Tariff Productivity Improvement Advice for the Electricity Sector – Jamaica

Overview

Kingston, 5-6 February 2017

Dr. Viren Ajodhia

Dr. Konstantin Petrov

Program outline

1. Forms of price control and Role of the X-factor
2. Productivity benchmarking techniques
3. Multi-dimensional analysis (DEA)
4. Using productivity targets

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Part 1: Forms of Price Regulation

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Table of Content

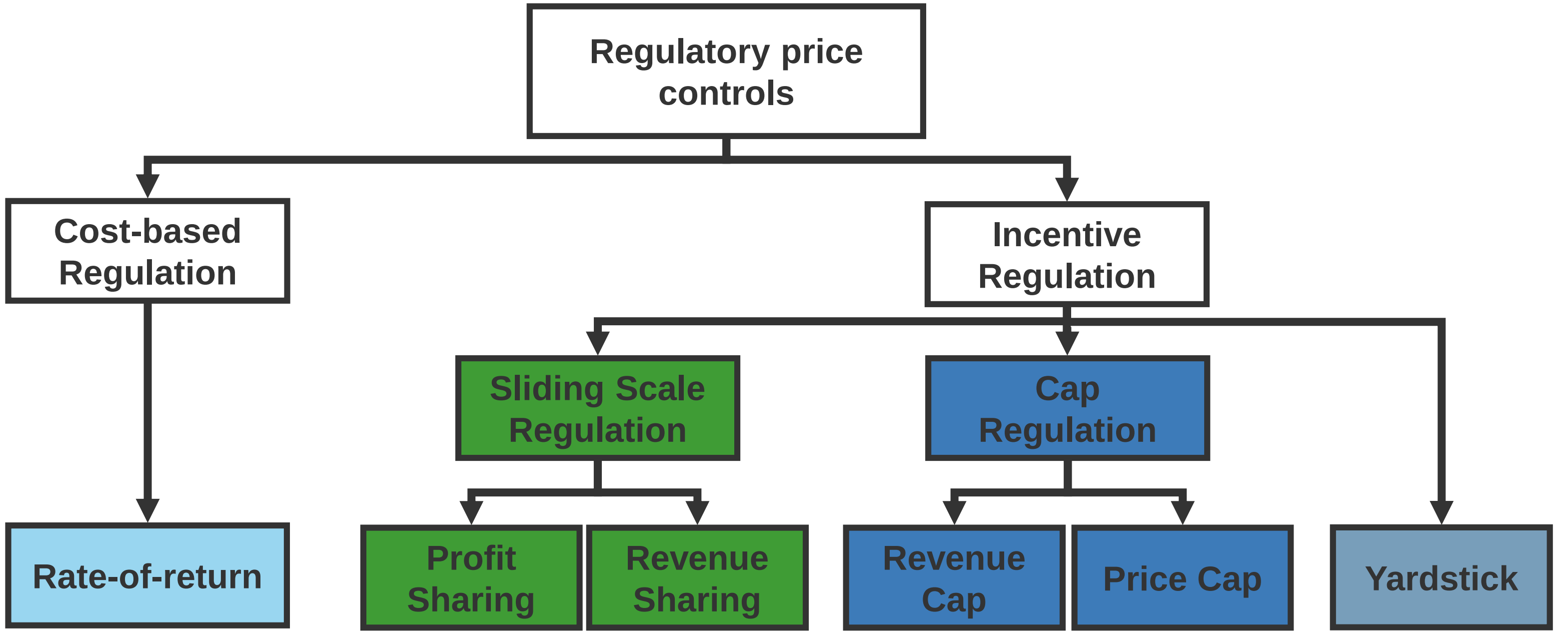
1. Introduction

Why Regulation?

- Competition provides best service to customers in terms of price and quality of service
- Competition not feasible in all segments of the power sector
- Transmission and distribution networks natural monopolies
- Regulation to ensure that network operators:
  - operate efficiently
  - charge fair prices
  - provide adequate quality of supply
- Regulator to balance interests of network owners and network users (producers, suppliers, end-user customers)
- Information asymmetries between companies and regulator

2. Major Price Control Models

a) Overview

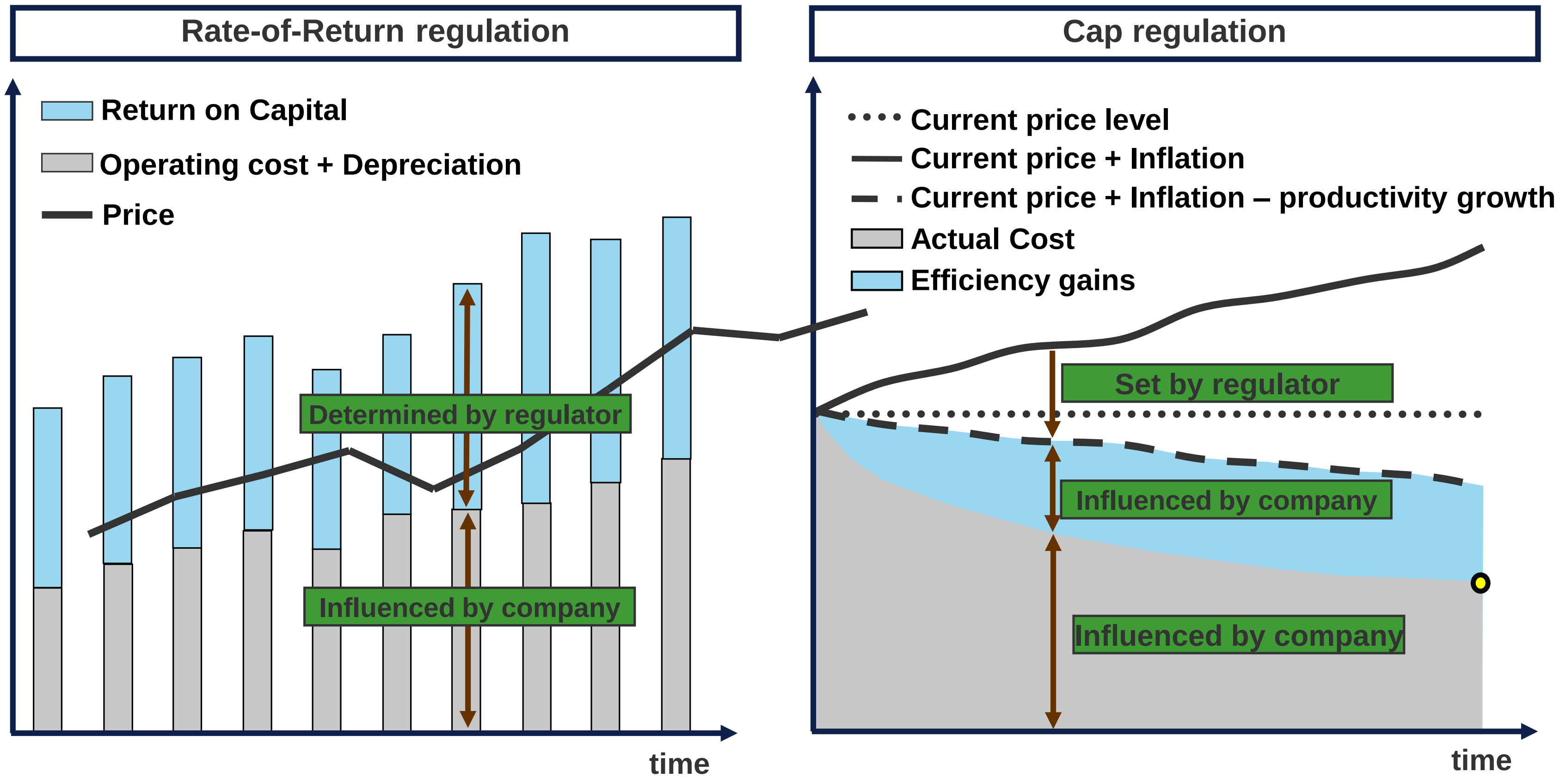


In practice also cases where

- elements of different regimes are applied simultaneously
- different regimes are applied for different services of the same company

2. Major Price Control Models

a) Overview – Rate-of-Return vs. Cap Regulation



2. Major Price Control Models

a) Overview – Theory vs. Practice

- Differences between regimes in practice less strong
- Depending on the details of the regulatory regime, differences might only exist in the name of the regime
- Hybrid forms (combinations of regimes) frequently applied in practice
- Almost all regimes require a calculation of the company's cost and price levels

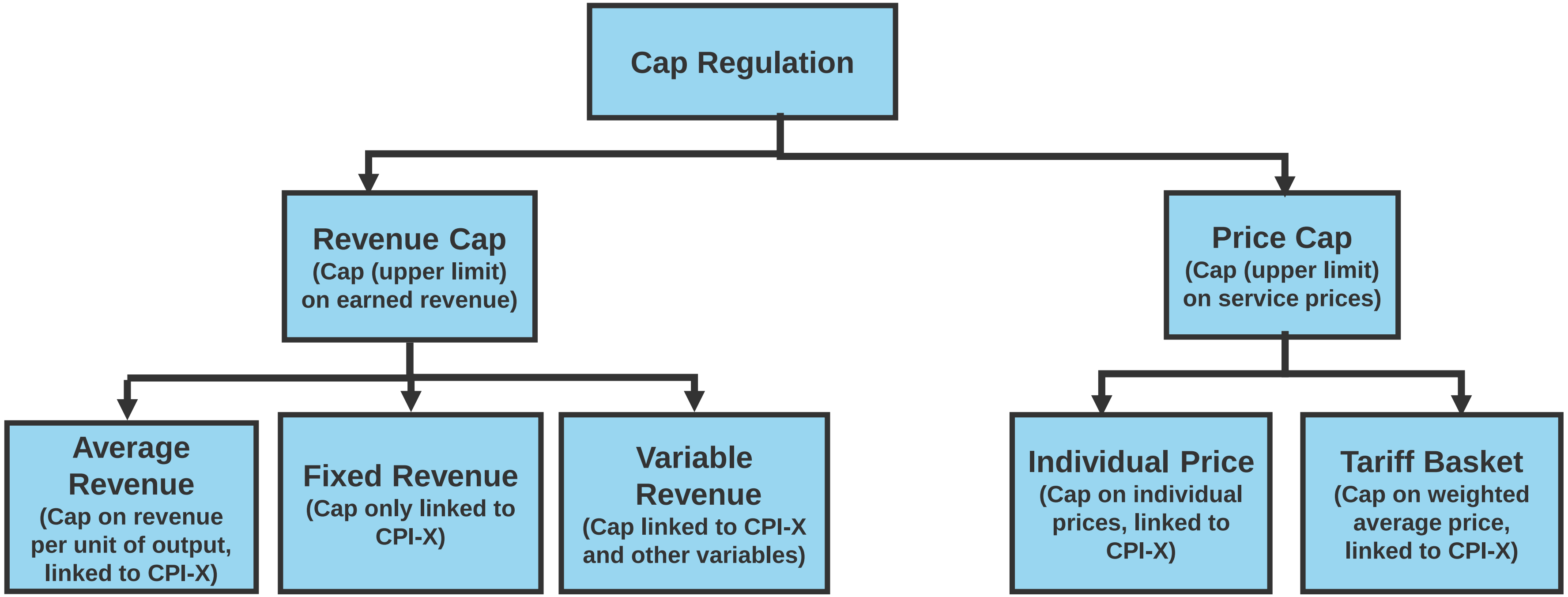
2. Major Price Control Models

b) Rate of Return Regulation

- Prices / revenues based on operating costs plus “fair” rate of return on capital (cost recovery principle)
- Frequent regulatory reviews (avoid deviation between actual cost and allowed revenue)
- Regulation period either very short or not pre-determined
- Primary objective: limit profits, prevent companies from pricing above costs
- In theory companies free to set prices as long as rate of return is not exceeded, in practice however prices often determined directly by regulator
- Traditional form of regulation (USA)

2. Major Price Control Models

c) Cap Regulation



2. Major Price Control Models

c) Price-Cap Regulation

- Sets an upper limit on prices
- Cap set for individual price(s) or set on weighted average price (tariff basket)
- Applies longer regulatory lag (pre-determined regulatory period of 3-5 years)
- Requires explicit productivity increase via price formula (X-factor, company specific)
- Adjustment factor for inflation (consumer price index, retail price index,…)
- Other adjustment factors (changes in input prices, industry-wide productivity growth, network development costs, quality targets)
- Allows retention of efficiency gains
- Decouples partially costs from revenue / price
- Primary objective: limit prices, not profits
- Incentive to increase profits by saving costs may deteriorate quality → regulation of quality necessary
- First applied in the UK, now widely applied, particularly for telecommunication and electricity networks

2. Major Price Control Models

c) Revenue-Cap Regulation

- Ex-ante determination of maximum revenue levels
- Cap fixes upper limit of total revenue or revenue per unit of output
- Requires explicit productivity increase via price formula (X-factor)
- Adjustment factor for inflation (consumer price index, retail price index,…)
- Other adjustment factors (changes in input prices, industry-wide productivity growth, network development costs, quality targets)
- Decision on output levels and prices remains at regulated company so long as revenues do not exceed cap
- Prices not necessarily capped
- Applied in many European countries

2. Major Price Control Models

c) Revenue-Cap Regulation (the slide is also relevant price-caps)

- Two major forms in practice: building blocks and total cost model (Totex)
- Building blocks
  - implemented as linked (coupled) cap regulation
  - explicit projection of Capex for the upcoming regulatory period
  - separate checks and inclusion of investments
  - formalised efficiency analysis of controllable Opex
- Totex scheme
  - implemented as unlinked (decoupled) cap
  - inclusion of (historic) capital cost into efficiency assessment modelling (total cost analysis)
  - Capex standardisation for benchmarking purposes

2. Major Price Control Models

d) Sliding Scale Regulation (Profit-, Revenue-Sharing)

- Regulator sets target level of profits / revenues the company is permitted to keep
- If company performs better than this target, gains have to be shared with customers
- If company performs worse than this target, losses are also shared with customers
- Main objective "fair" sharing of profits and risks between company and customer, compromise between cap and rate-of-return regulation
- Sharing usually takes place through adjustment of revenue in the next regulatory period
- Sliding scale is often applied together with cap-regulation
- Typically the regulator sets
  - a target range where no sharing arrangements apply (dead band)
  - a wider range (above/below target) where sharing arrangements apply
  - a maximum and minimum level of the sliding scale scheme

2. Major Price Control Models

e) Yardstick Competition

- Prices or revenues linked to the costs of a peer group of companies
- Companies not allowed to charge higher prices than the mean of the costs of peer group
- Sometimes yardstick based on the average industry productivity improvement
- Few cases of practical application, no pure model applied

2. Major Price Control Models

f) Regulatory Formulas (exemplary)

Rate-of-Return

$$R_t = C_t + D_t + T_t + RAB_t * r_t$$

- R_t: Required revenue in year t
- C_t: Operating costs in year t
- D_t: Depreciation in year t
- T_t: Taxes in year t
- RAB_t: Regulatory Asset Base in year t
- r_t: **Allowed rate-of-return in year t**

Price-Cap

$$P_t = (1 + RPI - X) * P_{t-1}$$

- P_t: Price in year t
- RPI: Retail Price Index (Inflation)
- X: Productivity growth
- P_{t-1}: **Price in previous year**

Revenue-Cap

$$R_t = (1 + RPI - X) * R_{t-1}$$

- R_t: Revenue in year t
- RPI: Retail Price Index (Inflation)
- X: Productivity growth
- R_{t-1}: **Revenue in previous year**

f) Regulatory Formulas (exemplary)

Sliding-Scale

$$R_t = (1 + RPI - X) * R_{t-1} - \mu (\Pi_{t-1} - \Pi^{reg}_{t-1})$$

- R_t: Revenue in year t
- RPI: Retail Price Index (Inflation)
- X: Productivity growth
- R_{t-1}: **Revenue in previous year**
- μ: **Sharing parameter**
- Π_{t-1}: Actual profit in previous year
- Π^{reg}_{t-1}: “Fair” profit determined by regulator for previous year

Yardstick Competition

$$AC_i = \sum (AC_j) / (n-1), \quad j \neq i$$

- AC_i: Average costs of company i
- ∑: Sum of all other companies
- AC_j: **Average costs of company j**
- n-1: Number of all companies in the market - 1

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3. Principle Design Criteria

a) Efficiency Incentives

Rate-of-Return	• Low incentive • No benefit of cost reductions as return is fixed • Costs can be shifted to customers, incentive to increase costs
Revenue-Sharing / Profit-Sharing	• Medium incentives • Revenues / profits resulting from cost reductions shared with customers • Large sharing rule → incentives close to Rate-of-Return regulation • Small sharing rule → incentives close to Cap Regulation
Revenue-Cap	• Medium to strong incentives • Profits can be increased by reducing costs as revenues are capped • Possibility to increase profits by increased prices and decreased output • Includes explicit factor for the anticipated efficiency increase (X-factor)
Price-Cap	• Medium to strong incentives • Profits can be increased by reducing costs as prices are capped • Possibility to increase profits by increased output • Requires explicit productivity increase via formula (X-factor)
Yardstick	• Strong incentives • Prices/revenues indexed to average cost/productivity improv. of industry • Profits can be increased by reducing costs in relation to other companies

3. Principle Design Criteria

b) Practicability – Information Requirements

Rate-of-Return	• Medium / high information requirements • Requires monitoring of revenue and cost data • High administration effort
Revenue-Sharing / Profit-Sharing	• Medium information requirements • Requires regular and reliable profit / revenue data
Cap	• Information requirements vary with the form of cap regulation (low to medium) • It may require explicit cost projections • Reduced monitoring of costs
Yardstick	• Comparably lower information requirements • Does require a sufficient number of comparative firms whose data can be used to form the yardstick

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3. Principle Design Criteria

c) Regulatory Capture and Gaming

Rate-of-Return	• Low threat of gaming, as rate of return can be reset frequently but incentives to keep high costs • High threat of capture, as profits depend on frequent reviews • Low risk of discretionary intervention as prices are set according to costs
Revenue-Sharing / Profit-Sharing	• Medium threat of gaming, risk of manipulating profits • Medium threat of capture, pressure to change profit levels or sharing rule • Medium risk of discretionary intervention as profits from cost-savings might be seen as excessive by the general public
Cap	• It may be exposed to gaming, incentive to inflate costs at the time the cap is set • Lower threat of capture, longer regulatory period • On the other hand it may be exposed to high risk of discretionary interventions as profits from cost-savings might be seen as excessive by the general public
Yardstick	• Low threat of gaming and capture, as costs are set by industry average • Medium risk of discretionary interventions if industry average is perceived as inefficient • Medium treat of collusion, incentive to inflate average industry costs at the time the yardstick is set

3. Principle Design Criteria

d) Impact on Investment

Rate-of-Return	• Potential of over-capitalisation / gold plating • "Averch-Johnson" effect (inefficiently high capital-labour ratio)
Revenue-Sharing / Profit-Sharing	• Investment impact depends strongly on the design • In general weaker (than rate-of-return regime) incentives for over-investment
Revenue-Cap	• Potential of underinvestment, however the investment impact / incentives depends strongly on the design • Requires supplementary quality regulation
Price-Cap	• Potential of underinvestment, however the investment impact / incentives depends strongly on the design • Requires supplementary quality regulation
Yardstick	• Potential of underinvestment, however the investment impact / incentives depends strongly on the design • Requires supplementary quality regulation

3. Principle Design Criteria

e) Regulatory Risk

Rate-of-Return	• Transparent, predictable • Intrusive • Cost immunisation → customers bear risk → lower risk for the firm → likely lower cost of capital
Revenue-Sharing / Profit-Sharing	• Risk and revenues shared between company and customers • Depending on sharing arrangements resemble rate-of-return or cap regulation
Revenue-Cap	• Due to the longer regulatory periods it may be less transparent but also less intrusive • Decoupling between costs and revenue may lead to higher risk for the company
Price-Cap	• Due to the longer regulatory periods it may be less transparent but also less intrusive • Decoupling between costs and revenue may lead to higher risk for the company
Yardstick	• Theoretically more transparent, but in practice several complexities • Non-intrusive • Owners bear risk, process similar to competitive markets

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Part 2 - Role of the X-factor

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Monopoly as a Disease

- What causes the disease?
- What are its symptoms?
- What cures are available?

Symptoms of Monopoly

- Allocative Inefficiency
- Low Productivity
- Suboptimal Quality

Symptoms: Productive Inefficiency

- High productivity implies
  - Using least amounts of inputs to produce highest level of outputs
  - Choose right combination of inputs and outputs
- Incentives under competition
  - Being more efficient than your competitors results in higher profits
- Incentives under Monopoly
  - There are no competitors
- Waste resulting from lack of productivity also known as: **X-Efficiency**

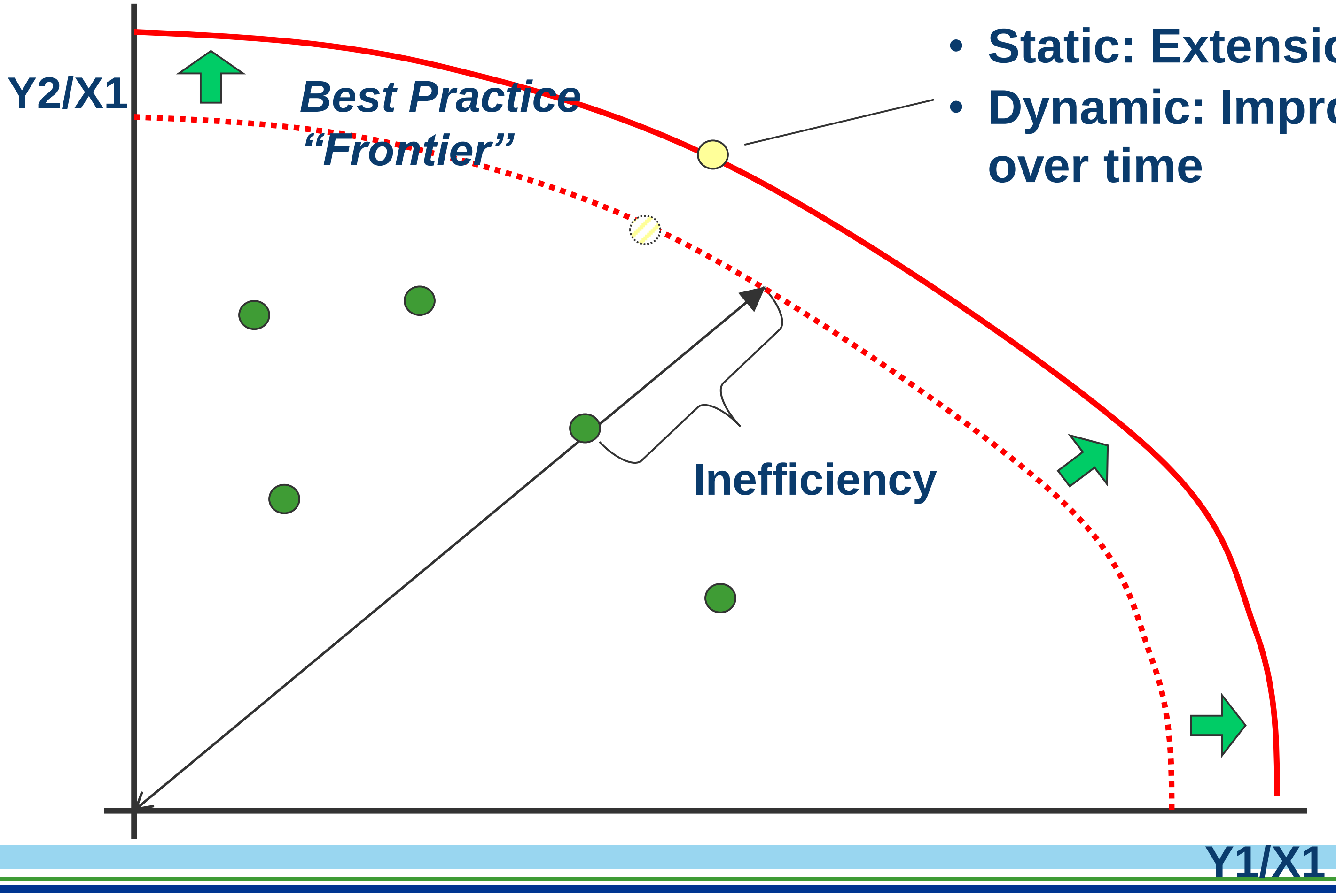
Cure: Incentive Regulation

- Formalization of the regulatory lag
- Revenue / price changes according to X-factor
- Correction for inflation and uncontrollable cost
- "Company is made claimant of residual gains resulting from better performance"
  - In normal words: If you reduce cost you make more profits, and you can keep these profits

$$p_t = p_0 \cdot (1 + CPI_t - X)^t$$

- The X-factor reflects the anticipated efficiency improvement potential of the company

Benchmarking: Identify Best Practice?



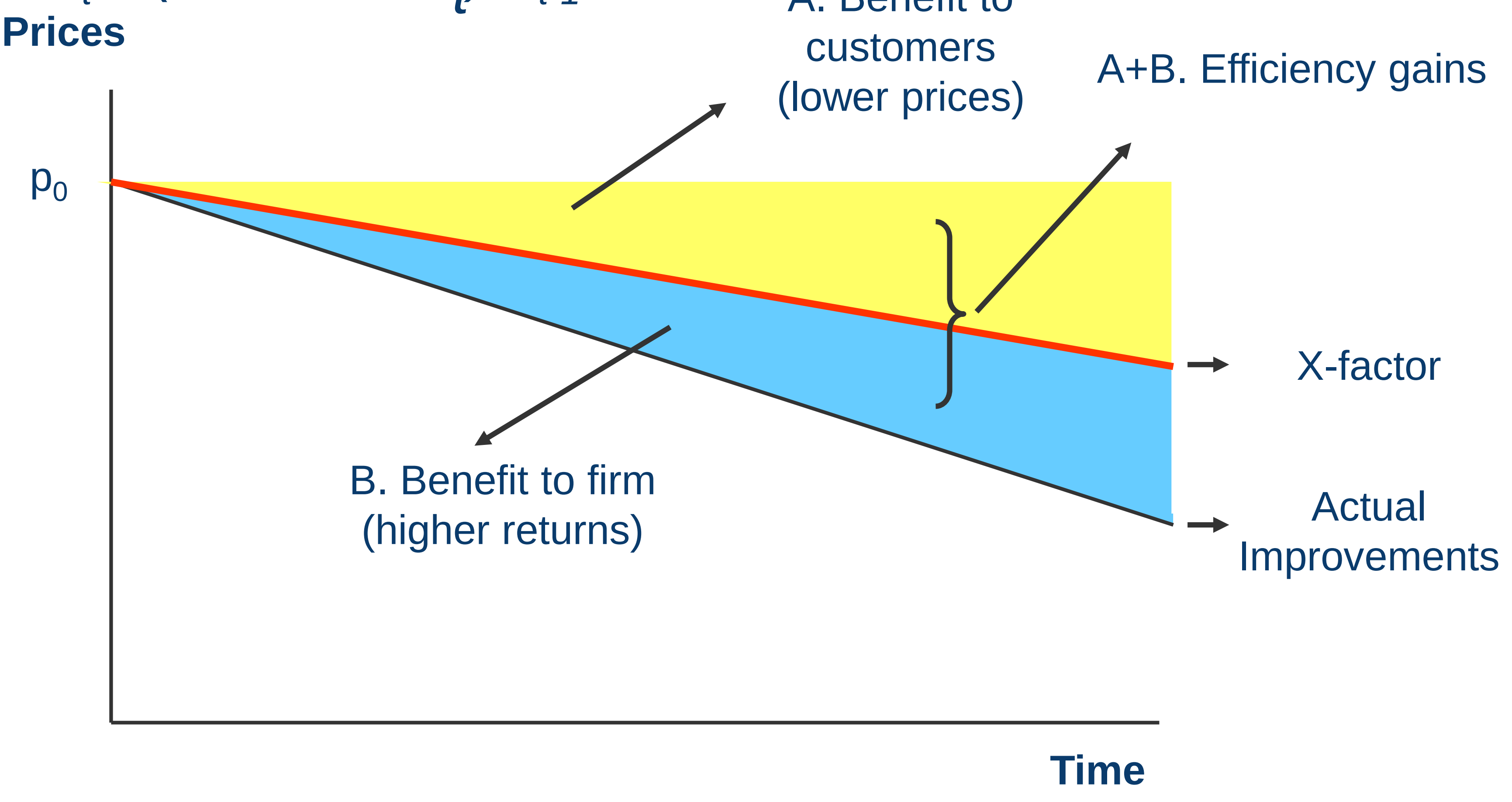
- **Static: Extension of Sample**
- **Dynamic: Improvements over time**

Perfect X-factor Does Not Exist

- Trade-off between rents and incentives
  - If the regulator would know the true efficiency improvement potential, it could simply set the X-factor on this basis
  - The company would become fully efficient and all rents would be transferred to customers
- In reality, determining the true efficiency improvement potential is impossible
- The X-factor is only a (sophisticated) guess
  - Benchmarking is an important regulatory tool

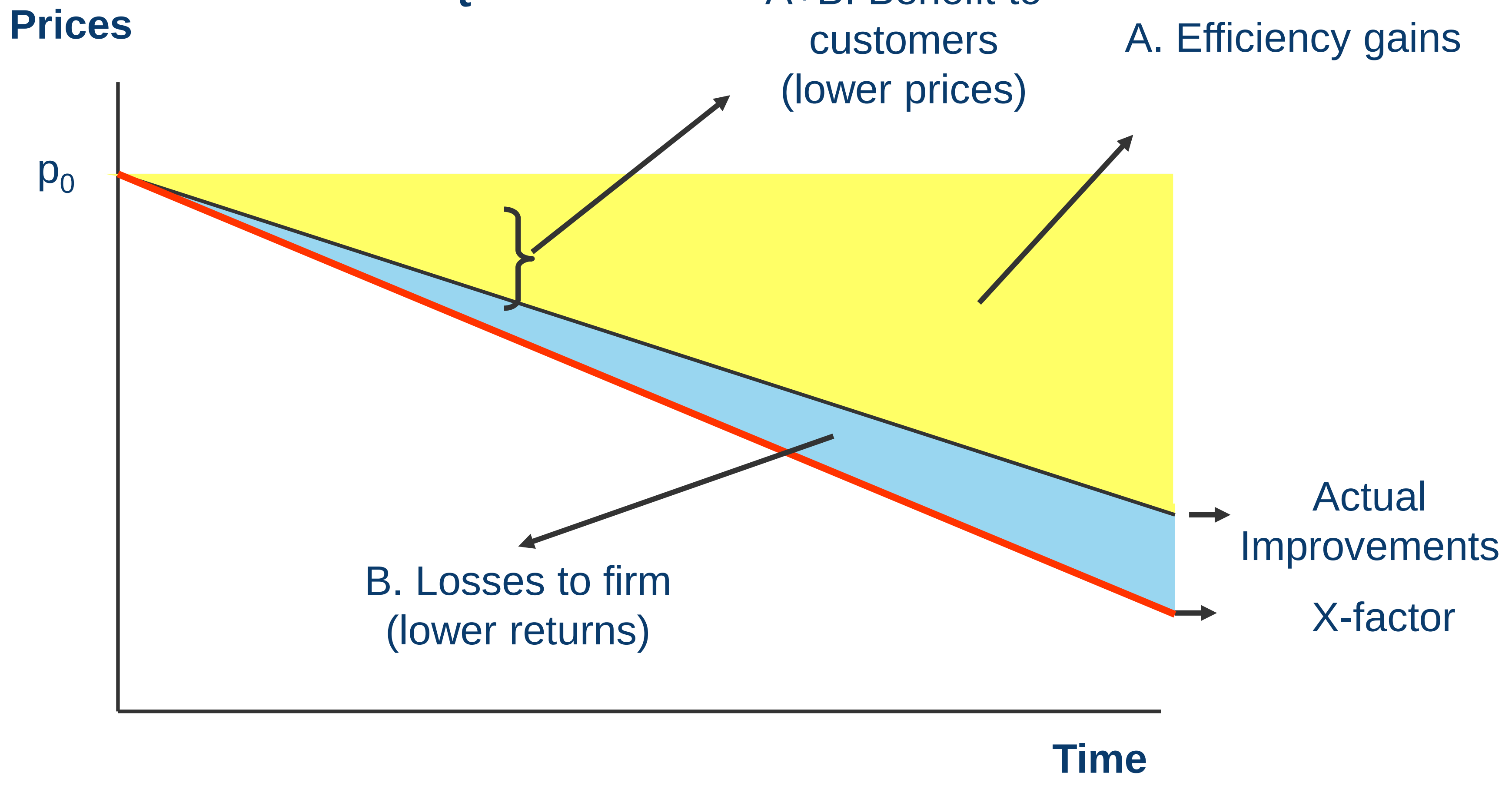
Underestimation of the X-factor

$$P_t = (1 + CPI - X_t)\, P_{t-1}$$



Overestimation of the X-factor

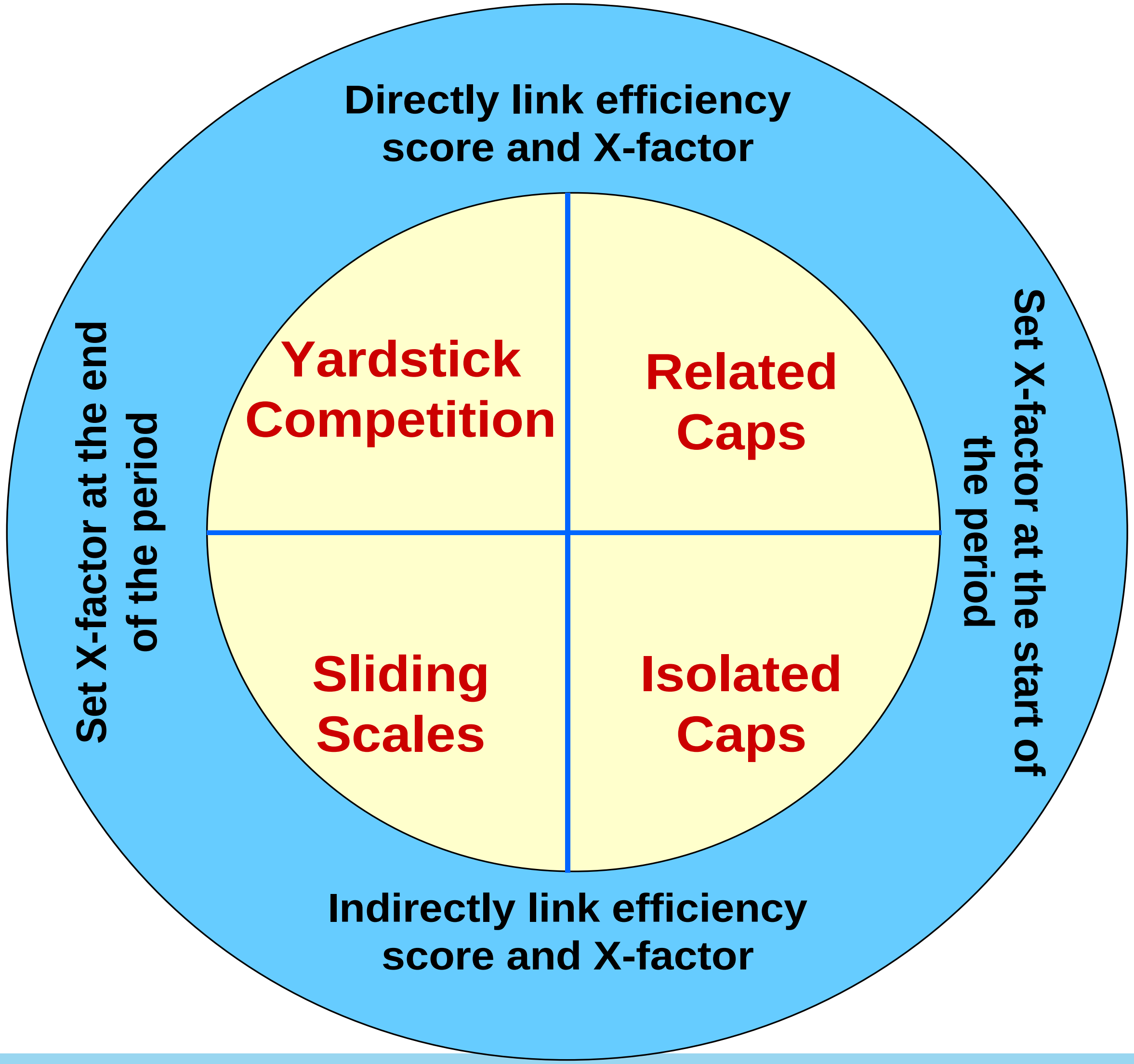
$$P_t = (1 + CPI - X_t)\, P_{t-1}$$



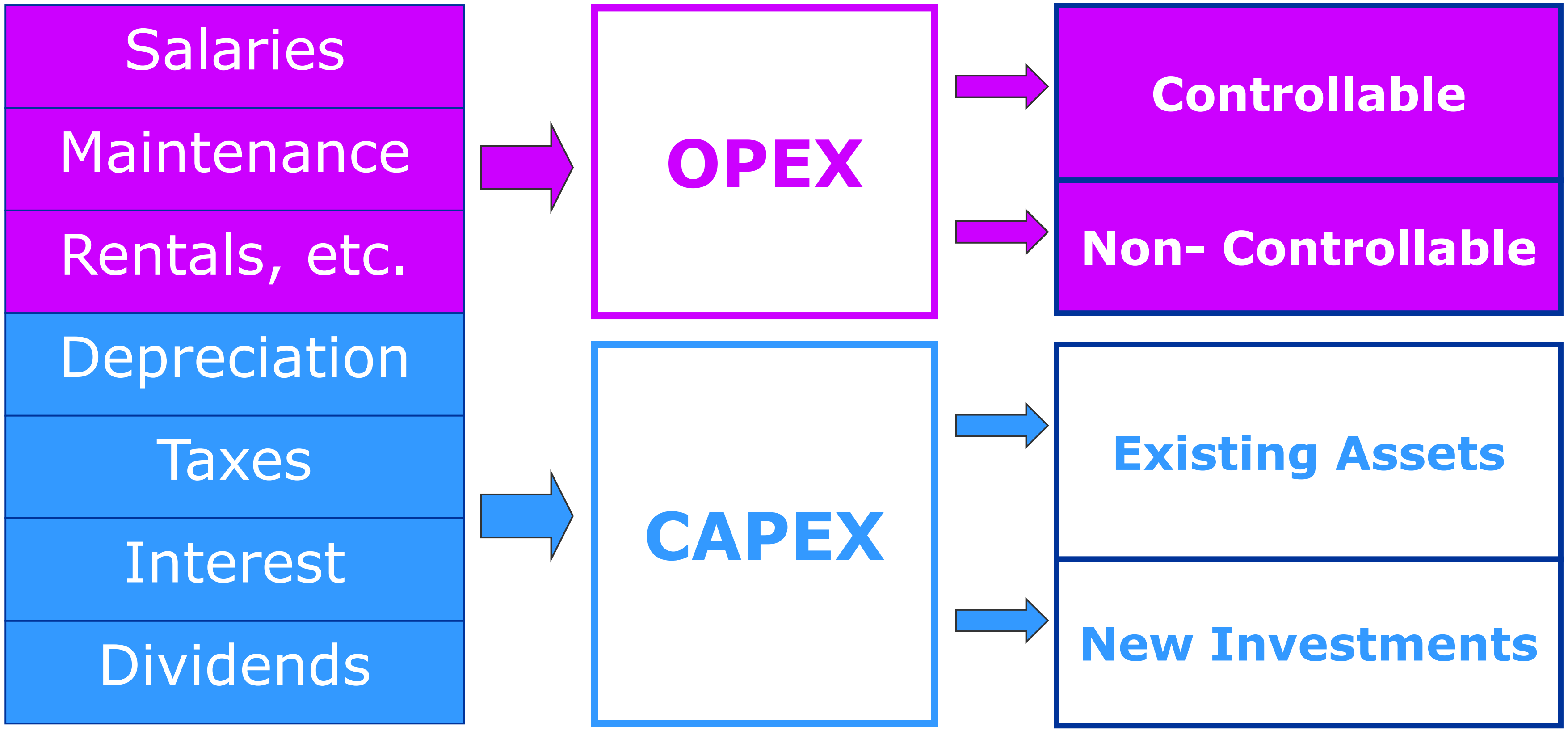
Strategies for Setting the X-factor

- Decision Variable 1
  – How tight is the link between the efficiency score and the X-factor?
- Decision Variable 2
  – Do you set the X-factor before or after the regulatory period?

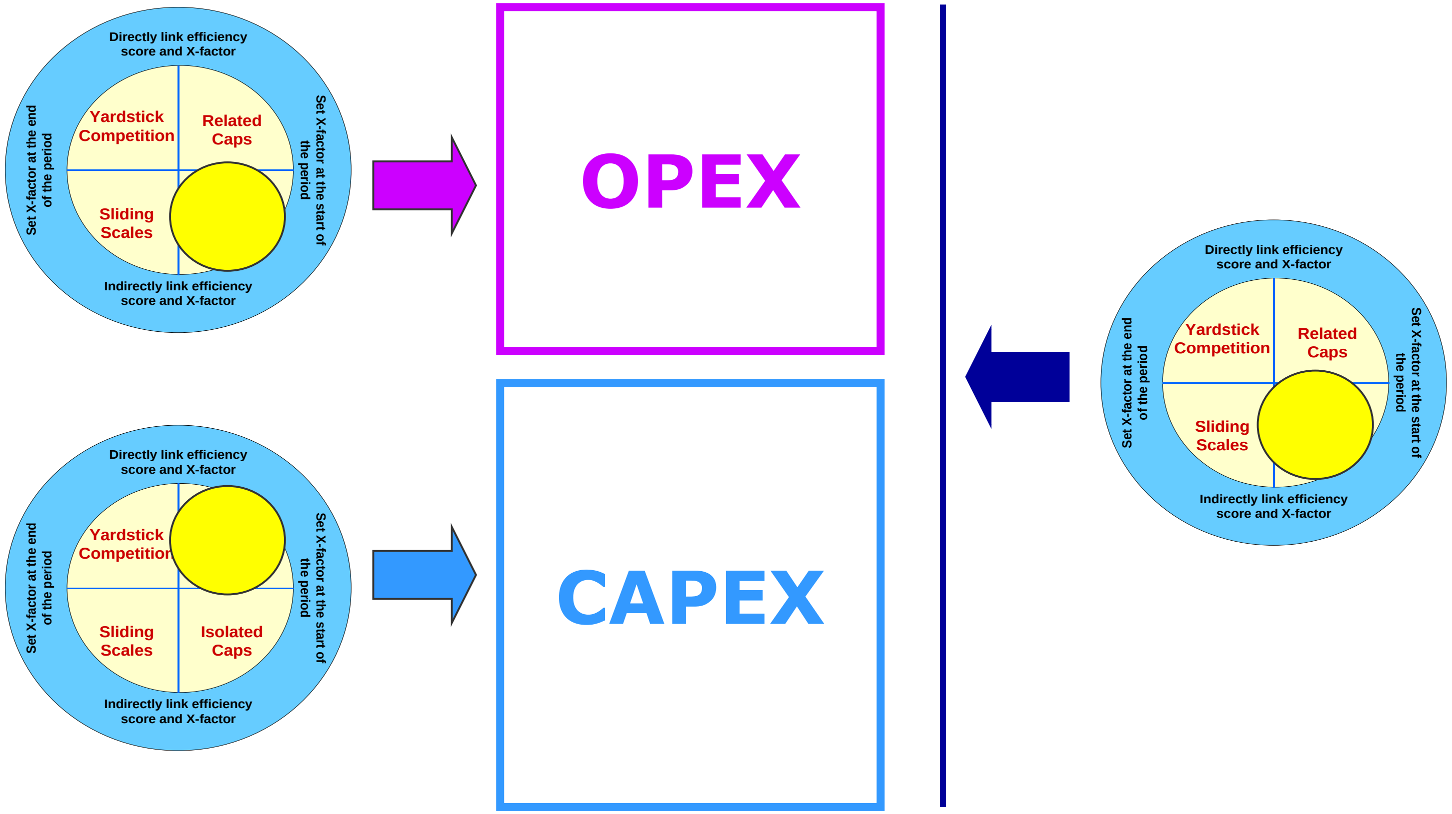
Price-Cap Strategies



Cost Categories



Building Blocks versus TOTEX



Building Blocks Approach

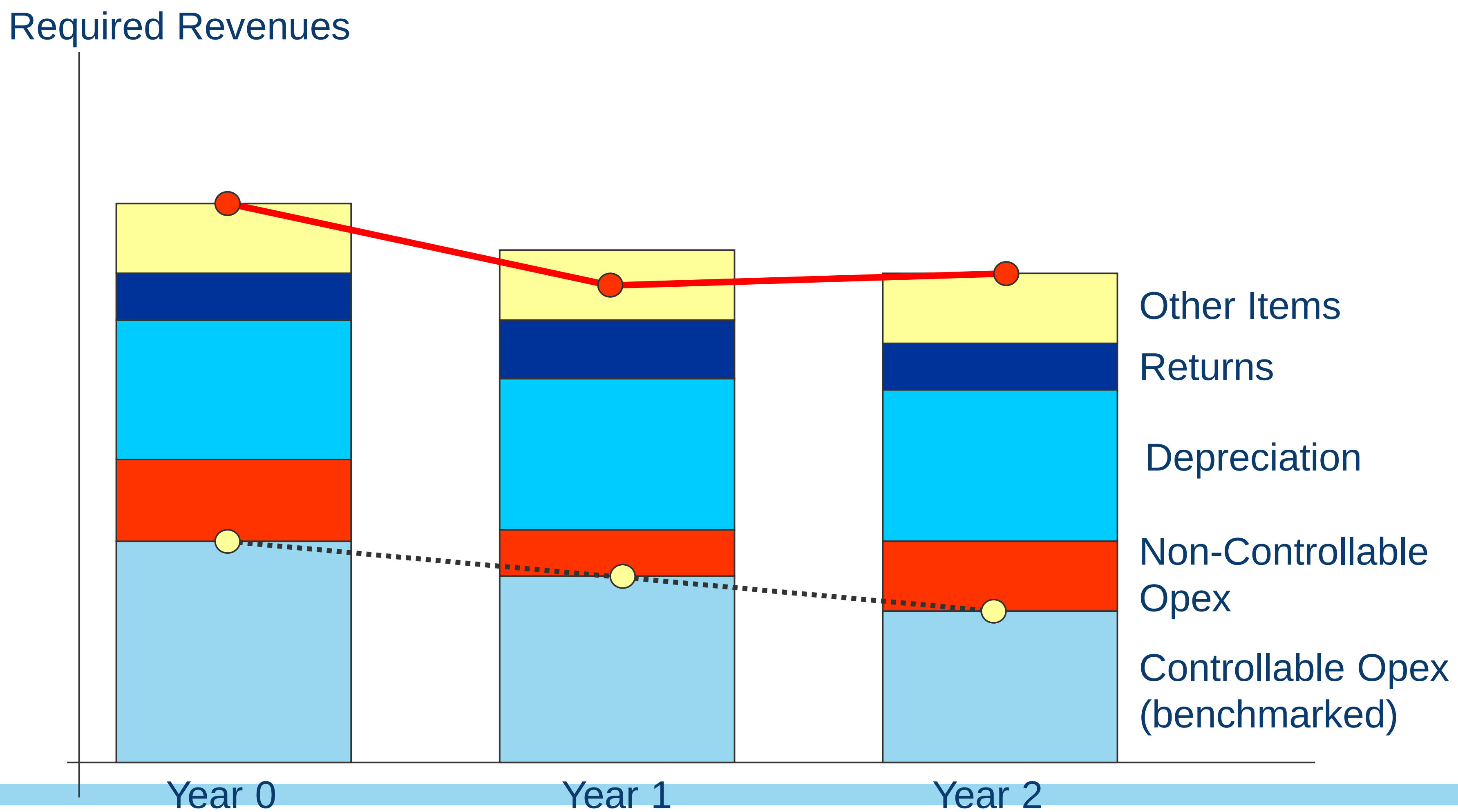
TOTEX Approach

Price-Cap Approaches

- Building Blocks Approach
  - Treats opex and capex separately
  - In principle different price-cap strategies
  - Even further distinction opex/capex sub-categories
- Totex Approach
  - Makes no separation between opex and capex
  - Same price-cap strategy is applied to the sum of opex/capex

- Note: Non-controllable costs are treated as pass-through under both approaches

Building Blocks Example



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Part 3 - Productivity Benchmarking Techniques

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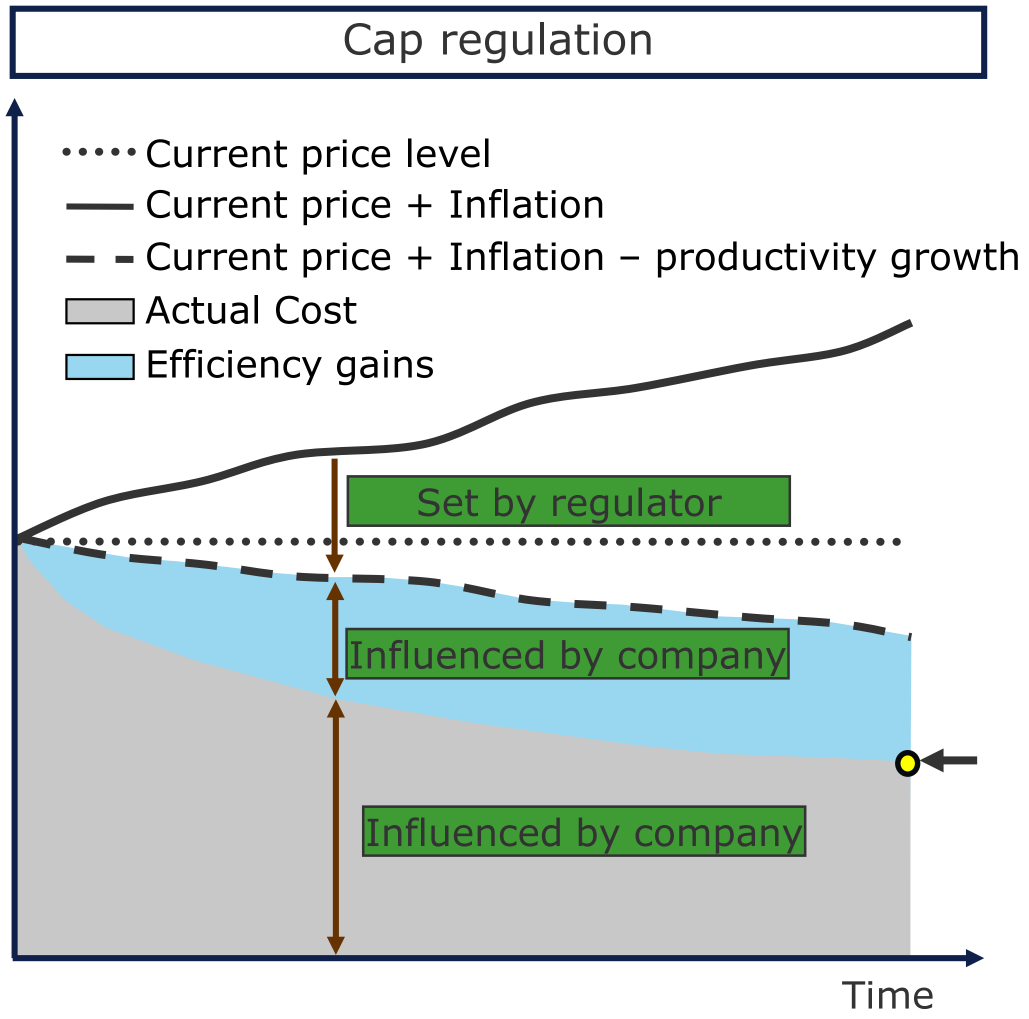
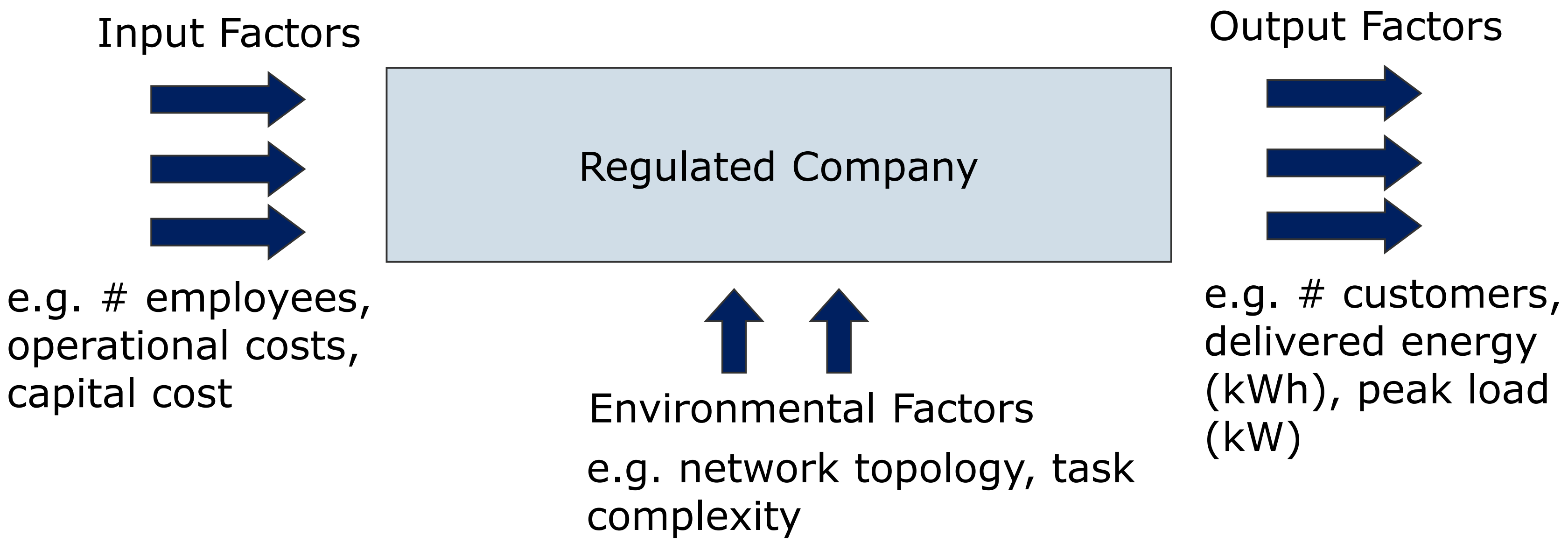
Why measure efficiency?

- Major Reasons
- Regulation is needed in areas where competition does not work (e.g. natural monopolies - transmission, distribution networks) to limit excessive pricing and to set incentives for efficient performance
- Regulators apply benchmarking to assess efficiency of regulated companies for the purposes of incentive regulation



Why measure efficiency?

Efficiency is measured by the ratio of output to input, usually on a comparable basis and by taking into consideration the operating environment.

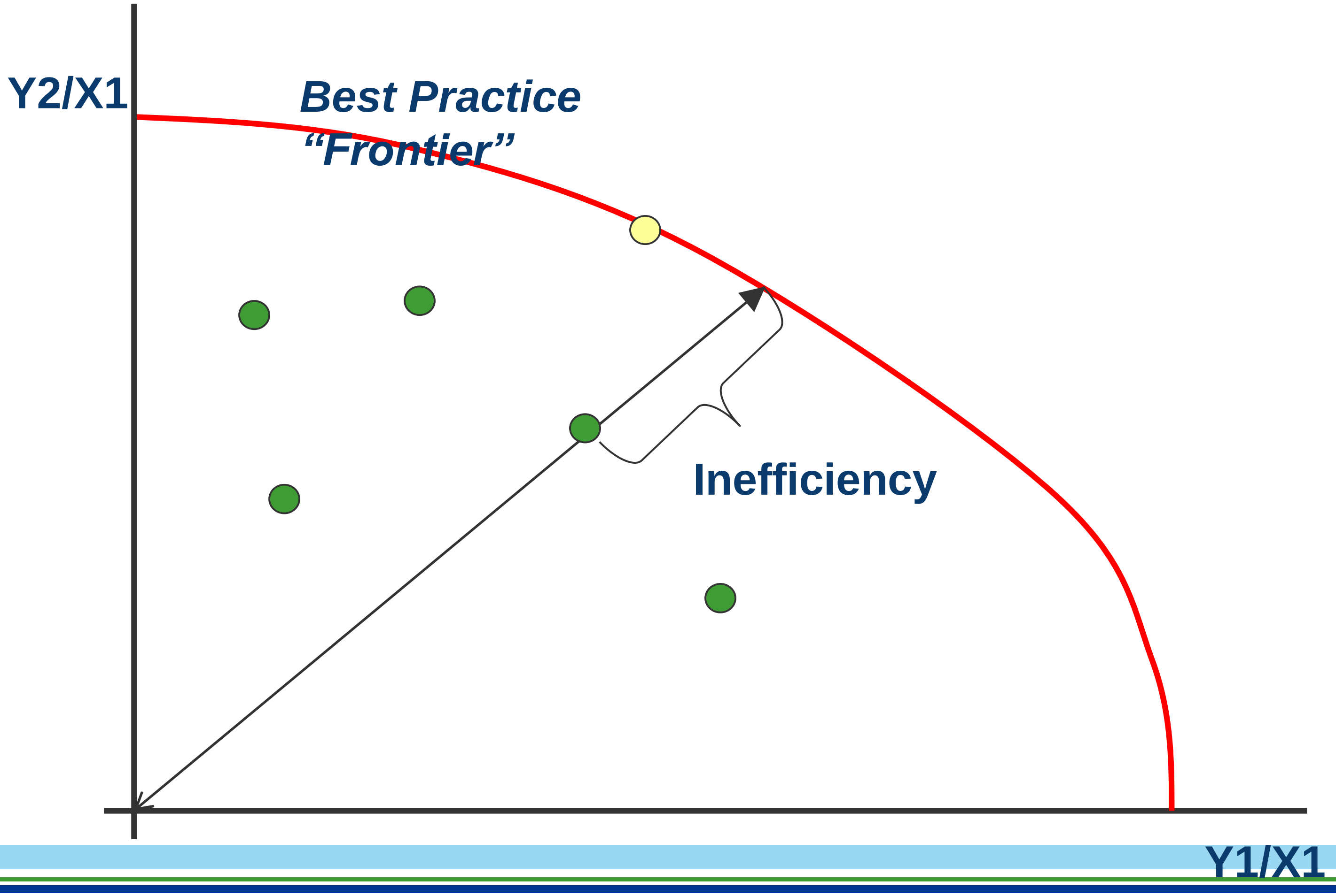


Why measure efficiency?

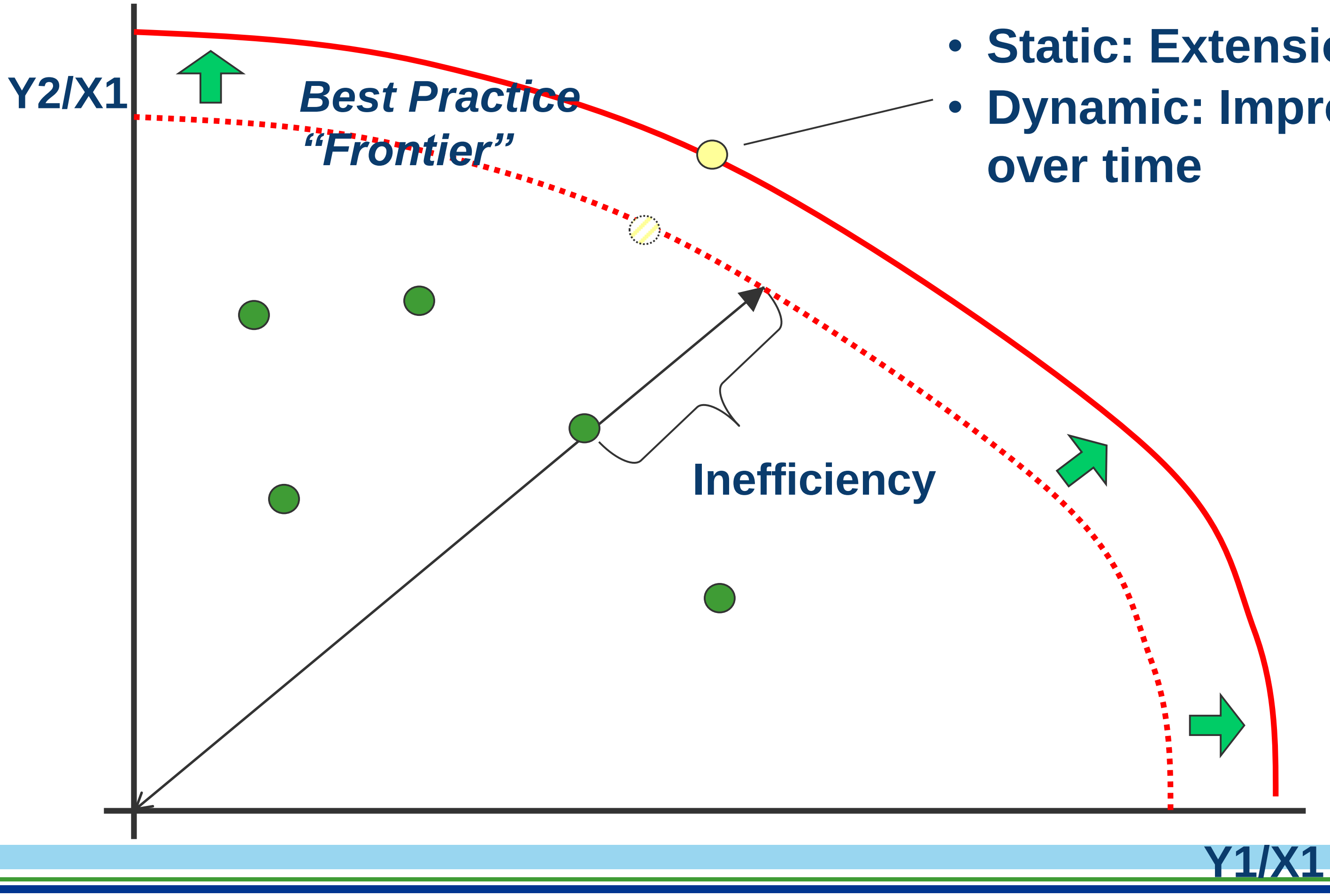
Reasons for efficiency changes

- Technological change (frontier shift): change in production technology within the sector
- Efficiency change (catch-up)
  - Change in efficiency of production (technical efficiency, input prices)
  - Change in the scale of production

Benchmarking: Identify Best Practice?



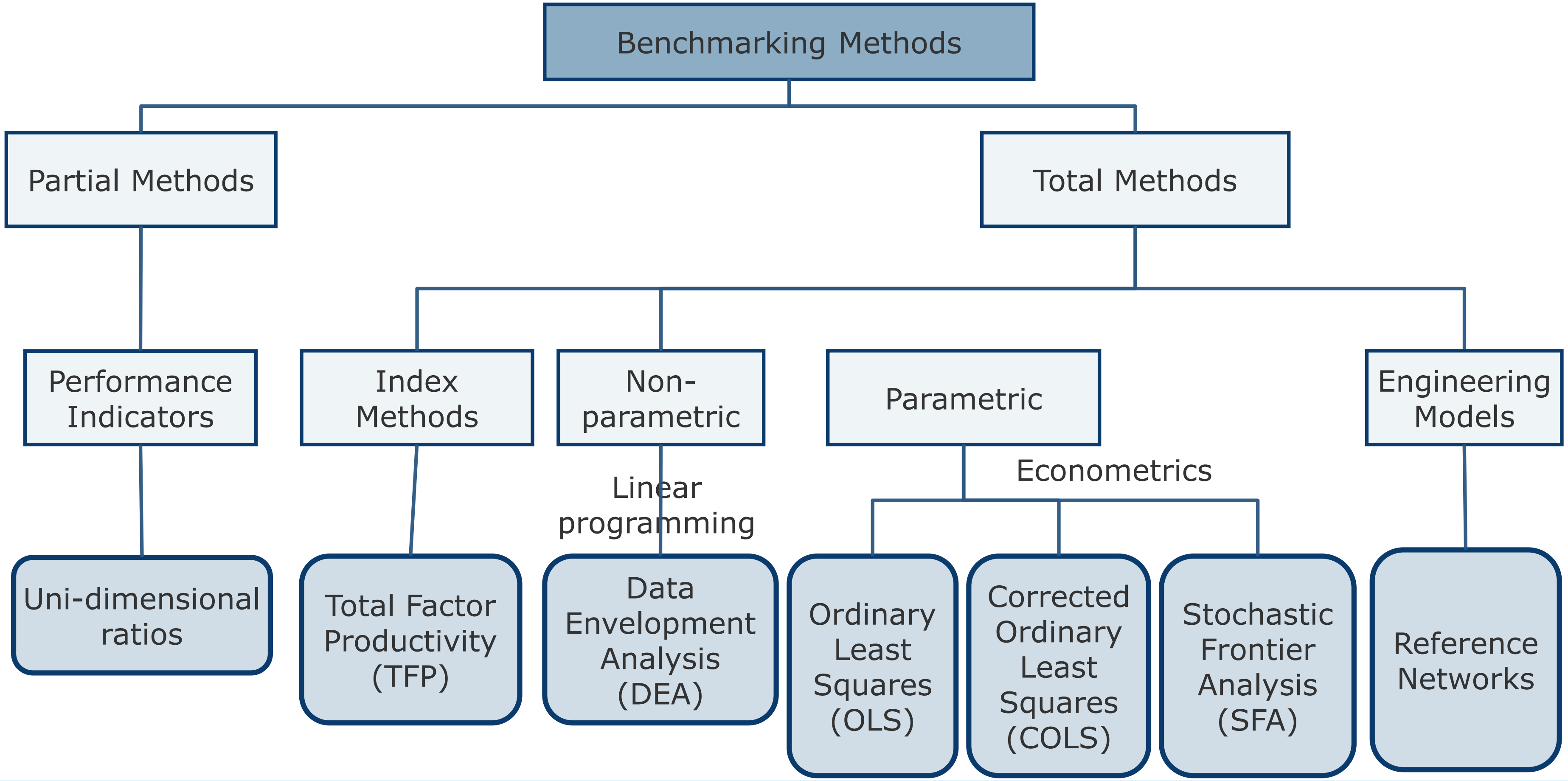
Benchmarking: Identify Best Practice?



- Static: Extension of Sample
- Dynamic: Improvements over time

Productivity Benchmarking Techniques

Overview of Methods for Efficiency Analysis



Productivity Benchmarking Techniques

Performance Indicators

- Uni-dimensional ratios compare single performance indicators
- It is simple and easily applicable
- It fails to account for the relationships between different input and output factors/ trade-offs between different improvement possibilities or areas

- Examples of performance indicators:

Productivity (Managerial) Indicators	Financial indicators
GWh / Employee OPEX / GWh OPEX / Employee GWh / Line Length	Debt / Equity Ratio Return on Investment (ROI) Return on Capital Employed (ROCE)

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Productivity Benchmarking Techniques

Index Methods – Total Factor Productivity (TFP)

- Total factor productivity (TFP) measures the ratios of the inputs and outputs of a regulated company
- It can be applied with multiple inputs and outputs
- Suitable for assessment of productivity of companies or sectors over time
- Used by regulators to estimate frontier shift
- In mathematical terms based on Malmquist TFP index or Tornquist TFP index

Productivity Benchmarking Techniques

Index Methods – Total Factor Productivity (TFP)

Tornqvist Index Method

- The Tornqvist Index measures the productivity change over time
- Productivity of a company is measured by the quantity of output produced per unit of input
- In the case of a single-output and single-input this would simply be the ratio of its output and input quantities
- When multiple inputs and/or multiple outputs are involved, one should add weights of the output and input quantities

Malmqvist Method

- The Malmqvist Index is able to decompose the productivity change into relative efficiency change (firms getting closer to the frontier) and technical progress (frontier shift)
- The Malmqvist Index measures the productivity change between two data points by calculating the ratio of the distances of each data point relative to a common technology
- The Malmquist Index usually relies on DEA analysis
- In order to carry out a reliable assessment on the Malmqvist Index one would need a data set for several companies

Productivity Benchmarking Techniques

Data Envelopment Analysis (DEA)

- Non-parametric approach based on linear programming, no functional relationships between input and output factors needed
- DEA benchmarks an individual company in relation to the best-practice (most efficient) companies, establishes peer companies
- Efficiency scores may be decomposed into scale and technical efficiency
- Small samples and a high number of input or/and output variables can result in an over-specification of the model and biased efficiency scores

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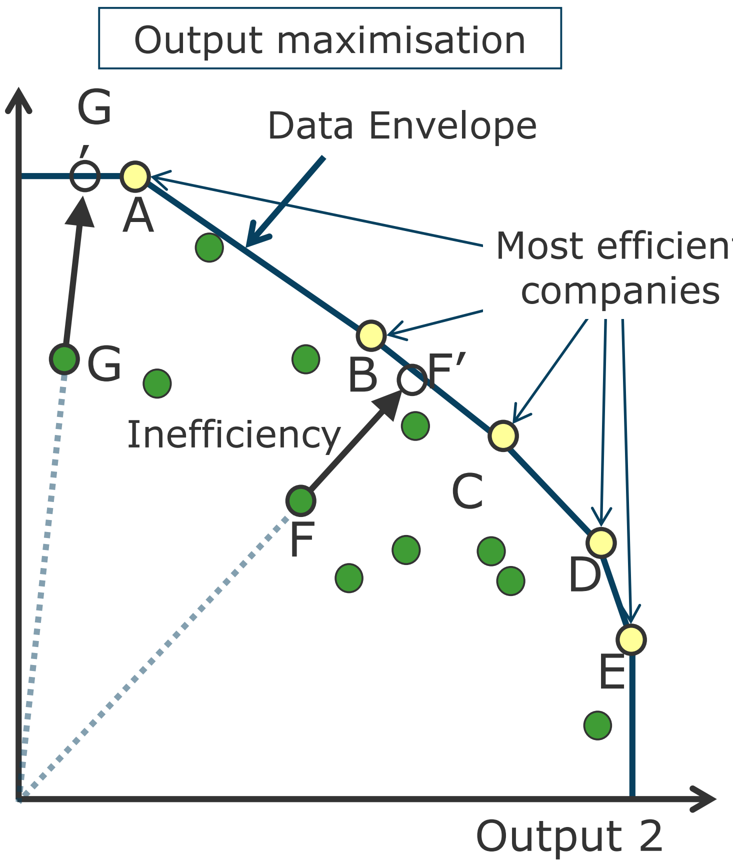
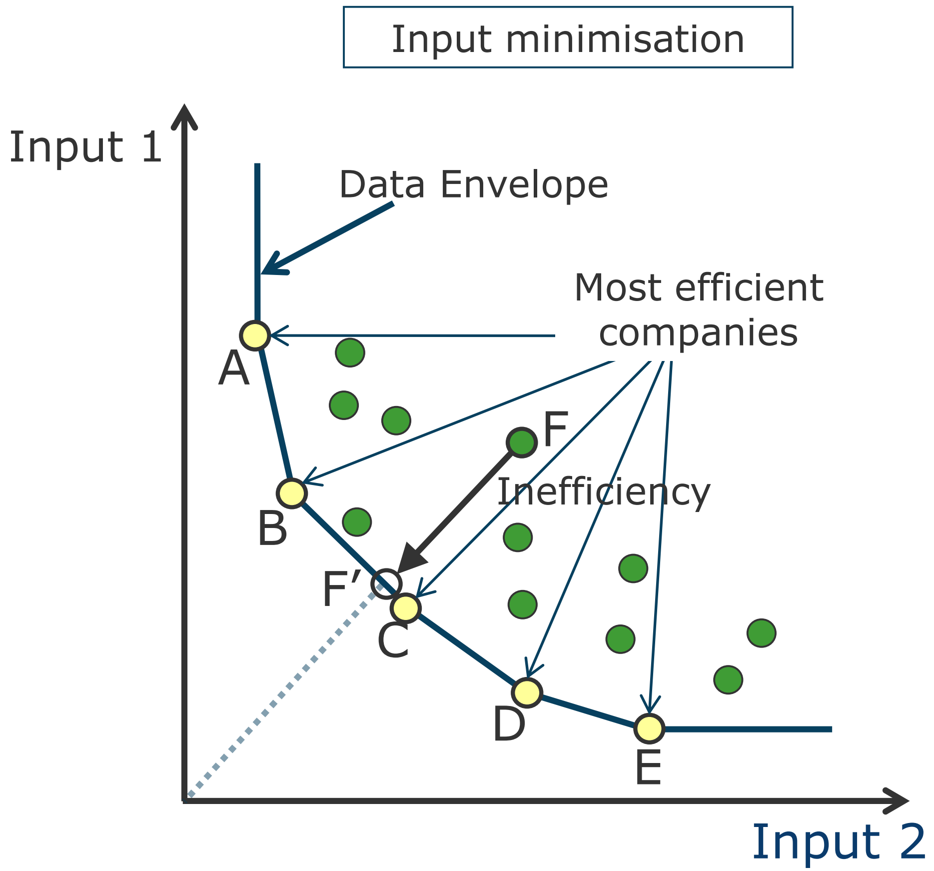
Productivity Benchmarking Techniques

Data Envelopment Analysis (DEA)





Corrected Ordinary Least Squares (COLS)

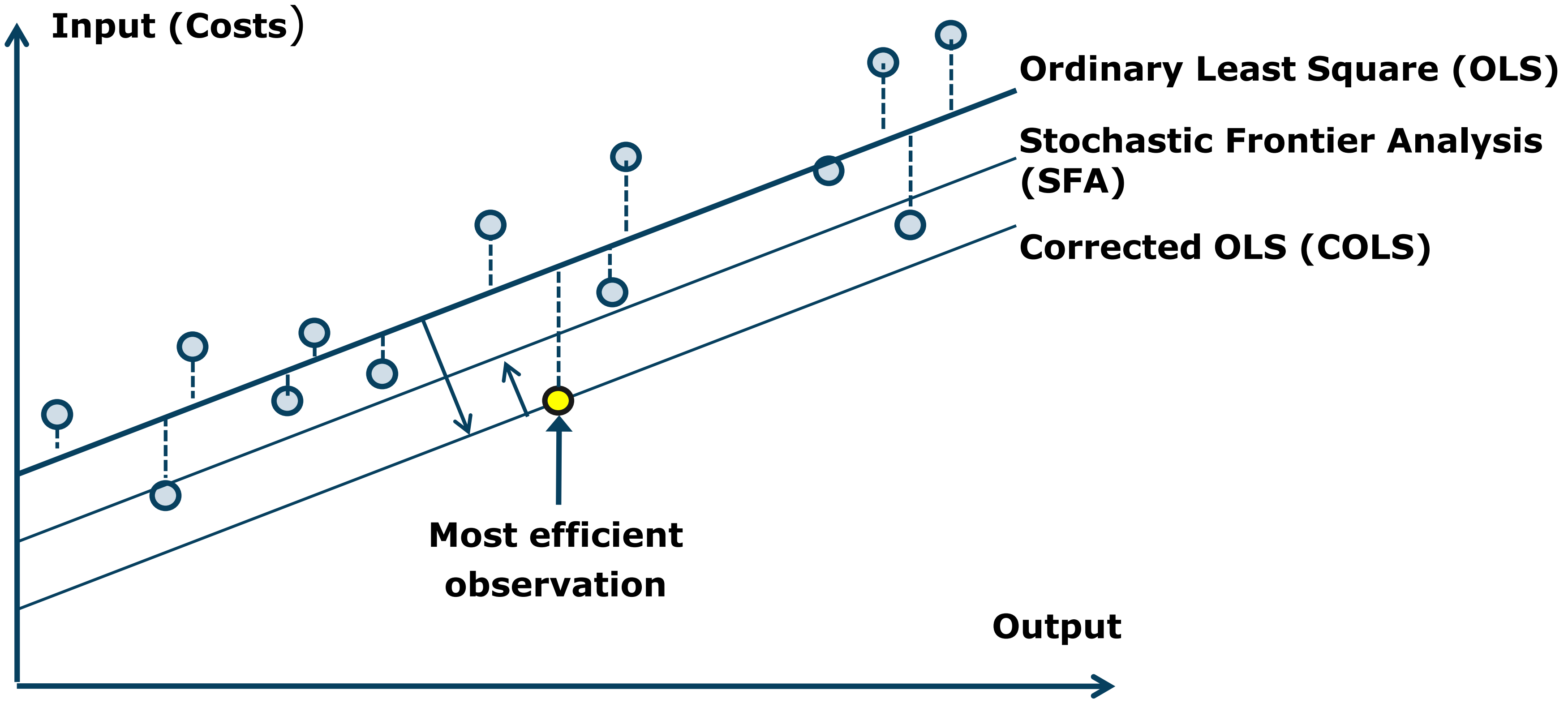
- Estimation of production or cost functions (not just price relationships) via Ordinary Least Squares
- Use of regression residuals to characterise relative distances between observations in the sample
- Calculation of relative distances by means of shifting the regression line to (unique) best-practice observation
- Very dependent on data quality and, in particular, sensitive to outliers

Stochastic Frontier Analysis (SFA)

- Uses same premises as COLS, but treats best practice as a "stochastic" process (a mix of true efficiency and "pure noise" effects)
- Several statistical assumptions behind the errors' split: for instance, gamma or half-normal distribution for the efficiency errors
  - Error = U (for Inefficiency) + V (for Random Noise)
- SFA requires a large sample size to be statistically relevant
- In the presence of patchy and/or too small samples, COLS is relatively more reliable than SFA (SFA cannot be drawn as a "frontier" line as COLS)

Productivity Benchmarking Techniques

COLS / SFA



Comparison of Techniques

- Uni-dimensional is simple but does not capture the multi-dimensional nature of the business
- COLS requires assumptions on functional form but does not separate efficiency errors from random noise (fewer assumptions but less precision)
- SFA allows hypothesis-testing but requires assumptions on functional form and on distribution of efficiency errors
- DEA is distribution-free and requires no specification of functional form, however it does not allow for specification testing

- None of them is unambiguously superior to the others
- Therefore, it is good to cross-check on the main methodology wherever possible
- DEA is generally preferred by regulators though because of the lower data intensity and intuitive appeal

Benchmarking Summary

- Benchmarking is a fundamental instrument for efficiency assessment and for the establishment of productivity improvement targets
- Data quality and model specification are fundamental for successful and defensible outcomes
- Benchmarking is not perfect but can be very useful –only if applied wisely
  - Take into account data and modeling restrictions
  - Feed these constraints into the step from benchmarking to the X-factor

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Part 4 - Uni-dimensional and Multi-dimensional benchmarking

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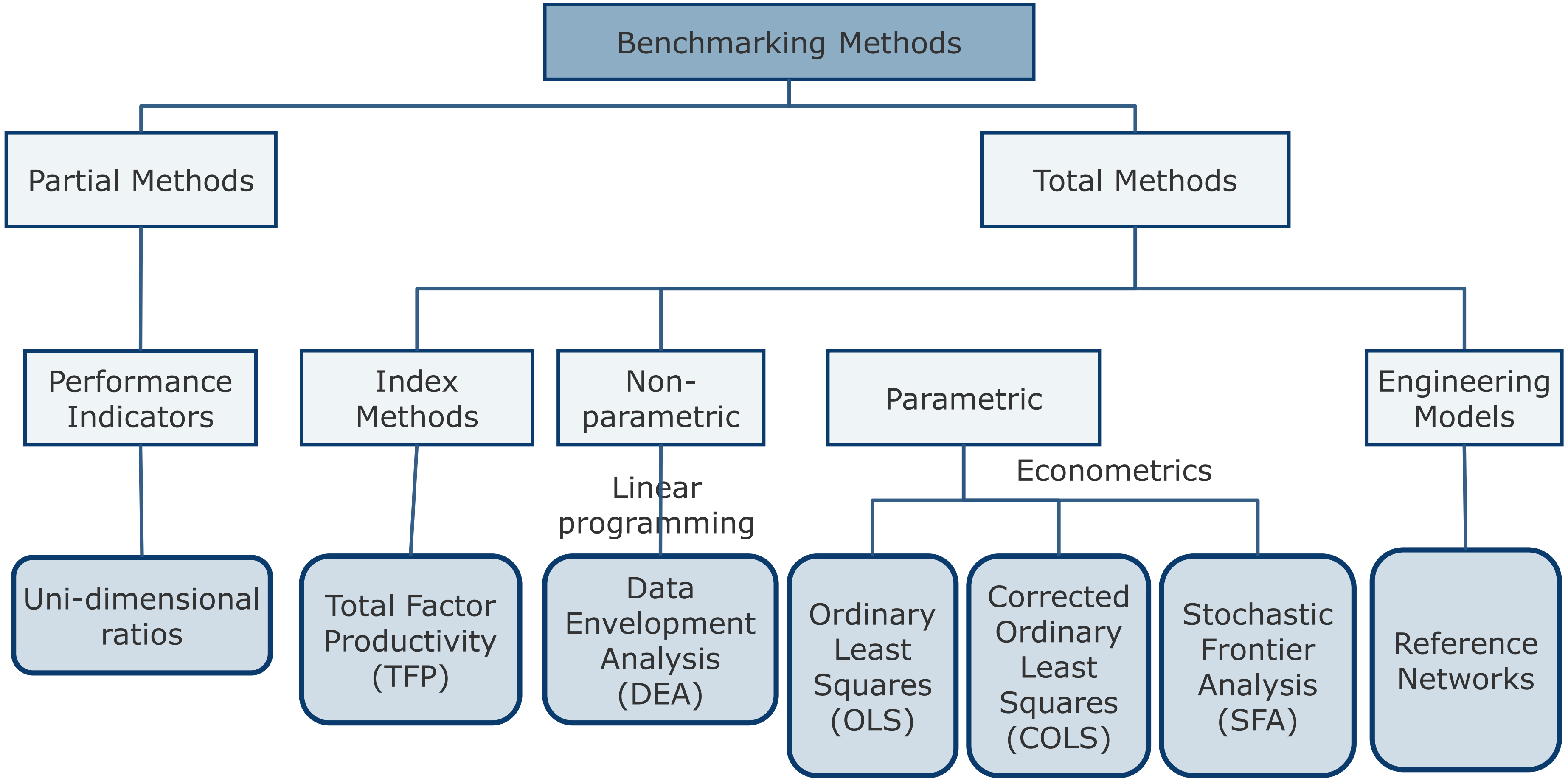
2. Methods for Efficiency Assessments

Overview of Methods for Efficiency Analysis



Comparison of methods

Method	Advantages	Drawbacks
Uni-Dimensional Ratios	• Simple to compute • Data typically readily available • Good indicative information	• Ignores complexity and multi-dimensionality
Total Factor Productivity	• Relatively simple to compute	• Implicit assumption is that there are no initial inefficiencies (catch-up)
Data Envelopment Analysis	• Covers multiple inputs and outputs • No functional relationships required • Scale effects can be incorporated • Can be applied using a relatively small dataset	• Sensitive to choice of input and output variables • Influence from extreme data points
OLS / COLS	• Simple to compute • Accommodates multiple inputs/outputs	• Requires a large data sample • Influence from single most efficient firm
Stochastic Frontier Analysis (SFA)	• Accommodates multiple inputs/outputs	• Requires a large data sample • Quite complex and statistically demanding • Genuine inefficiency can remain undetected
Reference Networks	• Bypasses the need for a data sample – focuses on one single company • Based on generally acceptable engineering assumptions	• High data requirements • Extensive modelling required • Complex and lengthy process

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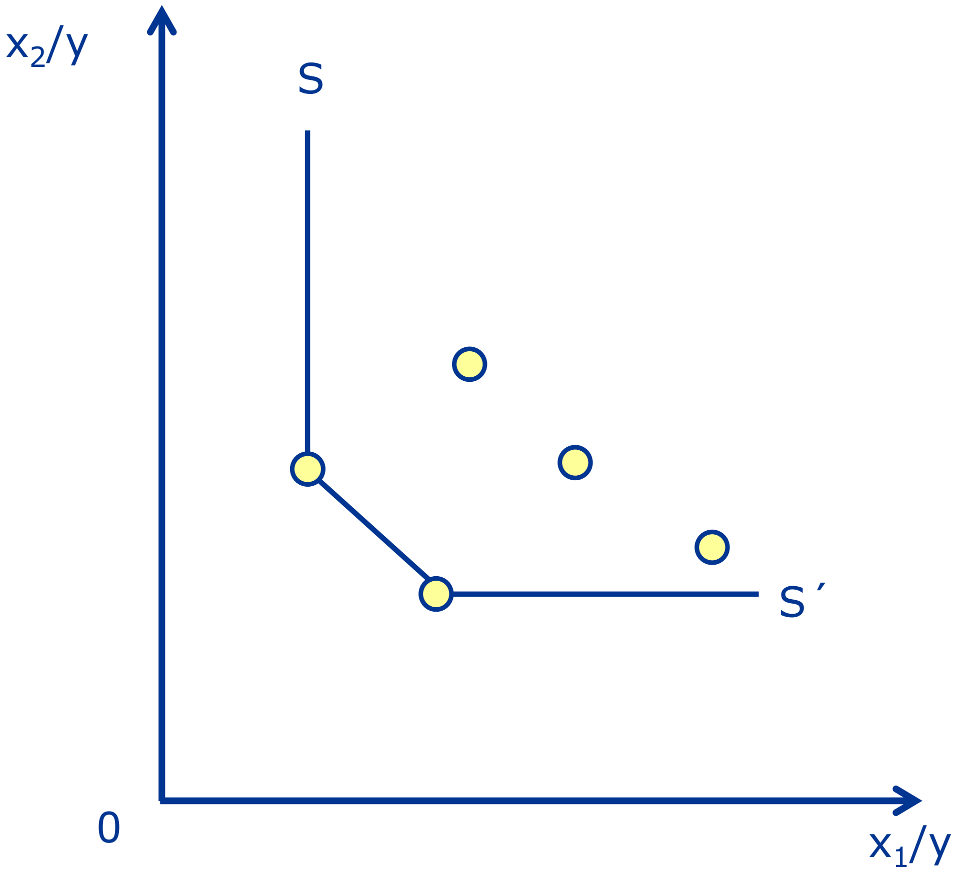
The Data Envelope



$$\max_{u,v} \frac{u^T y_i}{v^T x_i}$$

$$st$$

$$\frac{u^T y_i}{v^T x_i} \leq 1, j = 1 \ldots N$$

$$u, v \geq 0$$

$$\max_{u,v} u^T y_i$$

$$st$$

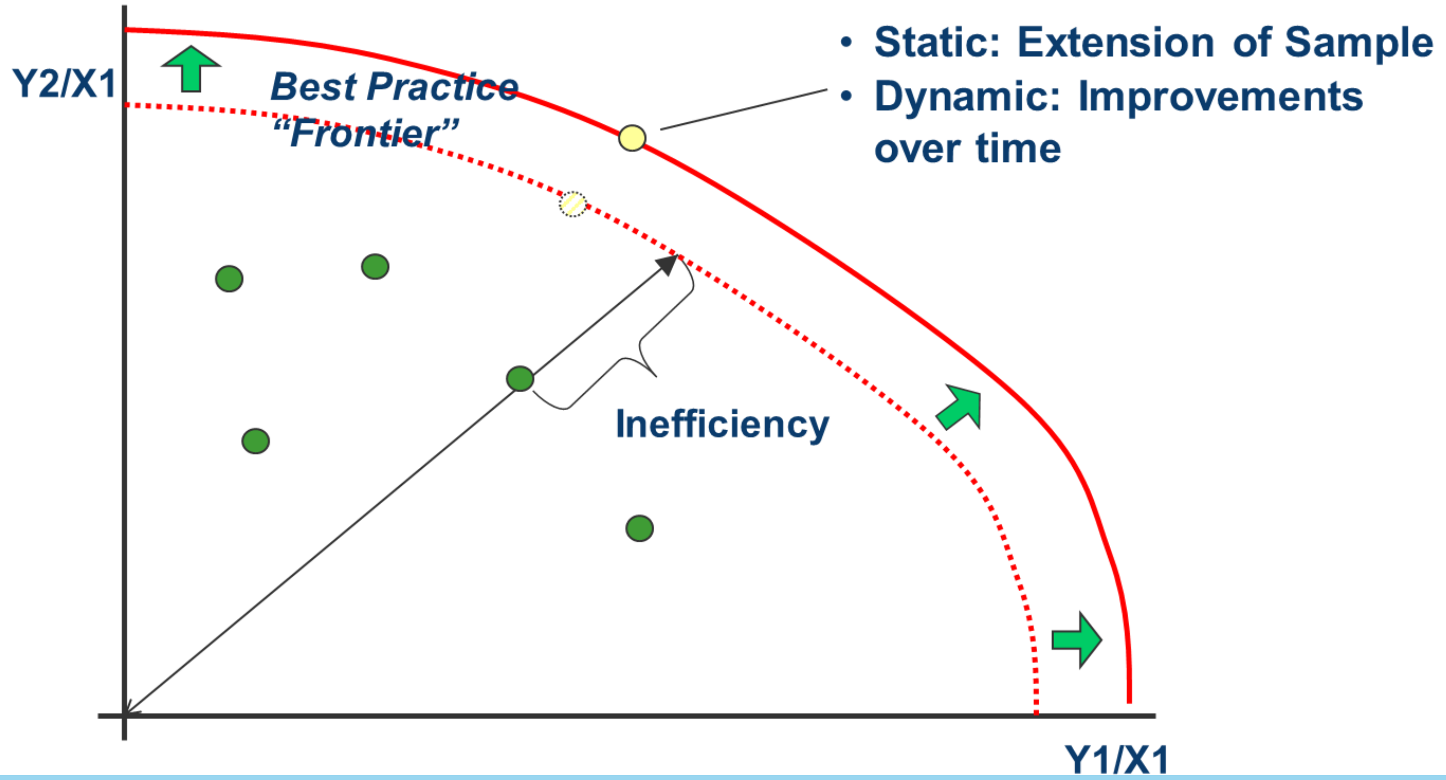
$$v^T x_i = 1$$

$$u^T y_j - v^T x_j \leq 0, j = 1 \ldots N$$

$$u, v \geq 0$$

DEA focuses on best performers

- DEA compares performance against ”best in the class”
- Having a high efficiency score does not necessarily imply best efficiency



The DEA Linear Programme

$$\min_{\theta,\lambda} \theta$$

$$subject\,to$$

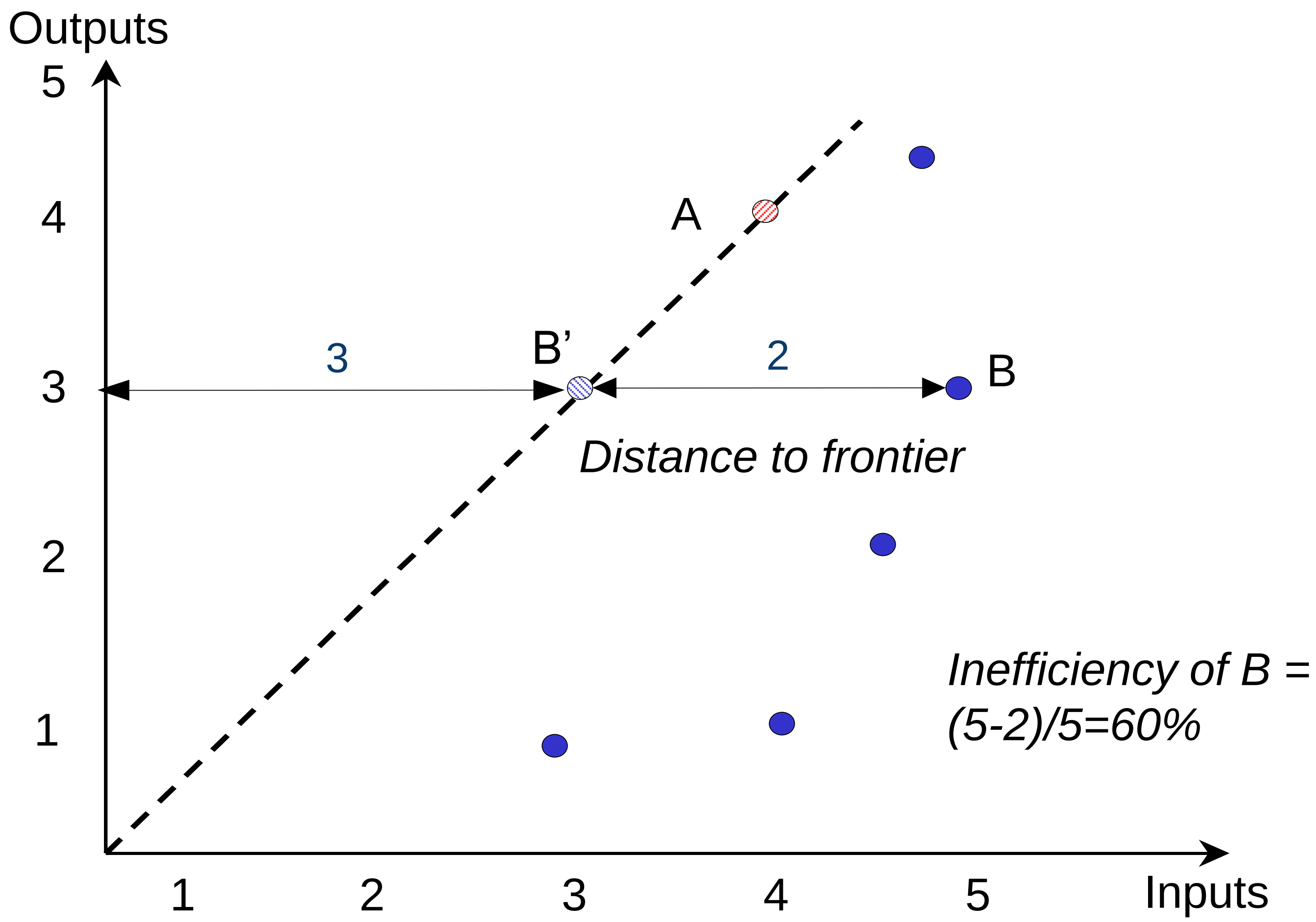
$$-\mathbf{y}_j + \mathbf{Y}\cdot\lambda \geq 0$$

$$\theta\cdot\mathbf{x}_j - \mathbf{X}\cdot\lambda \geq 0$$

$$\lambda \geq 0$$

- The objective function is to minimise the distance (or ‘inefficiency score’, θ) between the observed point (firm) and the best-practice frontier – ‘put the firms under the best possible light’
- The constraints are such that all firms must be either on or within the best practice production possibilities frontier (contour)
- The input and output weights must be non-negative

DEA (simplified 2 dimensions)



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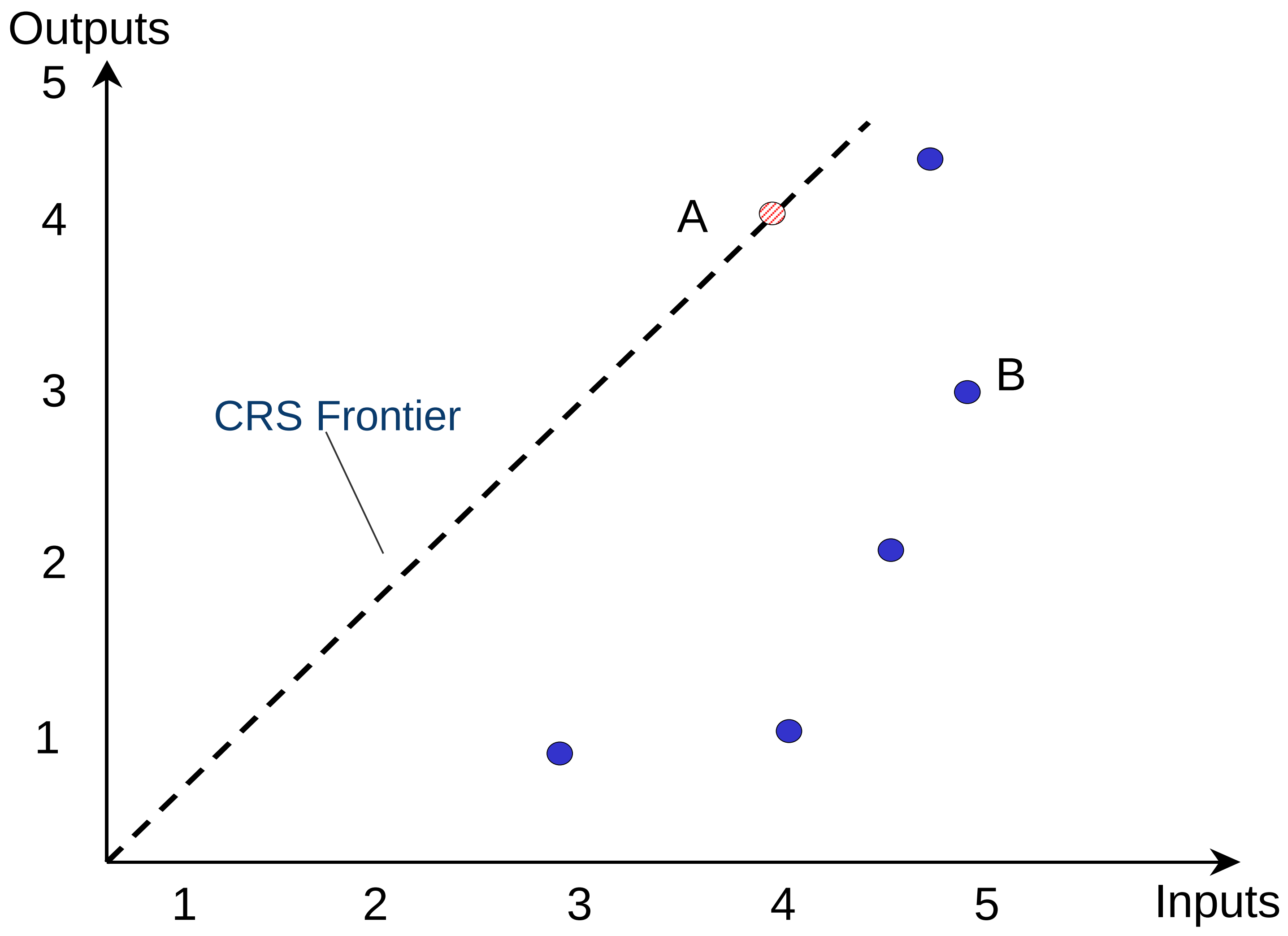
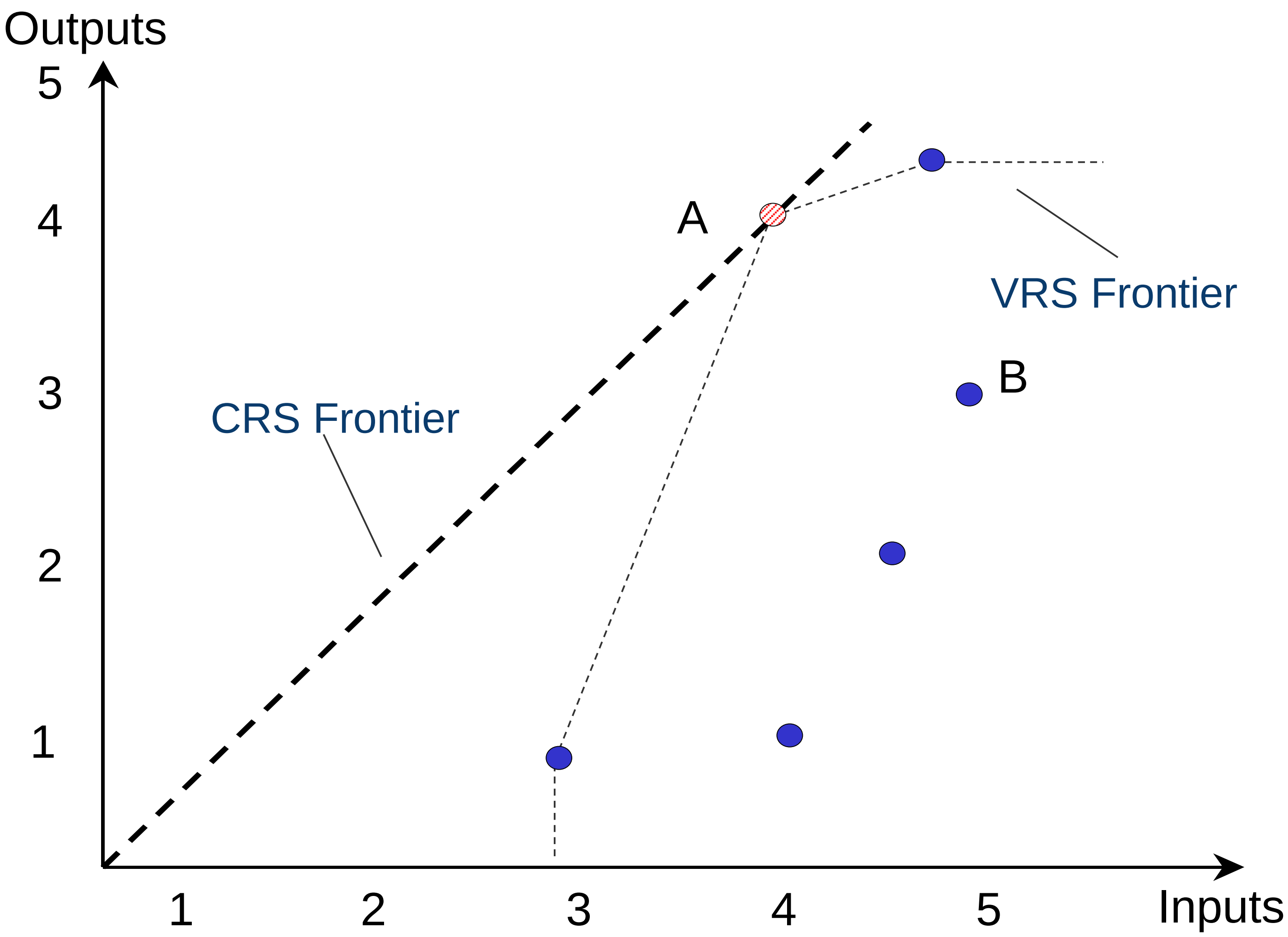
DEA (simplified 2 dimensions) – CRS frontier



DEA (simplified 2 dimensions) – VRS frontier



Tariff Productivity Improvement Advice for the Electricity Sector – Jamaica

Part 5 - Application of efficiency score to the revenue-cap

Kingston, 5-6 February 2017

Dr. Viren Ajodhia

Dr. Konstantin Petrov

New price control formula

Revenue Surcharge based on True-Up Mechanism

Interest

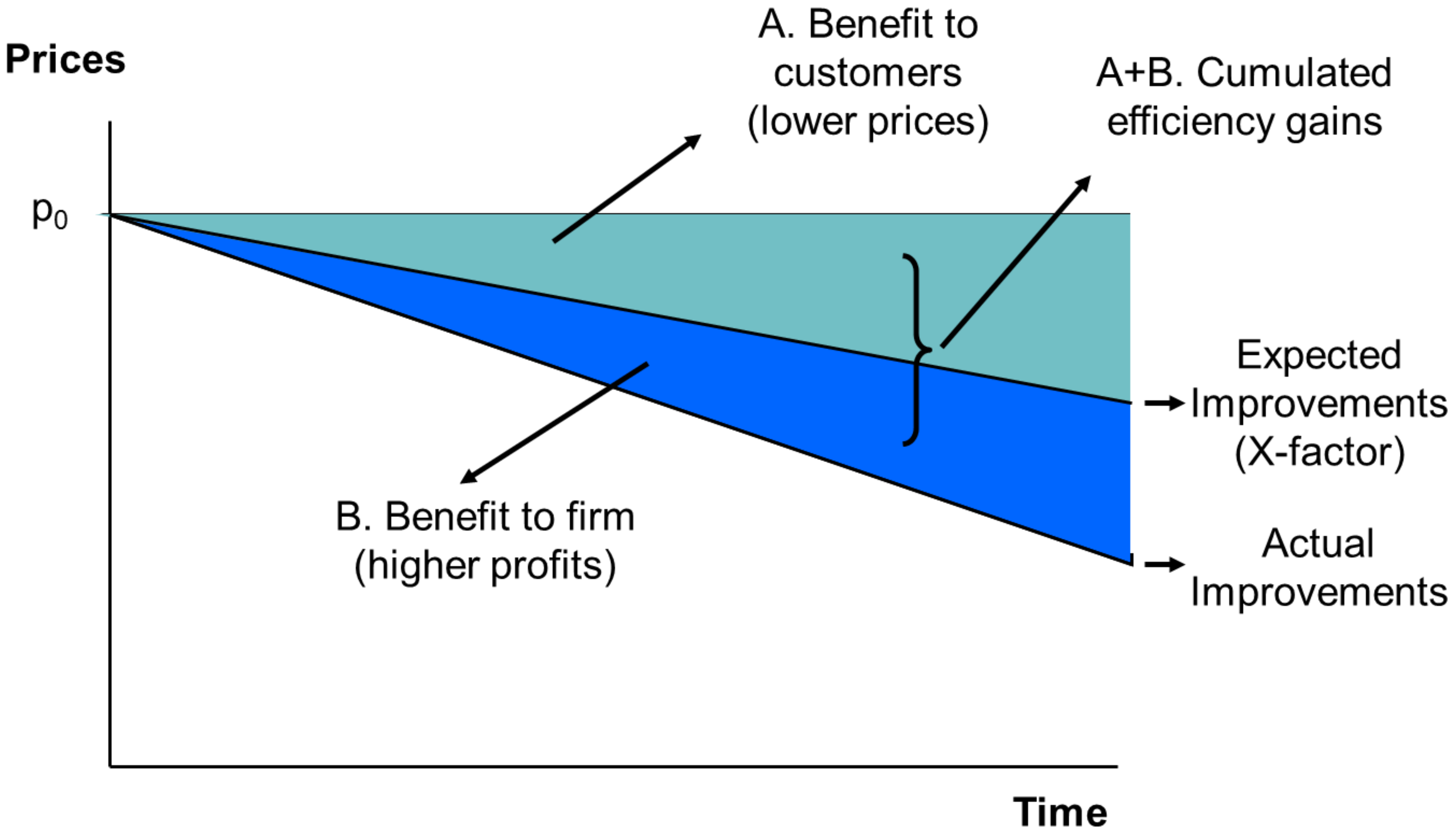
$$ART_y = RC_y(1 + dPCI) + \left(RS_{y-1} + SFX_{y-1} - SIC_{y-1}\right) * (1 + WACC)$$

Switch to Revenue Cap, Adjustment of Growth Rate

Foreign Exchange

$TUVol_{y-1}$ = {(kWh $Target_{y-1}$ - kWh $Sold_{y-1}$)/ kWh $Target_{y-1}$ }*Non Fuel Rev Target for Energy Rev_{y-1}+{(kVA $Target_{y-1}$ - kVA $Sold_{y-1}$)/ kVA $Target_{y-1}$ }*Non Fuel Rev Target for Demand Rev_{y-1}+{(# of Customer charges billed $Target_{y-1}$ - # of Customer charges billed Act_{y-1})/ # of Customer charges billed $Target_{y-1}$}*Non Fuel Rev Target for Customer Charges Rev_{y-1}

X-factor can be explicit or implicit

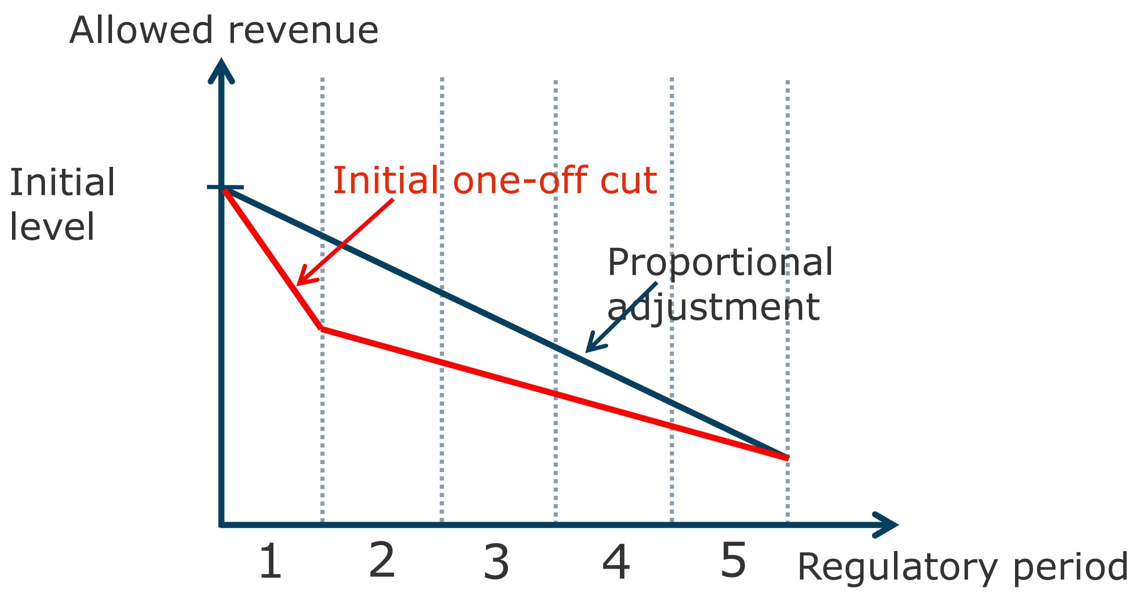


Policy decisions in implementing productivity targets (implicit X-factor)

- The starting level of the opex
- The efficient level of this starting opex, expressed in a percentage
- The period over which this efficient level will be achieved
- Incorporate demand growth

Starting opex

- Different options are possible
- Use historic opex has risk of ratchet effect
- Option to include a one-off cut
- Multi-year average can produce more stable base



Efficient level of starting opex (long-term target)

- Opex levels should move from current levels to the perceived efficient level
- What efficient opex is, can be identified through benchmarking
- Some degree of subjectivity will play a role

Time-path for achieving long-term target

- Benchmarking helps to develop view of efficient opex, but this can only be achieved after time
- Annual opex allowances need to take this into account
- Long-term efficiency target to be achieved over predefined period
- Results in a cap on the annual X-factor

Incorporation for demand growth

- Under a revenue-cap framework, opex allowances need to incorporate expected demand growth
- To assure consistency with the revenue correction mechanism, setting of opex levels should consider the three demand types
  - Sales (kWh)
  - Demand (kW)
  - Customers
- Risk of underestimating demand growth rates as this will increase the difference between outturn and forecast demand
  - Mitigated by strict scrutiny of demand projections

For more information please free to contact:

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