intuitive and easy to explain to firms (and judges!)
- **Disadvantages:**
  - Difficult to control for uncontrollable and unobserved variables (gnores the noise term)
  - Sensitive to "outliers"
  - Difficult to test hypothesis and identify determinants of firms' inefficiency

Basic Parametric Model (Corrected OLS)



Source: Elaboration inspired by Cossent (2013)

Stochastic vs. Deterministic Frontier Models

Stochastic cost function:

$$C = C^*(Y, w) + \cancel{v} + u$$

Non-negative random term = inefficiency = lack of ability to manage the firm

Deterministic frontier → DEA

Noise term = measurement errors, luck, etc.