Quantitative Methods in Transport

Lecture 6: The Econometric Approach to Efficiency Analysis. Application: Economic Regulation

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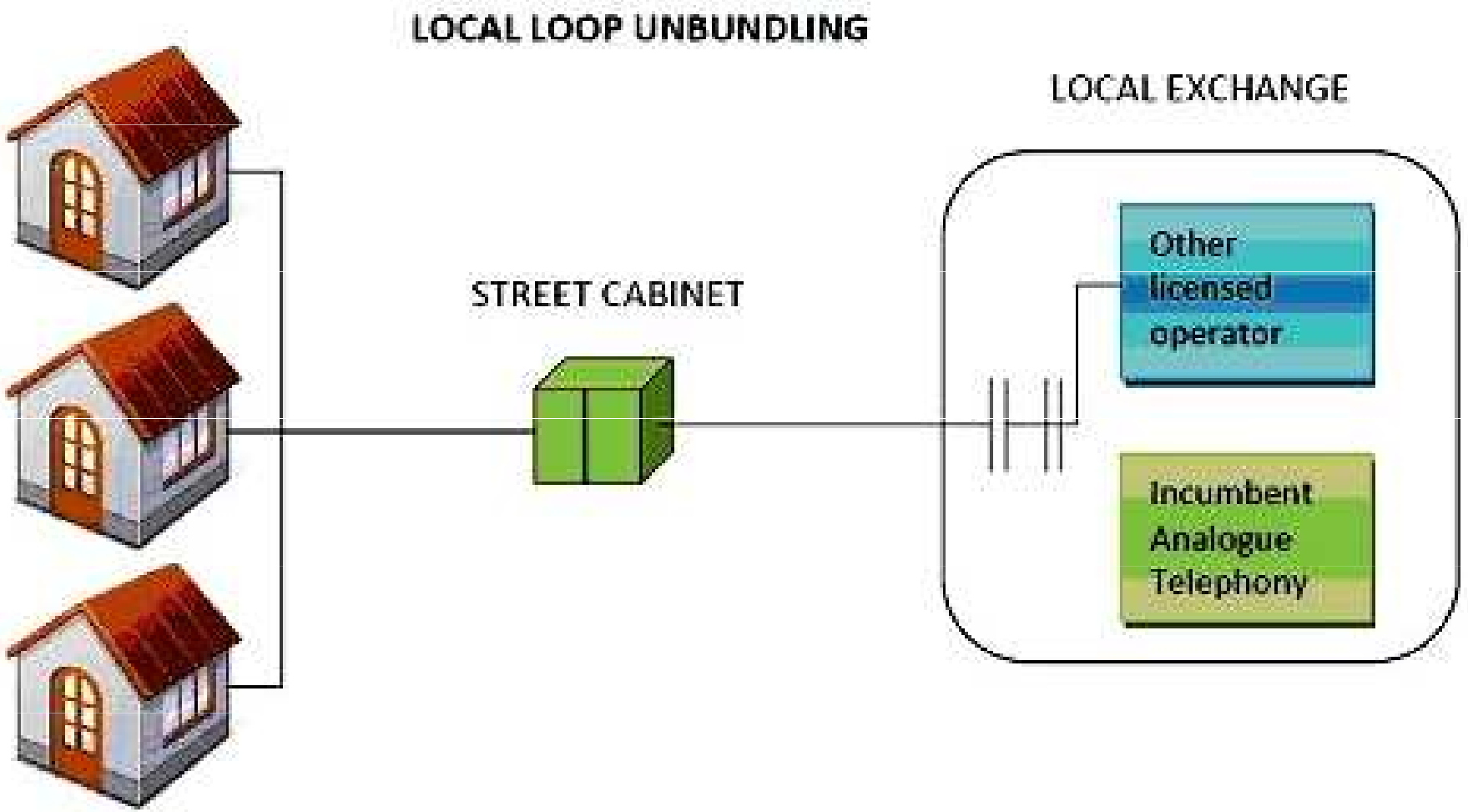
Telecoms



Source: http://images.huffingtonpost.com/2012-11-05-localloopunbundling.jpg

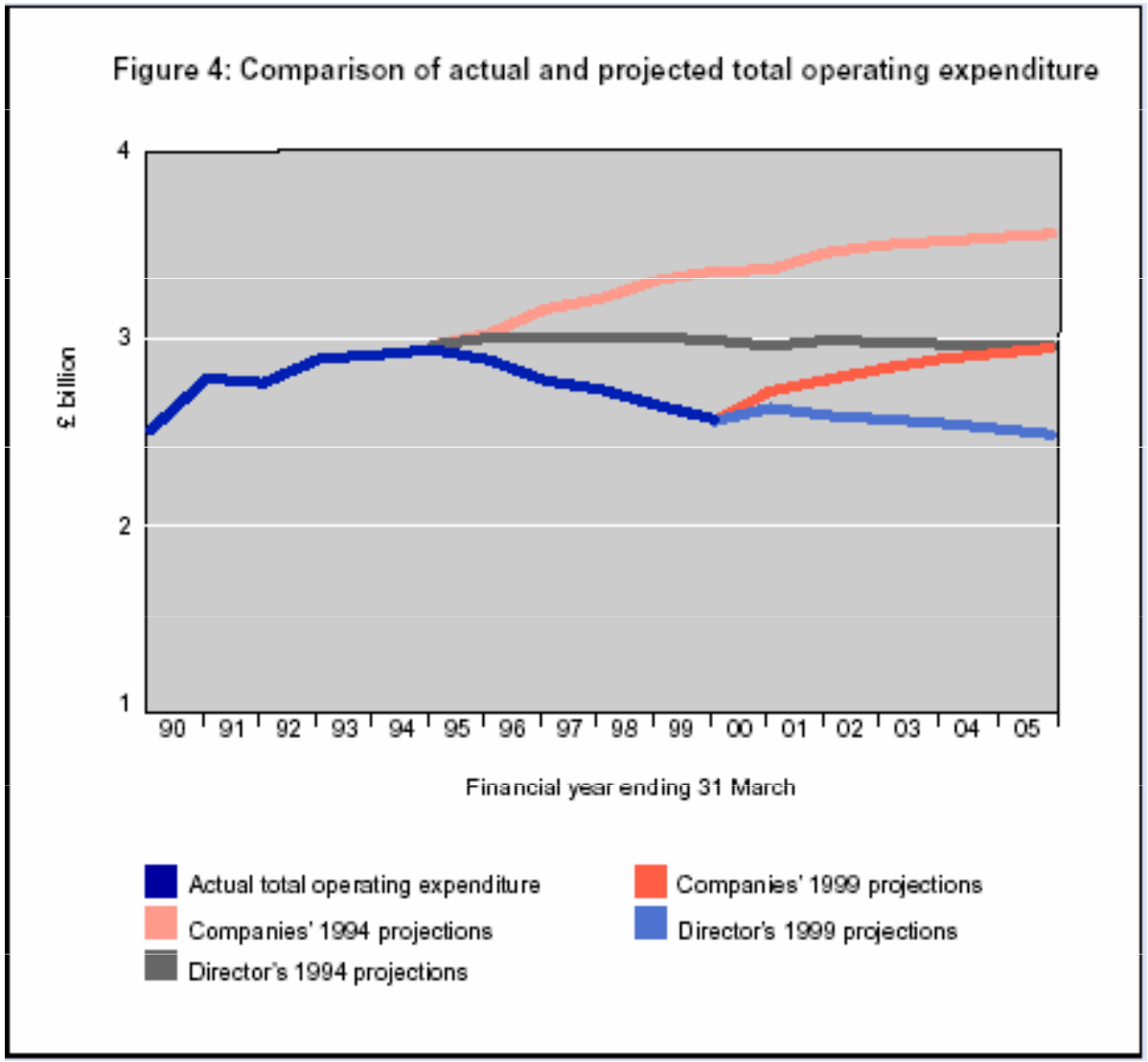
Example: regulating incumbent telecoms provider

- **What sorts of things would you want to regulate?**

So what's the problem?

- **Asymmetry of information**. Firms know more than regulators
- Efficient level of costs?
- If had perfect information, economic efficiency could be achieved
- Though still problem of pre-commitment, regulatory capture and regulatory burden

Can firms fool the regulator?



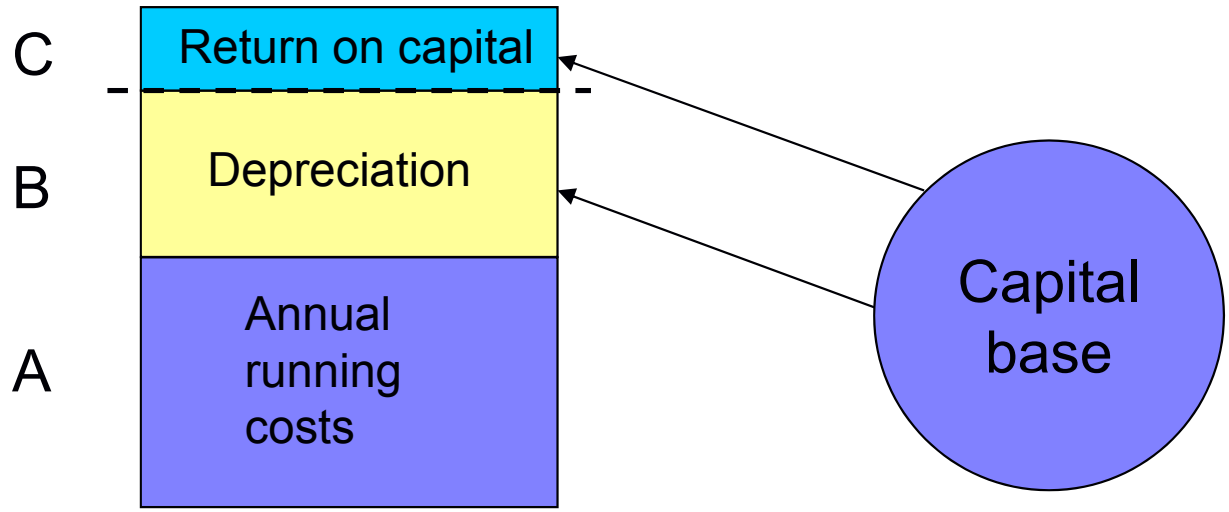
Two broad choices

- “Rate of return regulation”; or
- Price-cap regulation (or RPI-X).

Rate of return regulation (ROR): intro

For each period T…..

Allowed Revenue
= A + B + C



Rate of return regulation: example

	North Carolina Natural Gas Corporation		
$000	Year Ended Dec-31 19xx	Rate Increase Adjustments	Final Position
Revenues	**29,572**	**2,832**	**32,404**
Costs			
Purchased gas	19,412		19,412
Labour	2,968		2,968
Depreciation	1,235		1,235
Taxes	4,338	358	4,696
	27,953		**28,311**
Net operating income	**1,619**		**4,093**
Capital base			
Fixed capital (net of depreciation)	41,871		41,871
Working capital	1,003		1,003
	42,874		**42,874**
Rate of return	3.78%		9.55%

Source: Viscusi, et. al. (1992 (page 358)

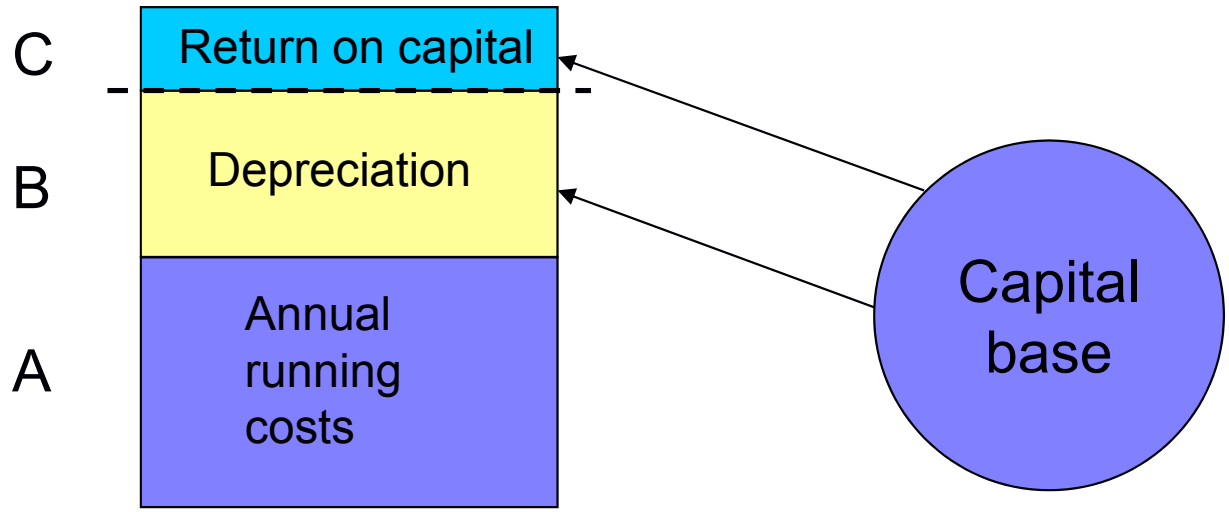
Incentive effects of ROR regulation

- Two basic issues with ROR regulation
- One is subtle
- The other more obvious
- Lets start with the “obvious” one

Rate of return regulation (ROR)

For each period T…..

Allowed Revenue
= A + B + C



Incentives to control costs (productive efficiency)?

Implications for profitability (and more widely allocative efficiency)?

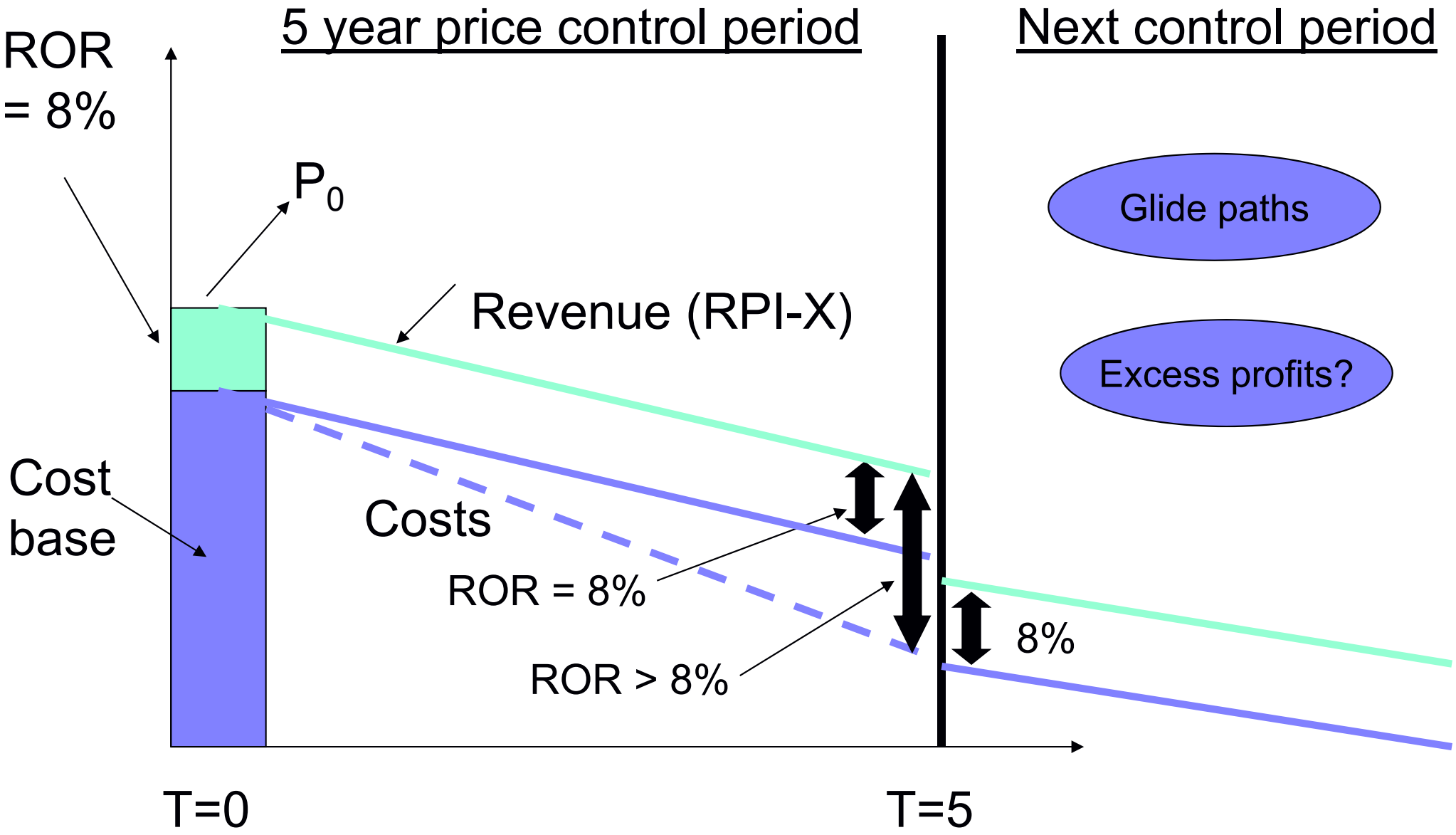
Price cap regulation (or RPI-X regulation)

Opposite end of the spectrum to ROR regulation

For period T, set $p = \bar{c}$ ⟸ Benchmark cost level

- Now what are the implications for cost control (productive efficiency)?
- And profitability (and more widely allocative efficiency)?
- Note: price caps usually set for five years
- Prices rise by RPI less an X factor (RPI-X)

Graphically…



UK Electricity Distribution
Price Controls

30% of electricity bills

About £3 billion per year

1990/91-1994/95	Prices up 2.5% above inflation
1995 – 1995/96	Cut of 14% (one-off price change)
1996 – 1996/97	Cut of 10-13 (one-off price change)
1997 to 2000	3% per annum fall
2000 to 2004/05	One off fall of 23%; then 3% per annum fall

Source: Jamasb and Pollitt (2007). Table 3

Impact of RPI-X more generally

Control period	Savings per year
First	2.2%
Second	6.8%
Third	6.3%
Fourth	3.4%
Fifth	2.6%

OXERA (April 2008), *Network Rail's scope for efficiency savings in CP4: prepared for Office of Rail Regulation*, London (http://www.rail-reg.gov.uk/upload/pdf/pr08-oxeraeffic-160408.pdf)

So how to determine efficient costs?

- Efficient costs determination is central to RPI-X regulation
- Why not just compare unit costs across companies and set efficient costs that way?
- This is a common question, particularly from industry

A starting point for measuring efficiency – unit costs or KPIs

Unit cost measures widely used as a starting point

KPIs – Key performance indicators

Cost per track km

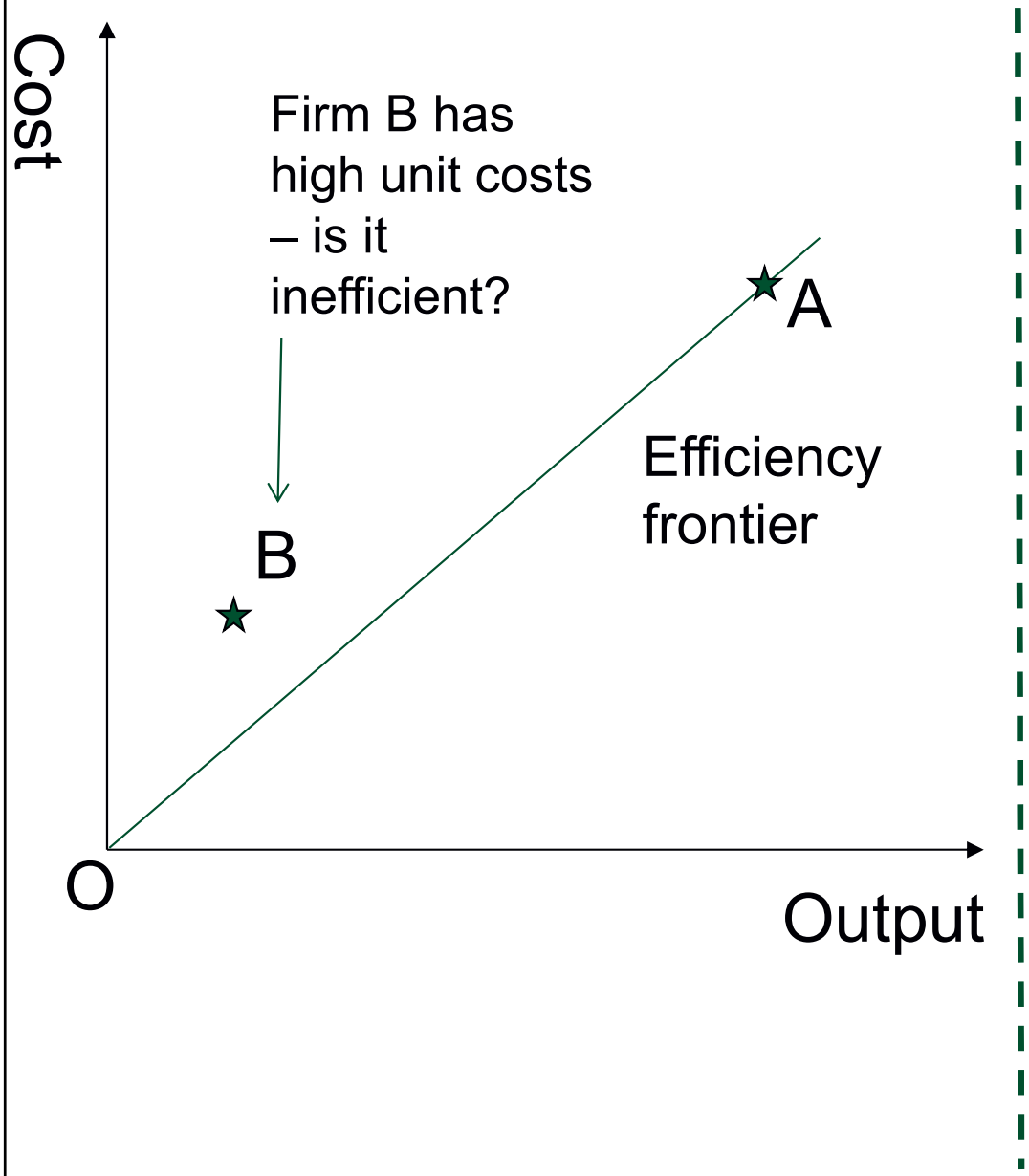
Cost per train km

Problem: which denominator to use?

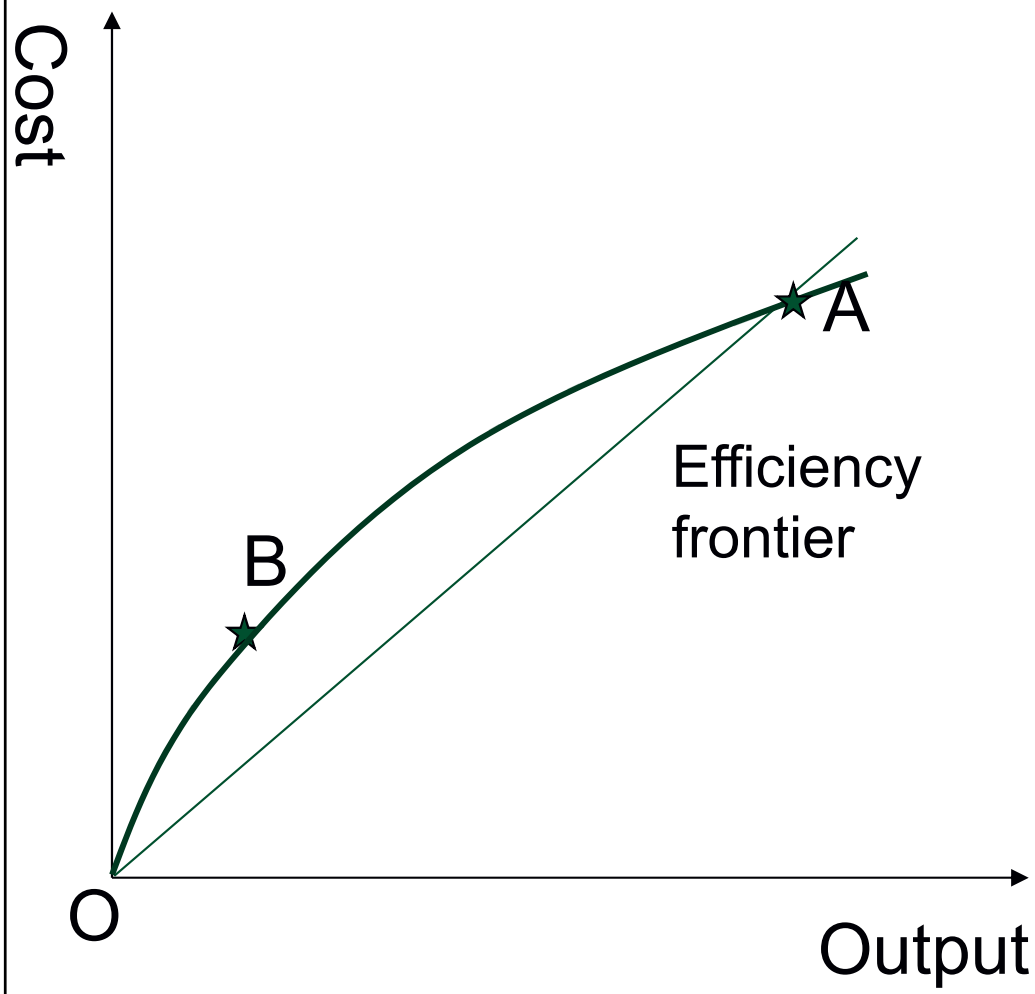
Econometric methods give a **single measure** of efficiency that **simultaneously** takes account of variation in train-km and track-km (and other cost drivers)

An added and key benefit of econometric methods: important information on scale / density economies

Why a statistical / econometric model?



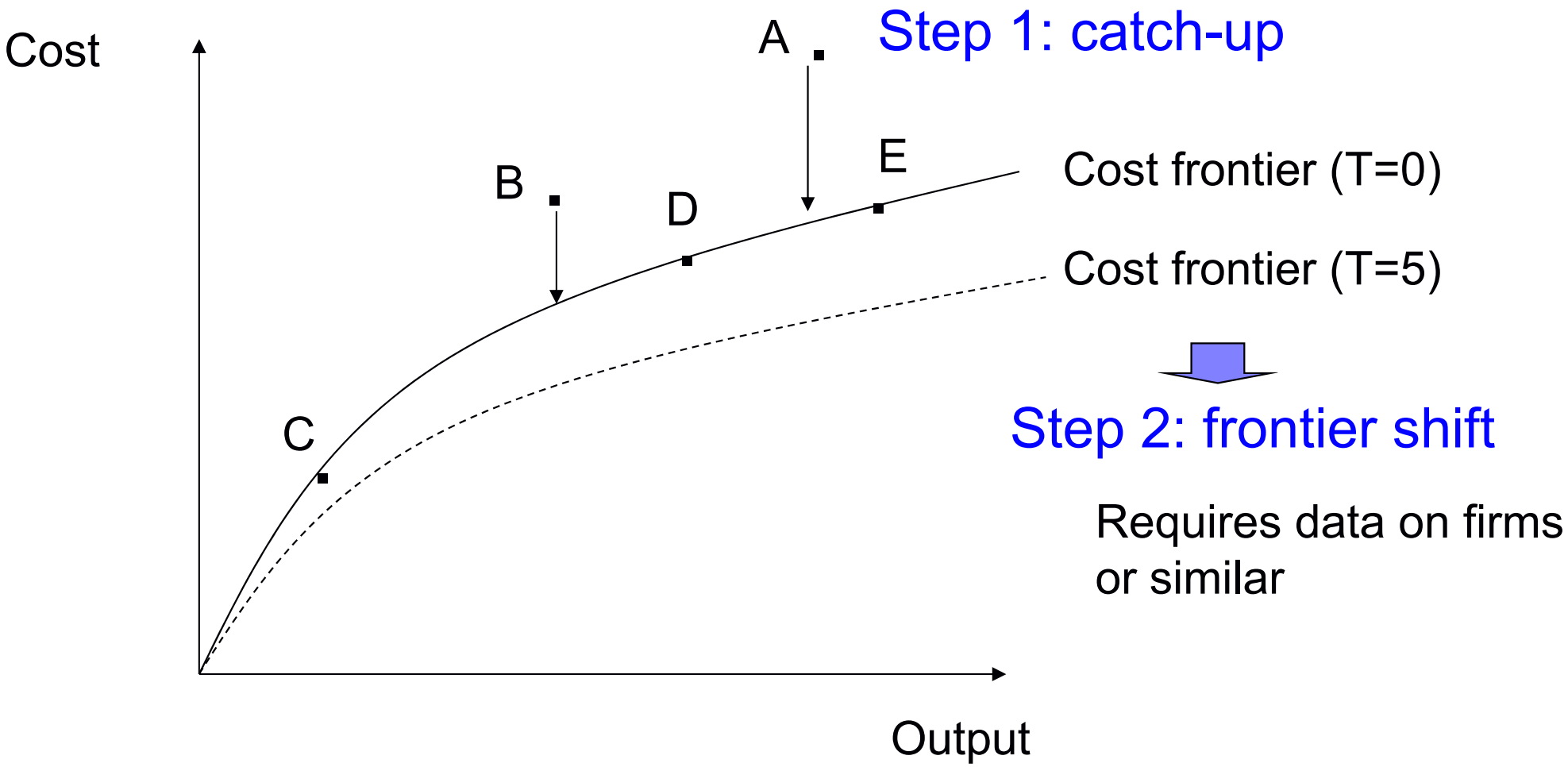
Why a statistical / econometric model?



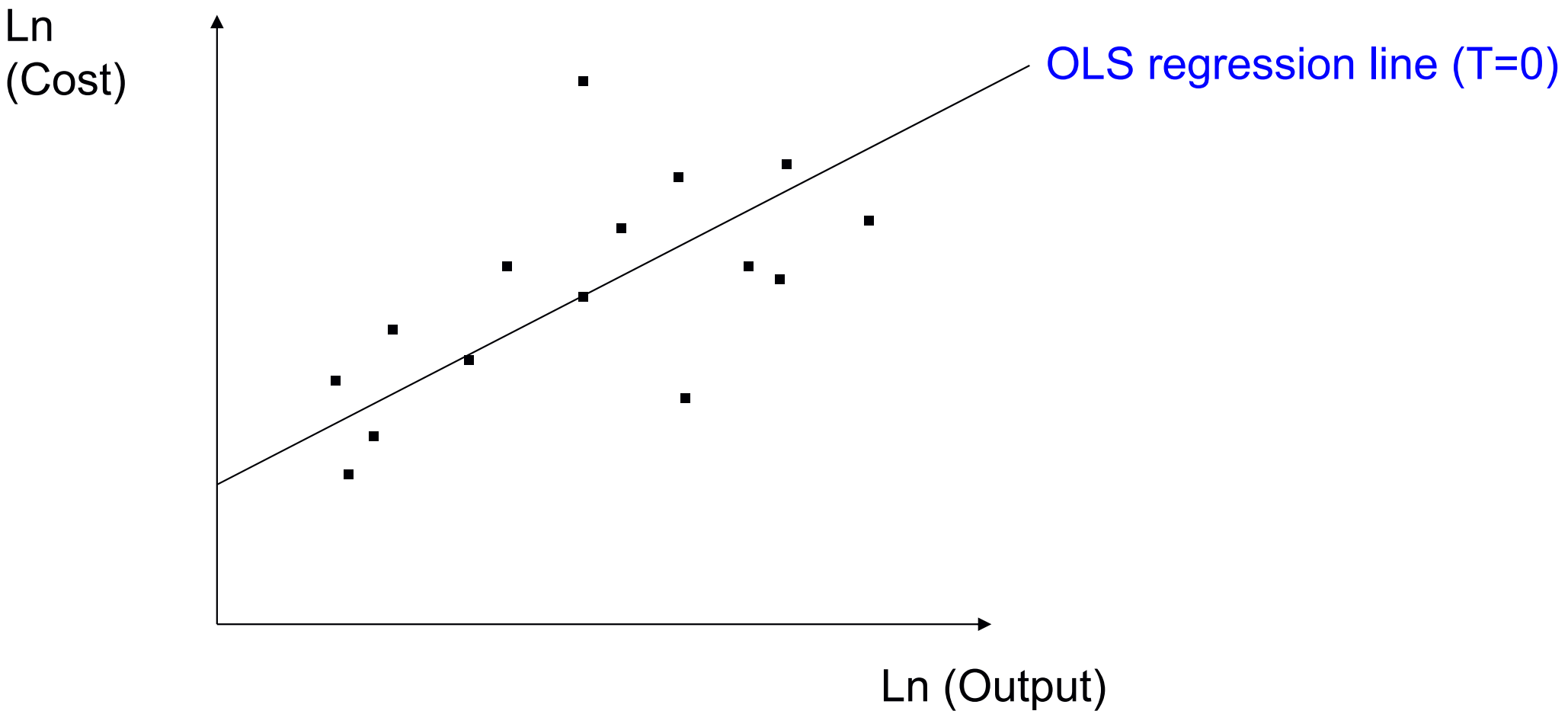
- Allow flexible shape of the cost-output relationship (e.g. allow for possible scale / density economies)
- Allow multiple outputs / other cost drivers (e.g. train and track-km)
- So we can explain costs in terms of a set of explanatory factors, e.g.
  - Network size; traffic density and type; other (e.g. electrification; multiple track); potentially, others…
- Having accounted for these factors, and random noise, produce an **overall measure of efficiency**

Yardstick Competition Approach: Overview

Regulator eliminates inter-company efficiency differences

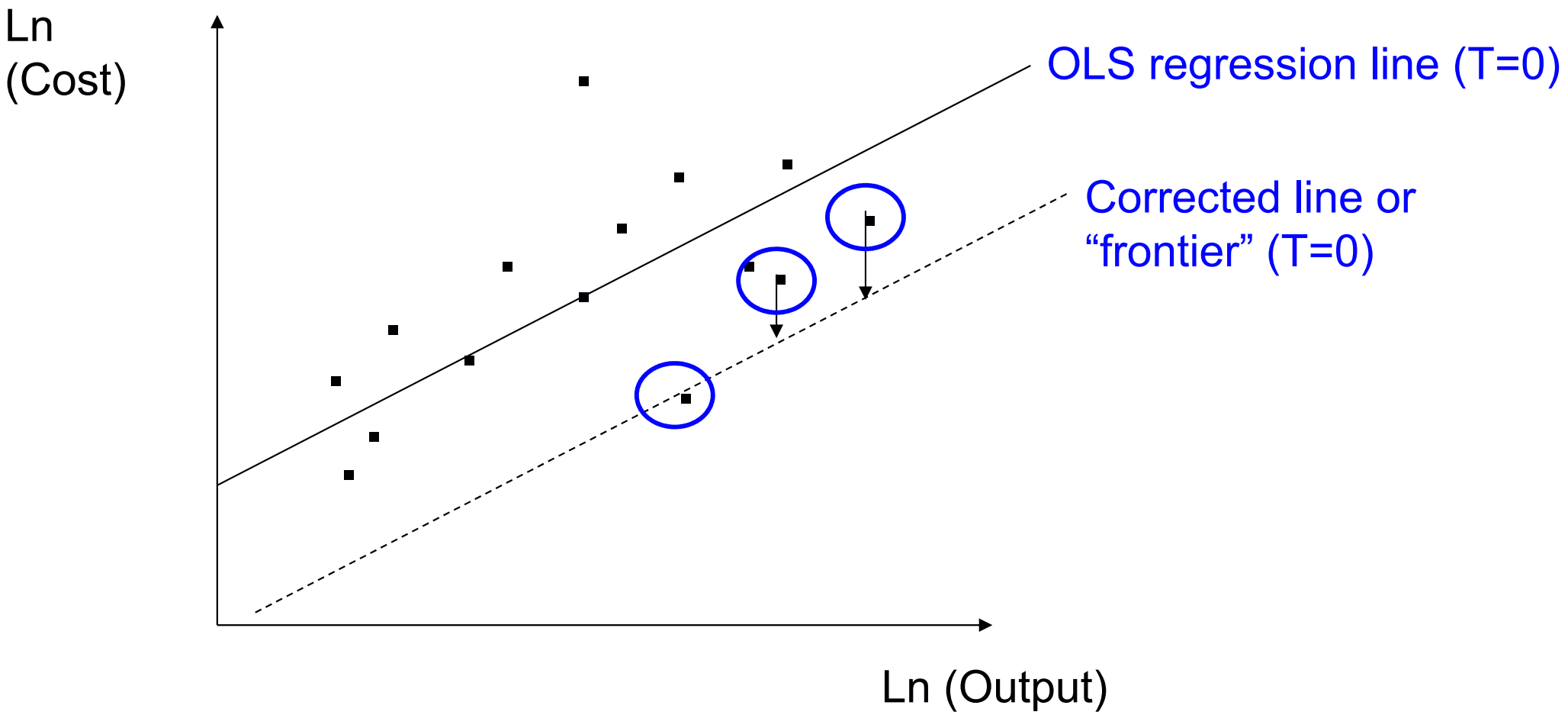


How do we draw the frontier?



What's wrong with this approach?

How do we draw the frontier?



Method referred to as COLS (corrected OLS)

More complex approach of stochastic frontier estimation also used

COLS example

See spreadsheet

Stochastic Frontier Model

Decompose error into inefficiency and random noise

Now have a stochastic frontier:

$$C_i = \underbrace{f(Y_i, P_i; \beta)}_{\text{Deterministic Frontier}} + \underbrace{v_i}_{\text{Noise}} + \underbrace{\mathrm{u}_i}_{\text{Inefficiency}}$$

$$\underbrace{\qquad\qquad\qquad\qquad\qquad\qquad}_{\text{Stochastic Frontier}}$$

Each firm has its own frontier comprising a deterministic component and an unexplained (random) component

Distributional assumptions

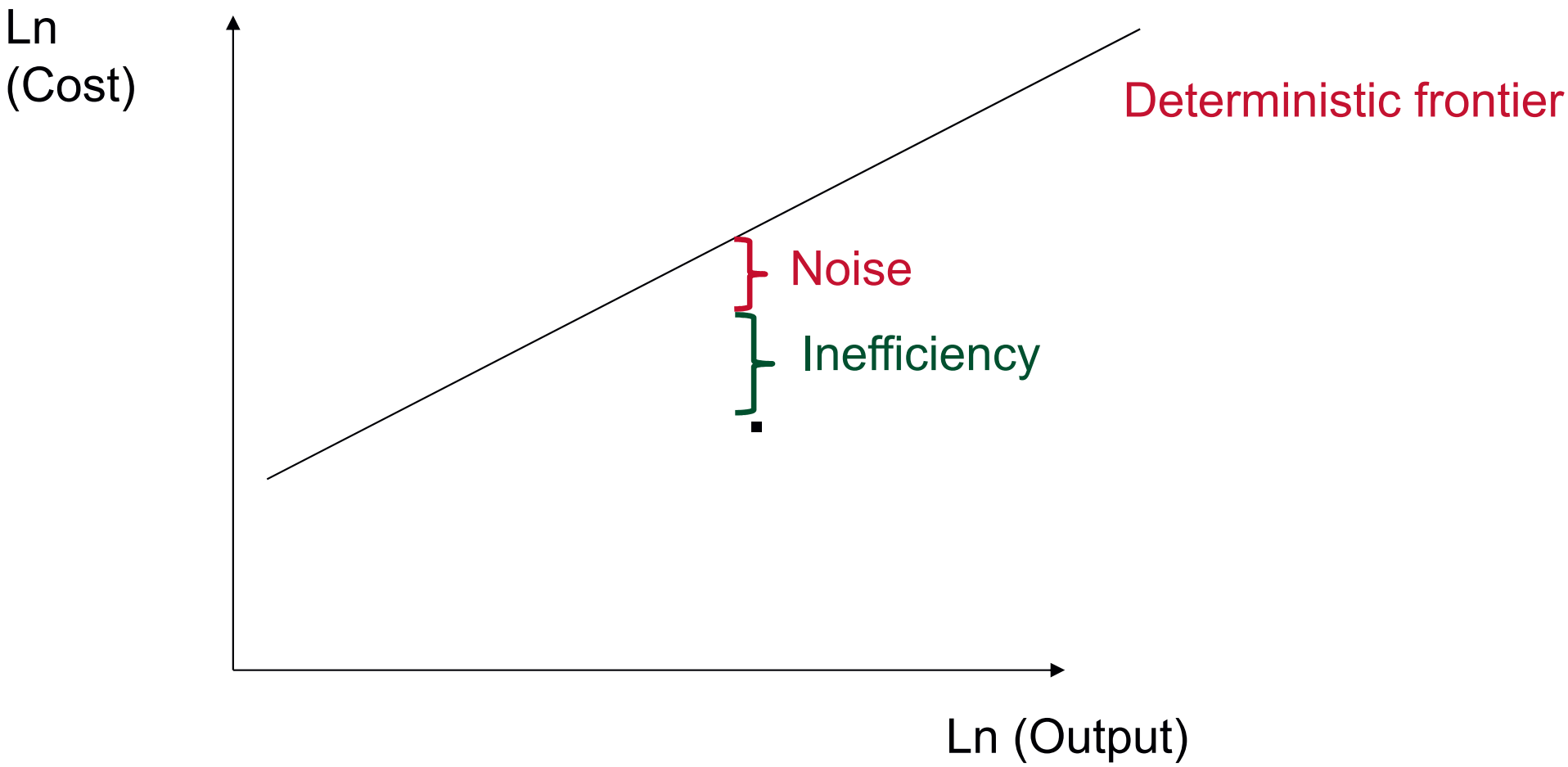
$$u_i \sim \left| N\left(0, \sigma_u^2\right) \right|$$

$$v_i \sim N(0, \sigma_v^2)$$

So v_i is the standard noise term in a standard OLS model (normally distributed)

u_i is (in the standard SFA model) assumed to be half normal

SFA diagram


Ln
(Cost)
Deterministic frontier
Noise
Inefficiency
Ln (Output)

Firm specific efficiency scores

We get an estimate of inefficiency (u_i) as from the distribution of u_i conditional on the overall error term

The expected (or mean) value is one such reasonable estimate to take from that distribution

$$E(u_i / \varepsilon_i)$$

Key features of the SFA model

The model “decomposes” the error term in random noise and inefficiency

However, it does require the imposition of (arbitrary) distributional assumptions to achieve this (at least in cross-sectional data)

Assumes noise and inefficiency uncorrelated with the regressors

The SFA model nests the OLS model – thus we can test the presence of inefficiency effects via a Likelihood ratio test

If the distributional assumptions are correct the model improves the “efficiency” with which the frontier parameters are estimated (more precise)

Worked example [1]

See example handout

Note likelihood ratio test for the presence of inefficiency:

LL OLS = 11.96346

LL SFA = 13.59530

LR statistic = 2* (13.59530-11.96346) = 3.264

5% critical value of this mixed Chi-squared distributions = 2.71

So we **reject the null hypothesis of no inefficiency effects**

Worked example [2]

See spreadsheet

Note the differences between the means and the standard deviations of the COLS and SFA efficiency scores

Note the differences in scores for individual firms

Note SFA shrinks the size of the variation in the data – but it does not overturn the rankings implied by the underlying residuals

Adapting panel data techniques for efficiency analysis

$$C_{it} = f(Y_{it}, P_{it}, N_{it}, \tau_t; \beta) + c_i + \varepsilon_{it}$$

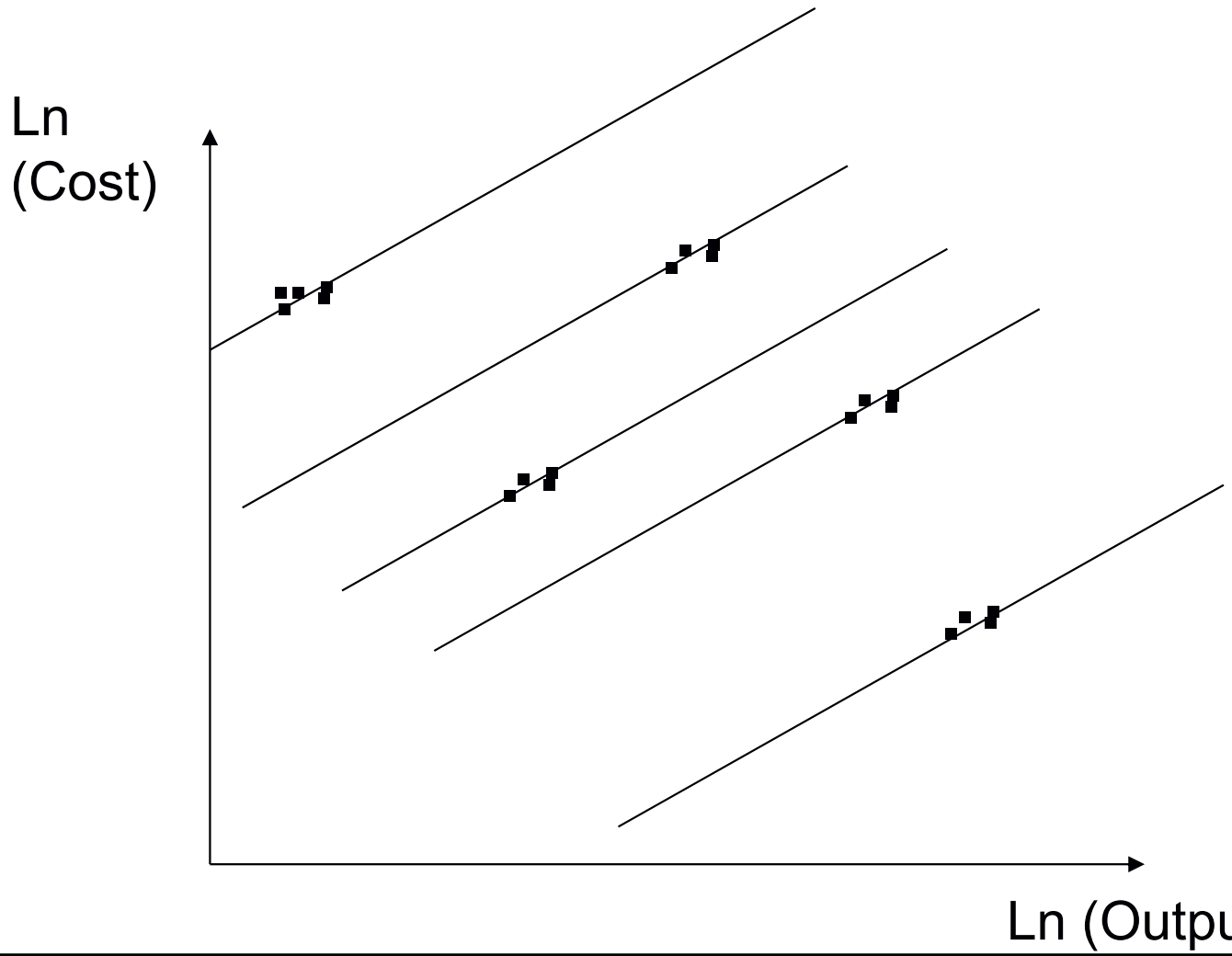
Standard Panel: c_i is unobserved heterogeneity; can be estimated by fixed (FE) or random effects (RE)

$$C_{it} = f(Y_{it}, P_{it}, N_{it}, \tau_t; \beta) + c_i + \varepsilon_{it}$$

Schmidt and Sickles (1984): c_i re-interpreted (time invariant inefficiency)

Usually we have panel data

If we have 18 water companies and 7 years = 126 data points – OLS treats these as 126 independent data points



Panel models include a **firm-specific effect**:

- Either a fixed effect (firm effect can be correlated with the other variables)

- Or a random effect (firm effect is assumed uncorrelated with the other variables)

Example: Rail
International benchmarking study

- Panel data:13 European countries over 11 years
- Used by International Union of Railways (UIC) in its benchmarking
- Standard definitions – to an extent

Cost Data	Network Size	Final Outputs	Network Characteristics
Maintenance costs	Track kilometres Route kilometres	Passenger train kilometres	Ratio of single track to route kilometres (as a measure of the extent of single / multiple track)
Total costs (Maintenance + renewals)	Single track kilometres	Passenger tonne kilometres	Proportion of track electrified
	Electrified track kilometres	Total tonne kilometres	Number of stations per route km
		Freight train kilometres	Number of switches per track km
		Freight tonne kilometres	
		Total train kilometres	

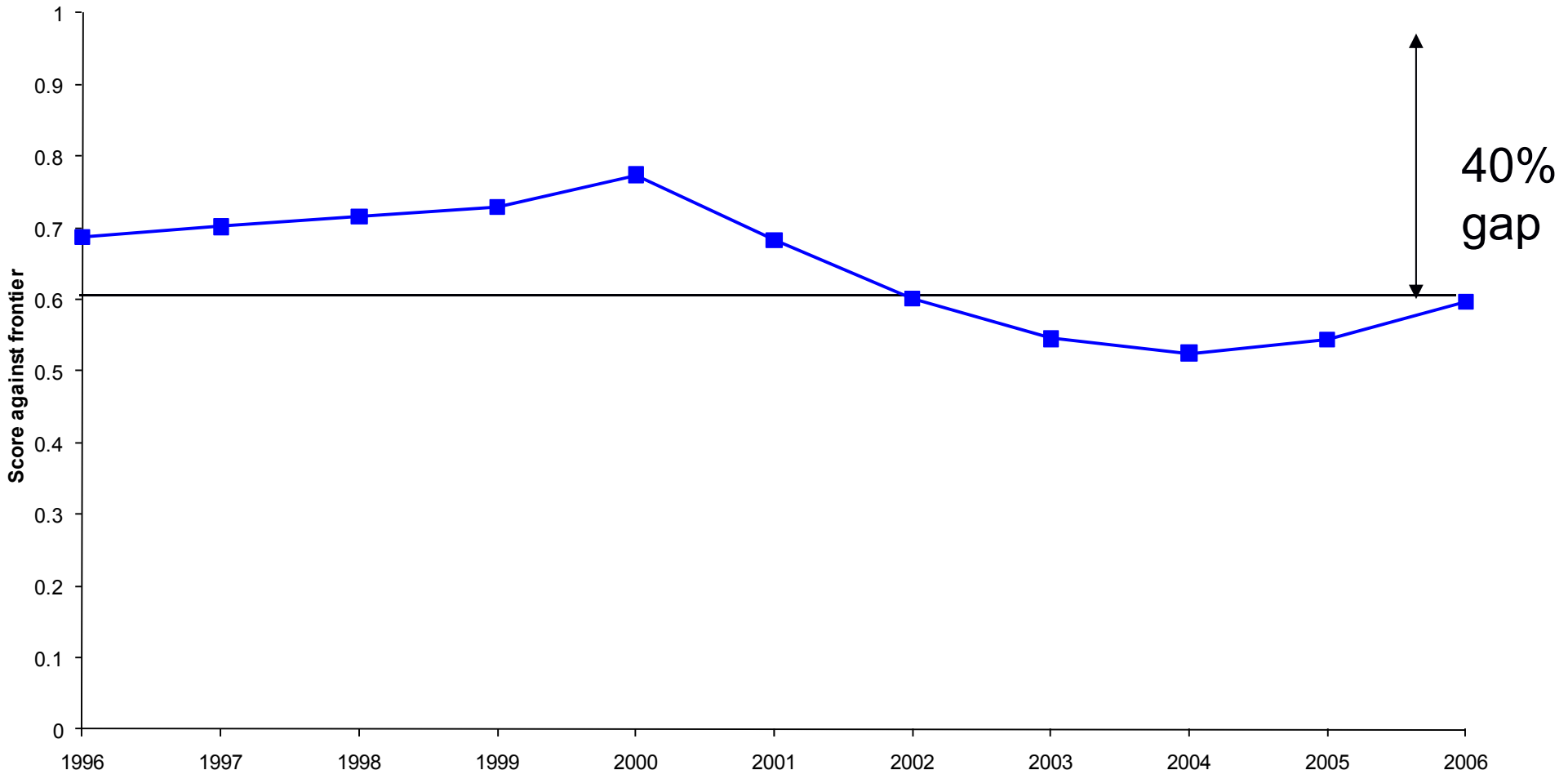
International benchmarking study: national data – frontier parameters

Preferred model Dependent variable: Total costs (steady-state adjusted)	Coeff.		**Comparator model** Dependent variable: Total costs (unadjusted)	Coeff.		**Comparator model** Dependent variable: Maintenance costs	Coeff.	
Frontier parameters								
CONSTANT	6.2453	***	CONSTANT	6.2382	***	CONSTANT	5.4770	***
ROUTE	1.0743	***	ROUTE	1.0913	***	ROUTE	0.8430	***
PASSDR	0.3345	***	PASSDR	0.3115	***	PASSDR	0.1362	**
FRDR	0.1792	***	FRDR	0.1472	***	FRDR	0.1567	***
SING	-0.9181	***	SING	-0.9681	***	SING	-0.7146	***
ELEC	-0.0370		ELEC	-0.0690		ELEC	0.0733	
TIME	0.0556	***	TIME	0.0561	***	TIME	0.0469	***
TIME2	-0.0048	***	TIME2	-0.0048	***	TIME2	-0.0027	**
Efficiency parameters[1]								
λ	4.0541	***	λ	4.1810	***	λ	3.6678	***
σ_u	0.4560	***	σ_u	0.4694	***	σ_u	0.3374	***
η_{R1}	0.0585		η_{R1}	-4.5467		η_{R1}	0.1634	**
η_{N1}	0.2252		η_{N1}	0.2031	**	η_{N1}	0.2689	**
η_{N2}	-0.0570	**	η_{N2}	-0.0513	**	η_{N2}	-0.0520	***

*** (**, *) indicates parameter significance at the 1% (5%, 10%) level

[1] Other firm specific η parameters are included in the model but not shown for confidentiality reasons. $\lambda = \sigma_u/\sigma_v$

Efficiency estimates for Network Rail (Smith, 2012)

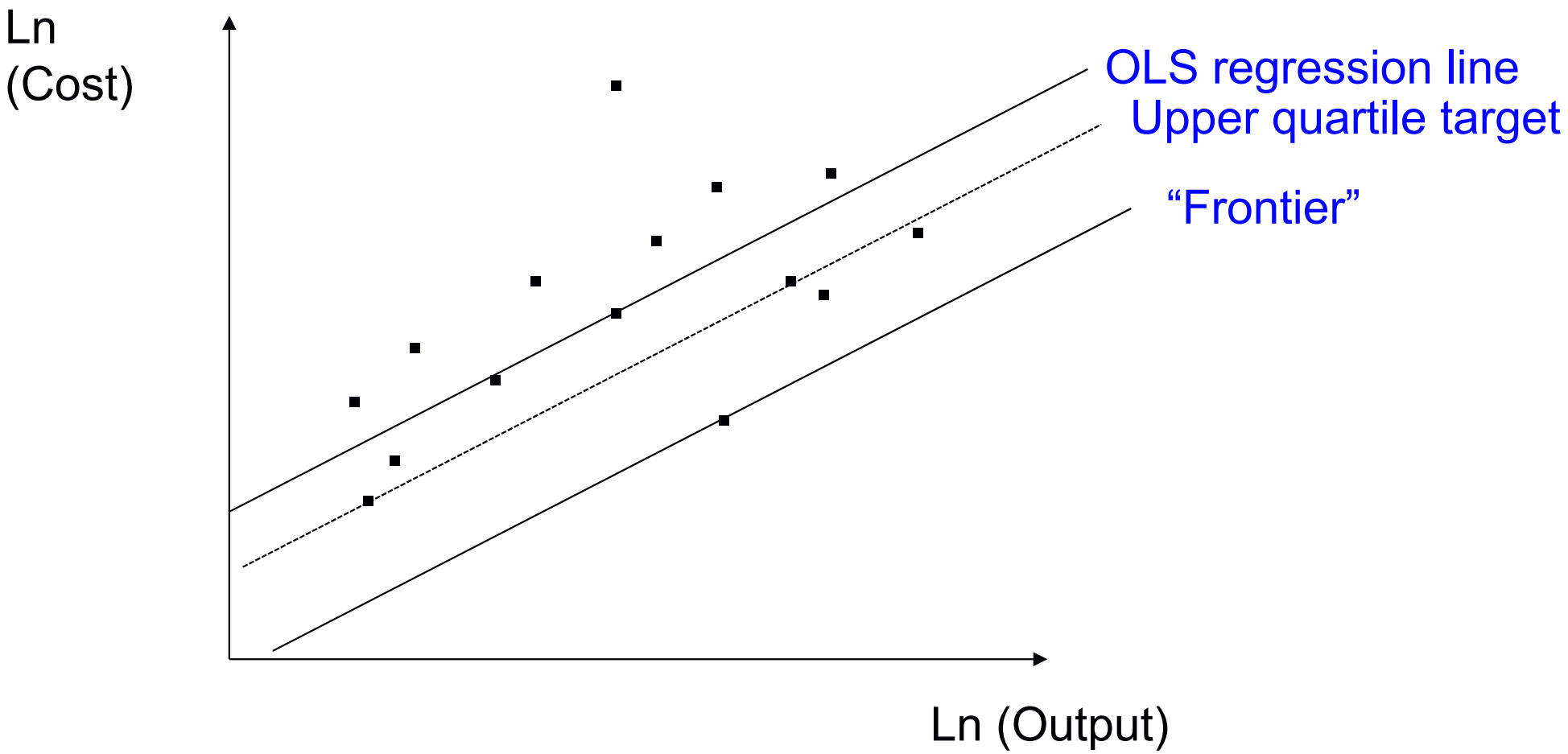


Implies a gap against the frontier of 40% in 2006

Regulatory challenges

- Do we believe the model? Will the companies accept it?
  - Eg. CMA enquiry in 2015;17 of 18 water companies accepted; 1 appeal
  - Engineering / management evidence?
  - Do different methods and specifications produce similar results? Triangulation.
- Is the data comparable between firms and over time? (international data compared to domestic?)
- Can firms reach the frontier and how quickly?
- Transparency; regulatory burden; incentives

How do we draw the frontier?



Timing: ORR also allowed the company ten years to close the gap

– so a 40% gap turned into 22% over 5 years (Smith et. al., 2010)

Concluding remarks 1

- Ultimately regulator interested in scope for efficiency gains - these drive real terms unit cost and in turn price reductions
- Benefits consumers – challenging but fair to firms
- But, Regulator faces asymmetry of information – needs methods and data to overcome this

Concluding remarks 2

- Many choices to be made in determining an econometric model / models for use in economic regulation
- It is not just a data fitting exercise – theory and engineering / business understanding are key
- Models do need to be subject to statistical testing – though not all tests necessarily have to be passed
- The model is ultimately an approximation to reality – is it credible? Data quality is key
- Is it transparent / simple?

References / readings

- Baldwin and Cave, Understanding Regulation (2012), Chapters 25 and 26
- Smith A; Wheat P; Smith G (2010) *The role of international benchmarking in developing rail infrastructure efficiency estimates, Utilities Policy, 18, pp.86-93.*
- Smith ASJ. 2012. The application of stochastic frontier panel models in economic regulation: Experience from the European rail sector. *Transportation Research Part E: Logistics and Transportation Review.* 48(2), pp. 503-51
- Coelli, T.J., Prasada, R. O'Donnell, C.J. and Battese, G.E. (2005), An Introduction to Efficiency and Productivity Analysis, Chapters 8 to 9 (chapter 10 also deals with panel SFA methods)
- Schmidt, P. and Sickles, R.C. (1984), 'Production Frontiers and Panel Data', *Journal of Business & Economic Statistics*, vol. 2 (4), pp 367-374.