Electricity Policy Research Group

UNIVERSITY OF CAMBRIDGE

Incorporating the price of quality into benchmarking UK electricity distribution

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Motivation

- Quality concern in incentive regulation
  - Ter-Martirosyan, A., (2003), *'The effects of incentive regulation on quality of service in electricity markets' (U.S.)*
    - → engenders an increase in the duration of electric outages
  - Joscow (2006), Sappington (2005), Ajodhia (2005)

- An extension of Giannakis et al's study (2005)
  - Cost-Quality Vs Cost-only benchmarking model
    - → inadequate to capture the quality aspect
    - → cost efficient firms: not exhibit high service quality

- Price for Input: Quality Dimension (CML)
  - Ofgem's survey on Customers' Willingness-to-Pay (WTP) for improvements in service
    - → Input price factor allows allocative efficiency measurement
    - → WTP to avoid 1 minute power interruption (14 DNOs - business & domestic)

Economic Significance

Trade-Off between Inputs

-Opex, Capex, Loss in distribution, Quality of Service

Economic Impact (2003/04)

- Allowed Revenue (14DNOs) : £2.9 billion
- National bill (Distribution) : £16 billion

- Capex : £1 billion
- Opex : £800 million
- Energy Loss : £551 million
- Aggregate Willingness-to-pay (WTP) (1 minute) : £40 million

- Cost of Interruption (CML:71.11minutes) : £2.8 billion

Incentive Scheme for Quality (2005/06)

- Revenue Exposure : 4% (CML, CI, Tele response)
- Max. Penalty : £120 million
- Profit Exposure : 13.9%

(in 2003/04 pounds)

Current Research

- 14 DNOs in the U.K.
- Methodology : Data Envelopment Analysis (DEA)
- Technical & Allocative Efficiency Measurement

- Benchmarking Model : Cost-Quality-Loss model
- Quality dimension : CML, Energy Loss
- Cost dimension : Totex, Opex
- Input price factors : WTP, Electricity price
- Data set : 1990/91 to 2003/04

Ofgem-Accent Customer Survey 2003/04

Customers' WTP for improvements in service

- 503 telephone interviews (Business Customers)
- 2,118 face-to-face interviews (Domestic Customers)
- Rural/Urban Breakdown by 14 DNOs
- WTP (% of bill) to reduce the average length of power cuts

Method of Survey

- Stated preference technique (conjoint research)
- Respondents are offered a series of choices between two packages
- Choose between one of the two packages in each pair
- To state the maximum amount of money that they would be willing to pay to receive this type of service rather than the service they preferred less.

Adjustment on WTP values (%) & Bill Amount

- Domestic

1. The WTP percentage of the bill for region 4 was not reported in Accent survey:
   - an average 0.3% (rural) and 0.2% (urban) of the bill → assign to SSE- Hydro and SP Distribution.
2. Target Rural/Urban Breakdown (table 9, p9) in Accent's report → reach the weighted-average of WTP.

- Business

1. DNO NEDL, WPS S Wales indicating zero as WTP in appendix → filled out with an average WTP (% of bill) of the regions they belong to
2. The WTP (% of bill) of SSE Hydro and SP Distribution → based on the regional figure (table 47, p49, Accent report)

Remark:

- Assumption : WTP % is consistent over the years (1990/91-2002/03) → based on WTP % in 2003/04
- WTP in £ : Bill amount * WTP (%)
- Bill amount : Unit of Energy delivered (By DNO) * Average electricity price (by DNO)

Estimation of WTP (£) 2003/04 – Domestic

- Domestic WTP to avoid one minute power interruption per year

DNO	OFGEM Survey Est. annual Bill (£)	OFGEM Survey Rural WTP (% of bill)	OFGEM Survey Urban WTP (% of bill)	Weighted avg WTP (% of bill)	Weighted avg WTP (£)	No of Customer (Thousand)	Total Domestic WTP (£)
-	(1)	(2)	(3)	(4)	(1) *(4)=(5)	(6)	(5)*(6)=(7)
EDFE EPN	326.58	0.30%	0.20%	0.23%	0.75	3083	230,5678
CN East	336.81	0.30%	0.20%	0.25%	0.84	2253	1,881,906
EDFE LPN	506.18	0.00%	0.20%	0.20%	1.01	1917	1,940,694
SP Manweb	383.73	0.30%	0.20%	0.23%	0.89	1334	1,182,479
CN West	408.39	0.30%	0.20%	0.25%	1.03	2165	2,228,094
CE NEDL	346.22	0.30%	0.20%	0.23%	0.79	1399	1,104,201
UU	313.08	0.30%	0.20%	0.23%	0.73	2132	1,548,569
EDFE SPN	363.3	0.30%	0.20%	0.22%	0.81	1916	1,559,225
SSE Southern	326.92	0.30%	0.20%	0.24%	0.80	2527	2,015,601
WPD S Wales	398.9	0.30%	0.20%	0.23%	0.91	1075	981,992
WPD S West	373.41	0.30%	0.20%	0.26%	0.98	1466	1,434,238
CE YEDL	394.1	0.30%	0.20%	0.23%	0.91	2060	1,875,713
SSE Hydro	569.55	0.30%	0.20%	0.27%	1.51	615	928,224
SP Distribution	396.82	0.30%	0.20%	0.25%	0.98	1818	1,789,119
Total:							22,775,733

Survey: OFGEM report – Consumer Expectations of DNOs and WTP for Improvements in Service (Report June 2004) 145f/04 (prepared by Accent Marketing & Research, London)

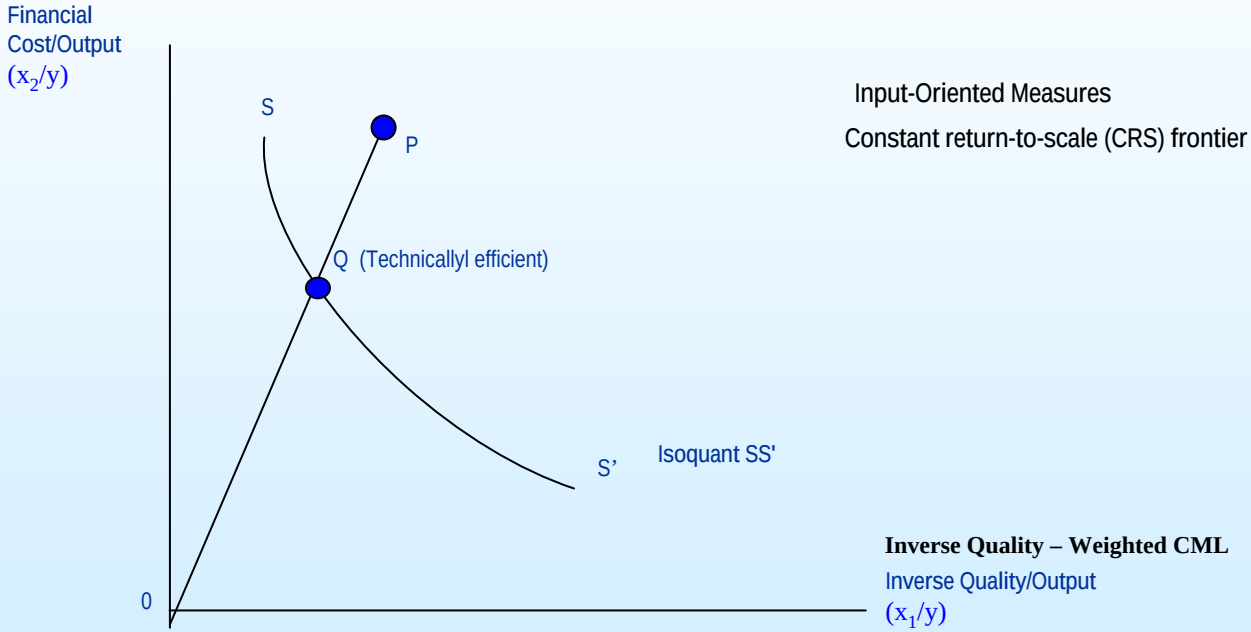
Estimation of WTP (2003/04) - Business

- Business WTP to avoid one minute power interruption per year

DNO	Region	Business annual Bill Estimation	Business WTP	Total WTP amount
-	No.	(£)	% of bill	(£)
-	-	(1)	(2)	(1)*(2)=(3)
EDFE EPN	2	903,104,207	0.10%	903,104
CN East	3	805,797,396	0.18%	1,450,435
EDFE LPN	-	1,408,862,609	0.12%	1,690,635
SP Manweb	1	462,115,139	0.24%	1,109,076
CN West	3	806,925,027	0.13%	1,049,003
CE NEDL	3	532,619,662	0.18%	958,715
UU	3	745,614,656	0.22%	1,621,712
EDFE SPN	2	612,890,962	0.15%	888,692
SSE Southern	2	535,323,555	0.19%	1,017,115
WPD S Wales	1	396,435,884	0.27%	1,050,555
WPD S West	1	462,253,635	0.29%	1,340,536
CE YEDL	3	726,708,274	0.38%	2,761,491
SSE Hydro	4	252,070,979	0.16%	403,314
Total				17,489,272

Based on Ofgem's customer Survey 2003/04 (Appendix)

Technical & Allocative Efficiencies



Economic Efficiency

TE = OQ / OP [1]

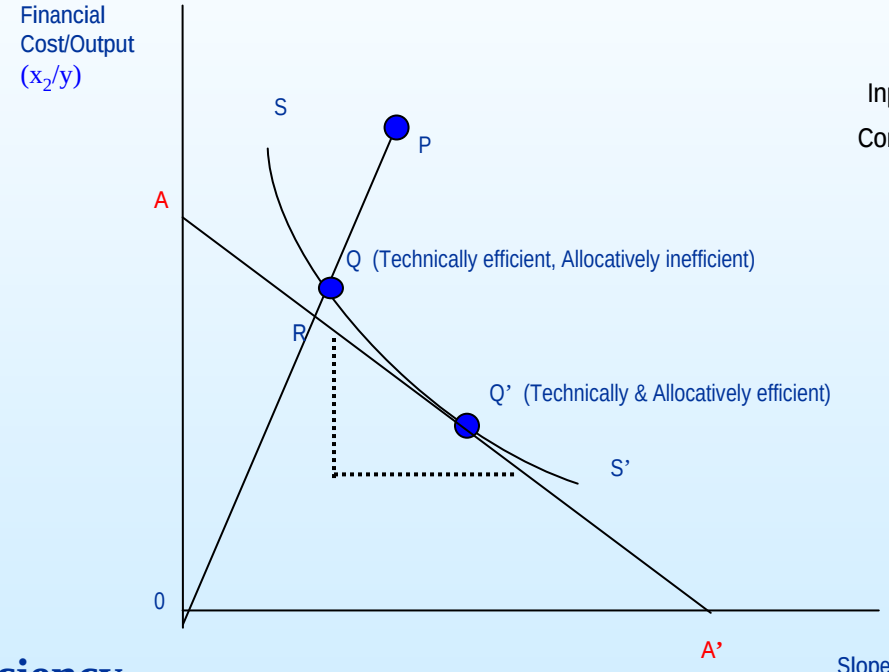
AE = OR / OQ [2]

TE*AE: EE = OR / OP [3]

Figure 1: Technical and Allocative Efficiencies

(Figure is adapted from Coelli et al. (1998))

Technical & Allocative Efficiencies



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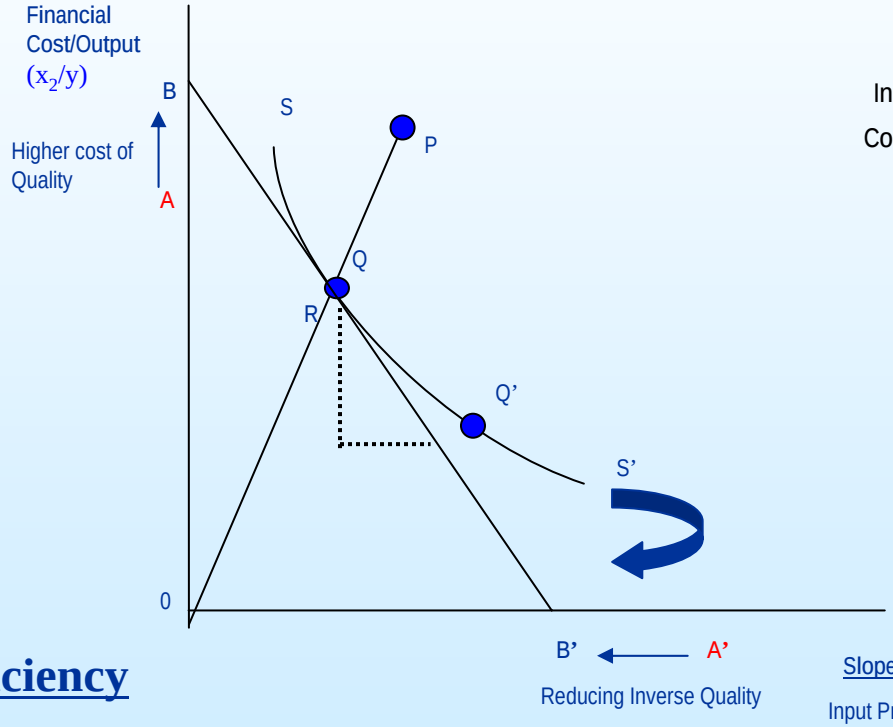

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Economic Efficiency

TE = OQ / OP [1]

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TE*AE: EE = OR / OP [3]

Model Specification – input/output

MODEL	1	2	3	4	5
INTPUT					
OPEX	√				√
TOTEX		√	√	√	
CML			√	√	√
ENGY LOSS				√	√
INPUT PRICE					
1 (TOTEX)			√	√	√
WTP (CML)			√	√	√
ENGY PRICE(LOSS)				√	√
OUTPUT					
CUST	√	√	√	√	√
ENGY DELV	√	√	√	√	√
NETL	√	√	√	√	√
EFFICIENCY					
	TE	TE	TE/ AE	TE/ AE	TE/ AE

Technical efficiency :
the ability of a firm to obtain maximal output from a given set of inputs.

Allocative efficiency:
the ability of a firm to use the inputs in optimal proportions, given their respective prices.

Overall Economic efficiency:
Product of Technical efficiency and Allocative efficiency

Remark:

TOTEX: OPEX + CAPEX
CML: Customer Minutes Loss
ENGY LOSS: Energy loss (Distribution)

ENGY PRICE: Energy Price
WTP: Willingness-to-pay

ENGY DELV: Energy Delivered
CUST: Customer No.
NETL: Network Length

TE: Technical efficiency
AE: Allocative efficiency

Model 1 - Opex

Input : Opex;
Output: Customer No. Network length, Units of energy delivered
Table Model 1 : Technical efficiency scores 1990/91 – 2003/04

Model 1 OPEX	1990/91-1994/95 TE	1995/96-1999/00 TE	2000/01-2003/04 TE	M1 1990/91-2003/04 TE
EDF - EPN	0.93	0.81	0.90	0.88
CN East	0.91	0.56	0.58	0.68
EDF - LPN	0.69	0.63	0.75	0.69
SP Manweb	0.89	0.74	0.60	0.74
CN West	0.85	0.71	0.60	0.72
CE - NEDL	0.77	0.52	0.63	0.64
UU	0.78	0.54	0.86	0.72
EDF - SPN	0.79	0.82	0.62	0.74
SSE - Southern	0.82	1.00	0.84	0.89
WPD S Wales	0.61	0.53	0.53	0.56
WPD S West	0.62	0.76	0.79	0.72
CE YEDL	0.88	0.75	0.70	0.78
SSE - Hydro	1.00	0.98	0.76	0.91
SP Distribution	1.00	0.73	0.76	0.83
Sector Average	0.82	0.72	0.71	0.75

Model 2 - Totex

Input : Totex;
Output: Customer No. Network length, Units of energy delivered
Table Model 2 : Technical efficiency scores 1990/91 -2003/04

Model 2 TOTEX	1990/91-1994/95 TE	1995/96-1999/00 TE	2000/01-2003/04 TE	M2 1990/91-2003/04 TE
EDF - EPN	0.99	0.91	0.99	0.96
CN East	0.83	0.75	0.83	0.80
EDF - LPN	0.70	0.71	0.93	0.78
SP Manweb	0.85	0.87	0.69	0.80
CN West	0.84	0.88	0.77	0.83
CE - NEDL	0.78	0.80	0.79	0.79
UU	0.79	0.65	0.80	0.75
EDF - SPN	0.80	1.00	0.79	0.86
SSE - Southern	0.78	0.89	0.99	0.89
WPD S Wales	0.59	0.60	0.69	0.63
WPD S West	0.65	0.90	0.83	0.79
CE YEDL	0.96	0.82	0.95	0.91
SSE - Hydro	1.00	0.92	0.99	0.97
SP Distribution	0.94	0.90	0.81	0.88
Sector Average	0.82	0.83	0.84	0.83

Model 3 – Totex-CML

Input : Totex, CML;
Output: Customer No. Network length, Units of energy delivered
Input price : 1, WTP
Table Model 3: Economic efficiency scores 1990/91 – 2003/04

Model 3 TOTEX & CML	1990/91-1994/95 TE	1995/96-1999/00 TE	2000/01-2003/04 TE	1990/91-2003/04 TE	1990/91-94/95 AE	1995/96-99/00 AE	2000/01-03/04 AE	1990/91-2003/04 AE	1990/91-2003/04 OE
EDF - EPN	0.99	1.00	0.99	0.99	0.98	0.96	0.85	0.93	0.92
CN East	0.86	0.83	0.84	0.84	0.74	0.96	0.82	0.84	0.71
EDF - LPN	0.95	1.00	1.00	0.98	0.95	0.97	1.00	0.97	0.96
SP Manweb	0.92	0.97	0.88	0.92	0.78	0.97	0.96	0.90	0.83
CN West	0.79	0.89	0.77	0.82	0.66	0.74	0.67	0.69	0.56
CE - NEDL	0.87	0.85	0.83	0.85	0.75	0.92	0.89	0.85	0.72
UU	0.91	0.84	0.93	0.89	0.95	0.92	0.98	0.95	0.85
EDF - SPN	0.87	1.00	0.81	0.89	0.85	0.92	0.91	0.89	0.80
SSE - Southern	0.89	0.99	0.99	0.96	0.89	0.99	0.83	0.90	0.86
WPD S Wales	0.67	0.61	0.76	0.68	0.52	0.77	0.91	0.73	0.50
WPD S West	0.76	0.94	0.96	0.89	0.70	0.96	0.96	0.88	0.78
CE YEDL	1.00	0.98	1.00	0.99	0.91	0.99	0.94	0.95	0.94
SSE - Hydro	0.92	0.94	1.00	0.95	0.81	0.85	1.00	0.89	0.85
SP Distribution	0.98	0.98	0.88	0.95	0.94	0.88	0.88	0.90	0.85
Sector Average	0.88	0.92	0.90	0.90	0.82	0.91	0.90	0.88	0.79

Model 4 – Totex-CML-Loss

Input : Totex, CML, distribution loss;
Output: Customer No. Network length, Units of energy delivered;
Input price : 1, WTP, Energy price
Table Model 4: Economic efficiency scores 1990/91 – 2003/04

Model 4 TOTEX, CML, LOSSES	1990/91-1994/95 TE	1995/96-1999/00 TE	2000/01-2003/04 TE	1990/91-2003/04 TE	1990/91-94/95 AE	1995/96-99/00 AE	2000/01-03/04 AE	1990/91-2003/04 AE	1990/91-2003/04 OE
EDF - EPN	1.00	1.00	1.00	1.00	0.99	0.98	0.87	0.95	0.95
CN East	0.97	0.99	0.98	0.98	0.73	0.86	0.74	0.78	0.76
EDF - LPN	0.99	1.00	1.00	1.00	0.95	0.98	1.00	0.98	0.97
SP Manweb	0.87	0.97	0.95	0.93	0.85	0.94	0.92	0.90	0.84
CN West	1.00	1.00	1.00	1.00	0.64	0.72	0.57	0.64	0.64
CE - NEDL	0.90	0.95	0.94	0.93	0.79	0.88	0.83	0.83	0.77
UU	0.98	1.00	1.00	0.99	0.92	0.83	0.94	0.90	0.89
EDF - SPN	0.93	1.00	0.87	0.93	0.84	0.95	0.89	0.90	0.84
SSE - Southern	0.92	0.99	0.99	0.97	0.89	0.99	0.84	0.91	0.88
WPD S Wales	0.74	0.80	0.89	0.81	0.57	0.63	0.82	0.67	0.55
WPD S West	0.82	0.99	0.98	0.93	0.73	0.95	0.96	0.88	0.82
CE YEDL	1.00	1.00	1.00	1.00	0.92	0.98	0.95	0.95	0.95
SSE - Hydro	1.00	1.00	1.00	1.00	0.90	0.87	1.00	0.92	0.92
SP Distribution	0.98	0.98	0.88	0.95	0.92	0.87	0.86	0.89	0.84
Sector Average	0.94	0.98	0.96	0.96	0.83	0.89	0.87	0.86	0.83

Correlations

	Model 1 Opex TE	Model 2 Totex TE	Model 3 Totex CML TE	Model 4 Totex CML-Loss TE	Model 5 Opex CML-Loss TE	Model 3 Totex CML AE	Model 4 Totex CML-Loss AE	Model 5 Opex CML-Loss AE	Model 3 Totex CML OE	Model 4 Totex CML-Loss OE	Model 5 Opex CML-Loss OE
Model 1 TE	1.0000	-	-	-	-	-	-	-	-	-	-
Model 2 TE	0.9092	1.0000	-	-	-	-	-	-	-	-	-
Model 3 TE	0.7714	0.7755	1.0000	-	-	-	-	-	-	-	-
Model 4 TE	0.6023	0.6835	0.7362	1.0000	-		-	-		-	-
Model 5 TE	0.5512	0.6295	0.7280	0.9762	1.0000			-			-
Model 3 AE	0.4559	0.4076	0.8263	0.4596	0.4815	1.0000	-	-	-	-	-
Model 4 AE	0.5712	0.5362	0.8848	0.4611	0.4843	0.9712	1.0000	-		-	-
Model 5 AE	0.5488	0.4726	0.8716	0.4665	0.4920	0.9771	0.9871	1.0000			-
Model 3 OE	0.6259	0.6023	0.9485	0.6140	0.6267	0.9587	0.9740	0.9699	1.0000	-	-
Model 4 OE	0.6566	0.6507	0.9469	0.6823	0.6996	0.9375	0.9615	0.9520	0.9869	1.0000	-
Model 5 OE	0.6149	0.5680	0.9221	0.6694	0.7011	0.9445	0.9496	0.9635	0.9793	0.9871	1.0000

Implications

- Holistic quality-incorporated benchmarking model.
- Input price factors for measuring allocative efficiency.
- The efficiency scores in cost-only model vary significantly from those of cost-quality-loss models → possible trade-off btn costs & quality.
- Correlation btn cost-only and cost-quality-loss model were low → cost-quality-loss model is not redundancy.
- Relatively lower score in allocative efficiency (AE) → the input factor mix is suboptimal with respect to prevailing input prices.
- Culprit: the separation of performance parameters (e.g., quality parameters) from the benchmarking practice → dilutes the utilities' effort in striking a good balance between cost & quality.
- If the divergence is caused by regulatory policy, DNOs would consistently under or over utilize inputs & this bias will continuously reflected in the AE.
- Cost-Quality-Loss (Model 4) model → better to address possible trade offs.