BENCHMARKING AND REGULATION OF ELECTRICITY TRANSMISSION AND DISTRIBUTION UTILITIES: LESSONS FROM INTERNATIONAL EXPERIENCE

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December 2000

Abstract

Since the early 1980's, many countries have implemented electricity sector reforms. Many of these reforms have unbundled the generation, transmission, distribution, and supply activities of the sector and introduced competition in generation and supply. An increasing number of countries are also adopting incentive regulation to promote efficiency improvement in the natural monopoly activities - transmission and distribution. Incentive regulation almost invariably involves benchmarking or comparison of actual vs. some reference performance. This paper reviews the main approaches to incentive regulation and discusses various benchmarking methods. We also present the findings of a survey of the use of benchmarking methods in the OECD and few other countries. Our survey finds a variety of methods used by the electricity regulators although with a notable preference for the non-parametric methods. We then draw conclusions based on the findings of the survey highlighting the main outstanding issues and lessons for best practice implementation of benchmarking in electricity regulation.

Keywords: electricity, benchmarking, incentive regulation, data envelopment analysis, stochastic frontier analysis

JEL classification: L43, L51, L94

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December 2000

1. Introduction

Since the late 1980s, a wave of reform has transformed the institutional framework, organisation, and operating environment of the infrastructure industries including that of the electricity sectors in many developed and developing countries.[2] In addition, a number of other countries are either implementing or evaluating some form of power sector reform. Although the structure of the power sectors and the approaches to reform vary across the countries, the main objective is to improve the efficiency of the sector.

The main feature of many power sector reforms is the market-orientation of their approaches to achieve the efficiency objective by using the discipline of the product and capital markets to achieve allocative and internal efficiency through the price mechanism, competition, and privatisation (see Vickers and Yarrow, 1988). These reforms generally involve introduction of competition into electricity generation, design of organised power markets, and unbundling of the electricity generation, transmission, distribution, and supply (or retailing) activities. Other power sector reforms have also involved ownership transfers and privatisation of the existing assets (see Joskow, 1998).

Most power sector reforms initially focus on the introduction of the price mechanism and competition in generation and supply of electricity while the transmission and distribution functions are, due to their natural monopoly character, less affected. As reforms in the competitive segments progress they call for regulatory reform of the non-competitive activities. Regulation of public utilities has traditionally been justified on the grounds of

[1] Corresponding author. The authors would like to thank the numerous people in the government agencies, regulatory authorities, and academic institutions in many countries for their generous contribution to this project with information and their time. We acknowledge detailed comments from Cemil Altin, David Newbery, Jon Stern, and Bernard Tenenbaum. The usual disclaimer applies. Support from ESRC project R00023 8563 is also gratefully acknowledged.

[2] See IEA (1999) and Bergman et al. (1999) for reviews of electricity reforms in the OECD countries and World Bank (1993; 1999) for developing countries.

public interest and natural monopoly characteristics of their industries (Priest, 1993). The dominant mode of utility regulation has been in the form of public regulation.[3] Some such as Littlechild (2000), view regulation as a necessary but temporary arrangement until effective deregulation involving competing private firms can be introduced.

The aim of the regulatory reforms is to provide the utilities with incentives to improve their investment and operating efficiency and to ensure that consumers benefit from the efficiency gains. In the US, incentive regulation is often termed as Performance Based Regulation (PBR). A related aspect of regulatory reform is that of regulatory governance which emphasises the formal status of the regulator and rules of conduct in carrying out their duties and exercising power (see ACCC, 1999; Newbery, 1999; Stern and Holder, 1999; Levy and Spiller, 1994; Berg and Jeong, 1991).

The recent interest in incentive regulation is not due to new contributions from economic theory. Rather, the need for practical solutions has resulted in design and implementation of regulatory arrangements that are not necessarily in line with the theory (Crew and Kleindorfer, 1996, p. 215). The regulatory reforms have emerged as an alternative to the traditional rate-of-return (ROR) or cost-of-service (COS) regulation of utilities and regulators have adopted a variety of approaches to incentive regulation. A common feature among the incentive regulation schemes is their use of benchmarking broadly defined as *comparison of some measure of actual performance against a reference or benchmark performance.*

This paper reports the results of an international survey on the use of benchmarking in incentive regulation of electricity distribution and transmission utilities. The survey covers the OECD and a few non-OECD countries. The following section is an overview of the main approaches to incentive regulation used by the electricity regulators. Section 3 reviews the benchmarking techniques used in incentive regulation. In Section 4 we present the main findings of the survey and highlight three selected cases of benchmarking. Section 5 is a conclusion suggesting some outstanding issues and lessons for best practice implementation.

2. The Main Approaches to Incentive Regulation

ROR Regulation

The ROR regulation is the traditional approach to regulation of privately owned monopolies and an alternative to public owned utilities. The method is a heavy-handed approach to regulation and it is generally identified with the regulation of investor-owned utilities in the US. The ROR regulation allows the utility to cover its operating and capital costs as well as a return on capital. Equation (1) shows calculation of the required revenue for firm *i*'s targeted rate of return in year *t* from projected costs.[4] Alternatively, the required revenue can be calculated from the firm's historical costs.

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[3] As opposed to private or voluntary regulation. See Blundell and Robinson (1999).

[4] See Hill (1995).

(1) $$RR_{i,t} = OE_{i,t} + D_{i,t} + T_{i,t} + (RB_i * ROR)_t$$

where:

RR_i = *required revenue*	OE_i = *operating expenses*
D_i = *depreciation expense*	T_i = *tax expense*
RB_i = *rate base*	ROR_i = *rate of return*

The shortcomings of ROR regulation are extensively discussed in the literature and were first presented in Averch and Johnson (1962). The main reservation against this approach is that it does not provide incentives for cost savings and efficiency improvements but rewards over-investments. Within the framework of the Principal-Agent theory, ROR regulation is believed to cause a managerial slack or X-inefficiency that is attributed to the absence of competition. In response to these deficiencies, incentive-based regulation methods such as price cap, revenue cap, sliding scale, partial cost adjustment, yardstick competition, targeted incentive, and hybrid schemes have been proposed. These methods are reviewed in what follows.[5]

Price Cap Regulation

The price cap approach to utility regulation, is perhaps the most widely discussed and significant innovation in utility regulation and alternative to ROR regulation. The method was first proposed in Littlechild (1983) and various versions of it have since been adopted in the regulation of infrastructure and utility industries in the UK and other countries.[6]

Price cap regulation essentially decouples the profits of the regulated utility from its costs by setting a price ceiling. The method is also referred to as the 'RPI-X' model. For each rate period, normally between 3 to 5 years, the price cap for each year is set based on the Retail Price Index (RPI) and an efficiency factor X.[7] Prices remain fixed for the rate period and the utility keeps or shares the achieved cost savings. In this regard price cap regulation resembles an ROR regulation with rate freeze or long regulatory lag. Equations (2)-(3) shows how the price ceiling for *i* is set.

(2) $$P_{i,t} = P_{i,t-1} * (1 + RPI - X_i) +/- Z_i$$

(3) $$P = \sum p_i q_i$$

For each year the price ceiling P_t is calculated based on the previous year's price ceiling P_{t-1} adjusted by RPI minus the efficiency factor X decided by the regulator. The price ceiling may be adjusted using a correction factor Z to account for the effect of exogenous extraordinary events affecting the utility's costs. The price cap P_t represents an index of the 'n' different tariffs $p_1 \ldots p_n$ of the regulated utility. The use of the price index often offers the utility some degree of freedom in setting the individual tariffs. A reservation against the use of price cap

5 The review of the incentive regulation methods in this section is largely based on Hall (2000); Comnes et al. (1995); Hill (1995); Joskow and Schmalensee (1986).

6 See Armstrong et al. (1994) and Rees and Vickers (1995) for detailed reviews of the price cap method and its application to privatised infrastructure industries in the UK.

7 In the US the corresponding price index is termed Consumer Price Index (CPI).

regulation, particularly in the US, has been that their sales maximisation incentive conflicts with the objectives of socially desirable programmes such as those of Demand-Side Management (DSM) measures that utilities may be obliged to implement (MDTE 1995, p. 22; SEE 1997, p. 52).

Revenue Cap Regulation

The revenue cap method regulates the maximum allowable revenue that a utility can earn. Similar to the price cap regulation, the aim of the regulator is to provide the utility with incentive to maximise its profits by minimising the costs and allowing the utility to keep the cost savings achieved during the regulatory lag. Equation (4) shows the main elements of revenue cap regulation for a given year.[8]

(4) $$\overline{R}_{i,t} = \left(\overline{R}_{i,t-1} + CGA_i * \Delta Cust_i\right) * \left(1 + RPI - X_i\right) + / - Z_i$$

where:

$\overline{R}_i$ = *authorised revenue*

CGA_i = *customer growth adjustment factor ($/customer)*

$\Delta Cust_i$ = *change in the number of customer*

X_i = *efficiency factor*

Z_i = *adjustment factor for events beyond management control*

The revenue cap method can also take the form of revenue-per-customer regulation in which case CGA is equal to average revenue per customer. In the UK, revenue cap regulation has been applied to the main transmission utility National Grid Company (NGC). An advantage of the method is that it can be aligned with DSM measures (MDTE 1995, p. 23). However, revenue cap regulation has been criticised for limiting the powerful incentive to increase the sales and competition and has therefore been characterised as inefficient (Crew and Kleindorfer, 1996).

Sliding Scale (ROR bandwidth)

In sliding scale or ROR bandwidth regulation, the utility's allowed rate of return is benchmarked against a target or reference ROR that lies within a pre-specified dead-band. Schmalensee (1979) points out that the first sliding scale regulations were used in England in the middle of the 19th century.[9] During the regulatory lag, the actual ROR can vary within the dead-band without causing rate adjustments. If the actual ROR falls outside the dead-band it can trigger profit sharing mechanisms or rate reviews. Equation (5) shows a simple sliding scale regulation.[10]

(5) $$r_t = r_{t-1} - \lambda\left(r_{t-1} - r^*\right)$$

[8] See Comnes et al. (1995).

[9] Cited in Joskow and Schmalensee (1986).

[10] See Hill (1995).

where:
r_t = *allowed rate of return for the period under consideration*
r_{t-1} = *actual return in the pervious period*
r^* = *benchmark rate of return*
λ = *sharing parameter*

When the r_{t-1} is within the predefined dead-band the sharing parameter λ is equal to zero. For r_{t-1} below or above the dead-band, the sharing parameter can, depending on the extent of deviation, take values ranging between zero and one. The sliding scale rate of return regulation may be combined with price or revenue cap regulation.

Yardstick Regulation

In yardstick regulation the performance of a regulated utility is compared against that of a group of comparable utilities. For example, the mean of the costs of a peer group of firms can serve as performance benchmark. The method was first proposed in Shleifer (1985) and can be used to promote indirect competition among regulated utilities operating in geographically separate markets. Equation (6) shows the main elements of a cost-based yardstick regulation.[11]

(6) $$P_{i,t} = \alpha_i C_{i,t} + (1 - \alpha_i) \sum_{j=1}^{n} (f_j C_{j,t})$$

where:
P_i = *overall price cap for firm i*
α_i = *share of firm's own cost information (p=0 representing pure yardstick regulation)*
C_i = *unit cost of firm*
f_i = *revenue or quantity weights for peer group firms j*
$C_{j,t}$ = *unit costs (or prices) for peer group firms j*
n = *number of firms in peer group*

Weyman-Jones (1995) discusses some of the complexities associated with the application of yardstick regulation to electricity distribution utilities while Sawkins (1995) reports a relatively functioning and well-received implementation of the method in the privatised UK water industry. A main concern in applying yardstick regulation to electricity utilities is the degree to which the operating environment of the firms in question and their circumstances (i.e. major recent investments) are comparable. Another concern is the extent to which the data may adequately be adjusted in order to account for these differences.

Partial Cost Adjustment

Another approach to incentive regulation is to link the price adjustments to changes in the utility's own costs observed in a reference year. The cost minimisation incentive is provided by price periodic adjustments that are less than proportional to the actual changes in the costs. Equation (7) shows a simple partial cost adjustment scheme.[12]

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[11] See Comnes et al. (1995).
[12] See Joskow and Schmalensee (1986).

(7) $$P_{i,t} = C_i^* + \lambda\left(C_{i,t} - C_i^*\right)$$

where:

P_i	=	*adjusted price*	C_i	=	*the actual cost per unit*
C_i^*	=	*reference cost per unit output*	λ	=	*sharing parameter*

Menu of Contracts

The menu of contracts method is an innovative approach to reduce the information asymmetry between the regulator and regulated firm. Under this scheme the regulator offers the utility a menu of incentive plans with constant consumer welfare. The utility can choose among the incentives and the flexibility in choosing among the alternatives reveals its welfare-enhancing preferences. The revealed preferences therefore represent a Pareto improvement (Crew and Kleindorfer, 1996). For example, a menu of incentives can be designed where the utility's share of profits σ or some specified reward is a function of deviation of the X-factor (or price cap) chosen by the utility from a base value (Equation 8).

(8) $$\sigma = f\ (X)$$

If the utility chooses a higher X-factor than the base value it will receive a higher reward as per equation. The major obstacles in the application of the method are the design of appropriate scheme as they require considerable information about distribution of efficiencies and the corresponding rewards.

Targeted Incentive Regulation

Targeted incentive schemes pursue narrower objectives than the broad incentive regulation approaches discussed in the above. The aim of these schemes is to target specific aspects of the operation of the utility and achieve an outcome that would not necessarily result from broad incentive schemes. Targeted incentive regulation may be used to promote DSM measures, environmental standards, technical efficiency, and improvement in quality of service. However, these schemes have been criticised on the ground that they distort efficient allocation of resources (Joskow and Schmalensee, 1986). Also, it has been suggested that such schemes cause distortionary effects and have been insignificant in the overall operation of the utility (Berg and Jeong, 1991).

Hybrid Schemes

The various incentive regulation methods discussed in the above are usually not observed in pure form. Rather, practical considerations and multiplicity of the regulatory objectives often result in using a combination of different incentive regulation methods. For example, targeted incentive schemes can supplement the broad incentive regulation methods. Also, incentive regulation may be combined with various profit or loss sharing schemes. As with targeted incentive, hybrid schemes may result in inefficient resource allocation.

3. Benchmarking Methods and Techniques

The main objective of incentive regulation method is to improve efficiency by rewarding good performance while the actual performance is measured relative to some pre-defined benchmark. As the rewards are based on performance measurements, two key issues are the choice of benchmarks and the techniques used to measure the performance. Regulators have adopted a variety of benchmarking methods and techniques in incentive regulation. According to one classification, actual performance can be measured against benchmarks that are "linked" (endogenous) or "un-linked" (exogenous) to performance or behaviour of individual firms (DTe 1999, p. 29). We use a somewhat different classification based on whether the benchmarks represent the 'best (frontier)' practice or some measure of 'representative (average)' performance.

From a regulatory policy point of view a major difference between the frontier and average benchmarking is that the former has a stronger focus on performance variations between the firms. The frontier methods are suitable at initial stages of regulatory reform when a priority objective is to reduce the performance gap among the utilities through firm-specific efficiency requirements. Average benchmarking methods may be used to mimic competition among the firms with relatively similar costs or when there is lack of sufficient data and comparators for the application of frontier methods.

3.1 Frontier Benchmarking Methods

The frontier-based benchmarking methods identify or estimate the efficient performance frontier from the best practice in an industry or a sample of firms. This frontier is the benchmark against which the relative performance of firms is measured. The main frontier benchmarking methods are Data Envelopment Analysis (DEA), Corrected Ordinary Least Square (COLS), and Stochastic Frontier Analysis (SFA).[13] DEA is based on the linear programming technique while COLS and SFA are statistical techniques.

In DEA the efficiency of the firms is computed rather than estimated. DEA identifies an efficient frontier made up of the most efficient firms in the sample and measures the relative efficiency scores of the less efficient firms in relation to these. Norway uses the DEA scores in setting the revenue caps for regional electricity transmission and distribution utilities. An advantage of DEA is that it does not require specification of a production or cost function. DEA allows calculation of allocative and technical efficiencies. The latter can be decomposed into scale, congestion, and pure technical efficiencies (Färe et al., 1985). DEA can also examine the effect of environmental variables (Yaisawarng and Klein, 1994). DEA results can be sensitive to the inputs and outputs in the model. The results are also sensitive to measurement errors in the frontier firms as the efficiency scores are measured relative to the frontier. Further, the number of efficient firms on the frontier is sensitive to the number of inputs and outputs.

[13] The review of these methods is based on Pollitt (1995). See also DTe (1999).

In SFA and COLS the relative efficiency scores are estimated rather than computed. Both techniques require specification of a production or cost function. The UK water and electricity regulators apply COLS to operating costs of water and electricity distribution utilities. Similar to DEA, the COLS technique assumes all deviations from the efficient frontier are due to inefficiency. The efficiency scores with COLS are therefore rather sensitive to the position of the frontier firms. On the other hand, SFA recognises the possibility of stochastic errors in the measurement of the inefficiencies. At the same time, if there are no inefficiency measurement errors in the sample, the error assumption would result in some inefficiency being regarded as noise. Consequently, due to the error factor, the estimated efficiency scores with SFA are likely to be higher than those measured by COLS.

There are also partial benchmarking methods such as the method used in the study of the distribution utilities Victoria (see UMS 1999). These methods assume separability of different cost categories and involve comparison of firms of different scales. This may however not be a problem for comparison of firms which have similar technologies and scale. The Norwegian Water and Energy Administration (NVE) uses a Value Chain Model (VCM) for one-to-one benchmarking of the state owned central grid utility Statkraft against the Swedish grid company Svenska Kraftnät. The model makes provision for adjustment of data for operational and environmental factors.[14]

3.2 Mean and Average Benchmarking

In contrast to frontier methods, benchmarking in incentive regulation can be in relation to some measure of mean or average performance. One such regression-based statistical method is the Ordinary Least Square (OLS) method that is closely related to COLS. However, OLS estimates an average production or a cost function of a sample of firms. The actual performance of firms can then be compared against the estimated performance by plugging their input, output, and environmental data measured into the estimated function.[15]

As discussed under yardstick regulation, the mean of the costs of a peer group of firms can serve as the benchmark for individual firms. In this approach, all the firms in the group are subject to the same price cap. A version of this approach is used by the National Energy Commission (CNE) in Chile to calculate the value added for the distribution services. The value added for a group of comparable firms is derived from a designed efficient model or reference firm (Rudnick and Donoso, 2000; Rudnick and Raineri, 1997). In Spain, the regulator uses model firms for specific geographical areas to allocate a portion of the total system revenues among distribution utilities.

Also, the sliding scale method can be viewed as a form of average benchmarking in which the target ROR in the dead-band is intended to represent a fair rate of return that is based on the return earned by comparable industries or firms in similar operating environments. The

[14] See Magnus and Midttun (2000) for a brief description of the method.
[15] See DTe (1999, pp. 30-31) for a comparison of the OLS, COLS, and SFA techniques.

regulated utility is therefore competing with the average performance in the industry or economy.

Another method based on average performance is to use Total Factor Productivity (TFP) as benchmark. This method can for example use the Tornqvist index as a measure of historical productivity growth of a firm, an industry, or the entire economy in setting the efficiency factor X in price cap regulation (see for example ESAA, 1994). The method is relatively easy to implement. However, less efficient firms may find it easier than efficient firms to outperform the TFP and earn large profits. Finally, targeted incentive schemes can use average or frontier performance benchmarks to address specific aspects of the operation of the firms. These benchmarks may be based on the past or expected performance of the firm or the industry.

4. Empirical Benchmarking Studies

A number of comparative performance studies have addressed efficiency aspects of the electricity industry. Many of these studies are concerned with economies of scale and density or the effect of the ownership form on utility efficiency (see Kumbhakar and Hjalmarsson, 1998). This section outlines some selected empirical studies of relative efficiency of electricity (mostly distribution) utilities. Most of these studies are conducted by third parties and are not, at least directly, part of the regulatory process. The scope of most of the efficiency studies is limited to relative efficiency in a single country while some studies have a cross-country focus. These studies illustrate the range of benchmarking techniques which have been applied to electric utilities.

4.1. Single-Country Studies

Weyman-Jones (1991) reports a DEA study of the 12 Area Electricity Boards (AEBs) in the UK in 1986/87 and finds a wide divergence among the AEBs while five of these are on the frontier. Burns and Weyman-Jones (1996) use SFA in a study of the Regional Electricity Companies (RECs) in the UK and find a significant but small cost-inefficiency and evidence of some economies of scale. Førsund and Kittelsen (1998) apply the Malmquist index to measure productivity development in the Norwegian distribution utilities between 1983 and 1989 and find an annual productivity growth of 2%.

Kumbhakar and Hjalmarsson (1998) apply DEA and SFA methods in a study of the distribution utilities in Sweden between 1970 and 1990 and find evidence of economies of scale, technical progress, and relative efficiency of private utilities. Hougaard (1994) in a DEA study of 82 Danish distribution utilities in 1991 finds significant potential for efficiency improvement. The study also shows that while the efficiency scores are sensitive to model specification the rank orders across the four models are rather robust.

Bagdadioglu, Price et al. (1996) in a DEA study find indication of relative efficiency among the Turkish distribution utilities offered for private franchise. Miliotis (1992) reports an efficiency study of 45 electricity distribution districts in Greece using DEA and econometric methods. Filippini (1998) and Giles and Wyatt (1993) use translog econometric models for Swiss and New Zealand distribution utilities and find economies of scale with the former recommending mergers among the utilities.

4.2. Cross-Country Studies

Benchmarking studies almost invariably focus on individual industries of one or more countries. Lawrence, Houghton et al. (1997) report a notable exception in the form of an international multi-industry benchmarking study by Australia's Bureau of Industry Economics. The project was carried out between 1991 and 1996 and examined relative efficiency of eight Australian infrastructure industries including the electricity sector using indicators of price, service quality, labour productivity, and capital productivity. The Australian electricity sector appeared to be closing some aspects of performance gap with international comparators.

Pollitt (1995) examines the effects of the public vs. private ownership on performance through an international comparison of electricity generation, transmission, and distribution utilities using DEA, COLS, and SFA models. IPART (1999) reports a cross-country study sponsored by a regulator that examines relative efficiency of 6 distribution utilities in New South Wales, Australia using a large sample of national and international comparators. Whiteman (1999) applies DEA and SFA to 7 Australian and an international sample of 32 electricity supply utilities and shows that X-inefficiency may have declined following the Australian electricity reform. In addition, Meibodi (1998), Yunos and Hawdon (1997), and Whiteman (1995) apply DEA to measure relative efficiency of the electricity systems in a number of developing countries.

Table 1: Single and cross-country benchmarking studies[16]		
Author	**Sample**	**Method of Analysis**
IPART (1999)	219 Australian, New Zealand, England & Wales, and US distribution utilities	DEA
Whiteman (1999)	7 Australian and in international sample of 32 utilities	DEA, SFA
Filippini (1998)	39 Swiss municipal electricity distribution utilities 1988-91	Translog cost function
Førsund and Kittelsen (1998)	1983-89 data on 150 Norwegian distribution utilities	Malmquist DEA
Goto and Tsutsui (1998)	9 Japanese and 14 US electric utilities 1983-93	DEA
Kumbhakar and Hjalmarsson (1998)	Swedish electricity distribution 1970-1990	Translog input requirement function, stochastic frontier framework, DEA
Meibodi (1998)	Panel data of 26 LDCs (2 years). Panel data of 30 Iranian plants (6 years) and 1 cross-section of 30 dist. organisations.	SFA, DEA
Zhang and Bartels (1998)	32 power supply authorities in Australia, 51 power boards in New Zealand, and 173 distributors in Sweden	DEA, Monte Carlo simulation, bivariate lognormal input distribution
Lawrence, Houghton et al. (1997)	8 Australian infrastructure industries incl. electricity 1991-96	Performance indicators, TFP, DEA
Yunos and Hawdon (1997)	Malaysian, 27 LDCs and the UK utilities	DEA
Bagdadioglu, Price et al. (1996)	76 Turkish distribution organisations (72 public, 2 private, 2 integ. private) 1991	DEA
Burns and Weyman-Jones (1996)	12 RECs in England 1980/81 to 1992/93	SFA using cross-sectional and panel data
Claggett et al. (1995)	74 municipals, 45 co-operatives under Tennessee Valley Authority 1985-89	Profit function mode, Cobb-Douglas model
Whiteman (1995)	Electricity systems of 85 LDCs	DEA
Berry (1994)	US rural electric co-operatives and investor-owned utilities 1988 (Gen., Trans, and Dist.)	Translog cost functions for IOUs and co-operatives
Burns and Weyman-Jones (1994)	RECs 1973-93	Non-parametric programming of relative efficiency, Malmquist productive indices
Claggett (1994)	157 TVA distributors 1982-89 (108 municipals and 49 co-operatives)	Standard translog cost function
Hougaard (1994)	82 Danish distribution utilities	DEA
Pollitt (1994)	129 US transmission utilities (23 public, 106 private), 145 distribution utilities (136 US, 9 UK; 119 private, 26 public)	DEA and OLS
Giles and Wyatt (1993)	60 regional Electricity Supply Authorities for New Zealand 1986/87	Translog cost model
Klein et al. (1992)	US Coal-Burning Gas Plants (a selection of plants 1975 to 1987)	DEA, Malmquist Index
Miliotis (1992)	45 electricity distribution districts of the Greek Public Power Corporation	DEA
Weyman-Jones (1991)	12 UK Area Electricity Boards (AEBs) for period 1986/87	Non-parametric linear programming efficiency measurement
Twada and Katayama (1990)	9 large Japanese electric power companies (generation only) 1965-82	Estimate production function for marginal productivity of factors
Charnes et al. (1989)	75 Texas electric co-operatives	DEA compared with existing ratios and regressions based systems

[16] Distribution utilities in the above studies usually include both the distribution and supply functions.

5. Results of the Survey

5.1. The Survey: Purpose, Scope, and Method

The previous sections emphasised that an increasing number of countries are implementing electricity sector liberalisation measures and regulatory reforms. We then reviewed the main models of incentive-based regulation and discussed the main benchmarking methods that are available to the regulators. In the wake of the regulatory reforms two central questions that emerge are: (i) to what extent the regulators have adopted or intend to use benchmarking in incentive regulation and (ii) what are the main features of the adopted benchmarking methods and processes?

In order to address these questions we conducted a survey of the electricity regulators in the OECD and a few other selected countries. In a few cases the information was provided by academic researchers with knowledge of the industry and regulatory process. The survey was conducted through a questionnaire containing 20 questions addressing different aspects of power sector and benchmarking methods and processes. The focus of the survey is on the regulation of transmission and distribution functions as the supply function is potentially competitive. Questionnaires were sent electronically to specific individuals who in advance expressed willingness to contribute to the survey. The recipients also received a complete questionnaire showing an example of full response. Some of the responses were followed up with additional questions. Several regulators who indicated no use or intention to use benchmarking were eliminated from the survey. Consequently, this survey includes 17 OECD and 4 non-OECD countries.

5.2. Review of the Findings

5.2.1. General Features of Power Sector and Benchmarking

Table 2 outlines the questions that form the basis of the findings presented in this paper. The questions are organised into three categories addressing (i) main features of the electricity sector, (ii) the adopted benchmarking method, and (iii) various aspects of the benchmarking process. A summary of the results are given in Tables 3 and 4. The results show that electricity regulators in several countries have adopted some form of benchmarking (Table 3). In addition, regulators in other countries such as Denmark, Ireland, and Brazil are planning or considering the use of benchmarking in regulation. Norway, UK, and Chile which were among the first countries to implement market-oriented reforms have also adopted, benchmarking in regulation of the natural monopoly segments. As shown in Table 3, other countries that use benchmarking have implemented power sector reforms during the second half of the 1990s.

The results also show that benchmarking is almost invariably conducted by independent regulators. The notable exceptions in this regard are Japan and Chile with government ministries functioning as the regulatory authorities. In the near future, more countries are expected to establish independent regulatory bodies. This is particularly the case in the European Union where the Electricity Directive has encouraged the establishment of electricity regulators in member countries and in the countries that seek membership of the Union. Also, the survey results indicate that countries that use benchmarking usually have or are in the process of establishing spot markets and a high degree of end-user market liberalisation both of which can be regarded as indicators of advanced levels of market liberalisation and regulatory reform.

However, there is a variety of benchmarking methods adopted by the regulators across the countries and jurisdictions within the same country such as in the case of the Australian states. As shown in Table 2, the regulators in Great Britain, Norway, Netherlands, New South Wales, and Colombia have used DEA in benchmarking as part of the price review process while in Finland the method has been used outside the price-setting process. The regulator in Queensland has replaced DEA with econometric methods. Regression based models are also used in Great Britain (COLS) in benchmarking of operating expenditures of distribution utilities.

The Ontario regulator uses the historical development of TFP in 47 distribution utilities. Among the average or mean-based benchmarking methods, regulators have generally chosen some form of yardstick regulation. In Japan, yardstick regulation is used together with ROR regulation by placing utilities in 3 performance groups for the purpose of setting the allowable costs and determining the rate base. Also, the Netherlands and Ontario envisage the use of yardstick regulation in the future following transition periods during which the performance gap among the utilities is reduced and better data is collected.

The regulators in Chile, and Spain, use theoretical or model firms in benchmarking of distribution utilities and yardstick regulation. The model firms are designed and dimensioned to represent efficient utilities that serve as reference or benchmark. This approach attempts to reduce the need for and reliance on cost information from the utilities to determine the benchmark by constructing models of efficient firms. In Chile, the representative model firms are used in yardstick regulation of distribution utilities. The Chilean model has also been adopted in some other Latin American countries (e.g. Peru). In Spain the model firms are used in allocating a portion of the total revenues of the system among the distribution utilities.

In addition to the above approaches, ROR can be combined with profit and loss sharing mechanisms and used in incentive regulation. The regulator in California uses a PBR scheme in distribution regulation of Southern California Edison (SCE) that combines price cap regulation with a profit and loss sharing schedule triggered by the difference between a benchmark ROR and the actual ROR. The electricity regulator of the state of Orissa, India uses a ROR-based reward system in a targeted incentive scheme. The utilities are rewarded with 1 percentage point ROR above the benchmark level for each percent reduction in transmission and distribution losses below the 35% level.

Nearly all regulators surveyed in this study have stated that they have full discretion with regard to the choice of the benchmarking method, model, and inputs. In addition, much of the implemented and proposed use of international benchmarking and performance comparisons are related to transmission activities. Regulators in the Netherlands, Norway, UK, and Colombia have engaged in international transmission benchmarking while the new regulator in Austria envisages use of cross-country comparisons in the future. This can be explained by the relatively limited number of transmission utilities in each country.

5.2.2 The Benchmarking Process

The length of the regulation lag in the countries that practice benchmarking is almost invariably between 3 and 5 years (Table 4). In addition, nearly all surveyed regulators have expressed at least one iteration in the process of setting prices with the industry in the form of consultation documents or issue papers the norm being 3 to 4 iterations. One exception in this regard is however Japan where the regulatory authority is not independent. With regards to treatment of operating and capital costs and possible trade-offs between these, the regulators in Belgium, Denmark, Northern Ireland, Norway, Spain, and Colombia do not separate these costs and just use total controllable costs.

Benchmarking of service quality is mostly in terms of setting minimum standards. However, Finland and the Netherlands have indicated their intention to include service quality in DEA studies while in Brazil the use of Multi-Criteria Decision Aid (MCDA) for ranking of the quality standards is under consideration.[17] In Great Britain, Brazil, Colombia, and Chile, the service quality standards are applied in conjunction with non-attainment penalties or compensation schemes.

Countries that use benchmarking in regulation also rely on the price and revenue cap arrangements as incentives for optimising investments. The Norwegian investment incentive is tied to the revenue cap by offering the utilities one-half of the percentage growth in demand. In Great Britain however, the investment incentive is based on a scheme for sharing the achieved savings in investments. The environmental impacts of electricity distribution activities are generally not considerable. However, it is possible to combine price or revenue regulation with incentive schemes designed to promote DSM programmes or green energy such as in the US and Belgium respectively.

Nearly all regulators require submission of information by the utilities in standardised formats. This information is however subject to different audit requirements. Most regulators rely on independent audits while others check or control the submitted information. However, publication of information on the regulatory procedures and decisions is not necessarily an integrated part of the benchmarking process. The most extensive public information is provided by the regulators in the Netherlands, Great Britain, Norway, Ontario, and the Australian states.

[17] See for example Yoon and Hwang (1995) for a review of some of the methodologies.

Further, among the countries surveyed Norway, Brazil, and Spain indicated active research sponsorship or joint studies and research projects. Indirect influence of academic and empirical research on adopting of benchmarking is rather difficult to determine but have been indicated by the regulators in Colombia and the Netherlands. However, several countries such as Turkey, Greece, Sweden, New Zealand, Switzerland, and Denmark for which there are independent efficiency studies do not to use benchmarking as part of the regulatory process (see Table 1).

Table 2: Survey questions

I. Power sector reform - general features

1. ***Formal status of the regulator.***
2. ***Initial dates of power sector reform and benchmarking.***
3. ***Regulated activities of the power sector.***
4. ***Types of power markets.***
5. ***Degree of market liberalisation.***
6. ***Number and ownership of transmission and distribution utilities.***

II. Benchmarking - method

7. ***Is benchmarking used by the regulator?***
8. ***The general benchmarking method used.***
9. ***Regulator's discretion in selecting benchmarking method, model, and inputs.***
10. ***Is international benchmarking used?***

III. Benchmarking - process

11. ***Length of regulatory lag.***
12. ***Number of iterations / consultations.***
13. ***Separate handling of OPEX and CAPEX?***
14. ***Is benchmarking of service quality used? Problems?***
15. ***Incentives for service quality.***
16. ***Incentives for optimum investments.***
17. ***Incentives for environmental impact.***
18. ***Is the required information standardised or audited?***
19. ***Amount of information published.***
20. ***Is adoption of benchmarking influenced by third-party studies?***

Table 3: Power sector reform and benchmarking features (abbreviations defined after Table 4)										
	Power Sector – General						**Benchmarking - Method**			
	1. Regulator status	**2. Reform & benchm. date**	**3. Regulated activities**	**4. Power markets**	**5. Degree of liberalisation**	**6. Ownership & No. Of utilities**	**7. Benchmarking in regulation**	**8. Benchmarking method**	**9. Regulator discretion**	**10. International Benchmarking**
OECD – Europe										
Austria	Independent regulator From 1.10.01	reform: feb. 1999	T, D, S	balancing market	full liberalisation from 1.10.2001	T: 15 D: 300 (min. 51% public)	under consideration	tbd	-	for cross-border tariffs (future)
Belgium	Autonomous	reform: 1999	T, D & S (to captive customers (ROR)	-	1999: +100 MW 2003: + 10 MW 2007: other	T: 1 (private) D: 37 (20% of which public/municipal owned, 80% mixed)	under preparation,	tbd	full discretion	yes
Denmark	Independent, subord. to Min. of En. & Env.	reform: 2000	T, D	spot market	1.1.2000: 100 GWh 1.4.2000: 10 GWh 1.1.2001: 1 GWh	T: 2 national + 13 region. (owned by Ds) D: 120 coop./municipal.	under preparation (planned fr. 2001)	DEA	methods prescribed by the Ministry	no
Finland	Independent subord. to Min. of Trade & Ind.	reform: 1995	T, D. (ROR-oriented ex post control)	spot & forward mkt. (Nord Pool), balancing mkt. (El-EX)	full liberalisation from 1997	T: 1 national grid & 10 reg. nets privatised D: state, 71 county /municipal., 35 private	intends to use an efficiency model for setting ROR	regulator has used DEA but not as regulatory tool	large degree of freedom	no
France	independent (fr. May 2000)	reform: 2000	T, D, S	spot & balancing market	16 GWh (1999) 9 GWh (2003)	T: 1 (state) D: EDF+180 DNN	under consideration	-	-	-
Great Britain ***England & Wales (T/D), Scotland (D)***	non-ministerial govt. dept.	reform: 1990 benchmarking: RECs 1995 NGC 1997	T, D, S	spot, forward, balancing mkt.	full liberalisation from June 1999	T: 1 privatised D: 12 privatised.	yes	T: TFP, DEA of 40 & survey of 15 utilities D: COLS for OPEX	large degree of freedom	yes. for National Grid Company
- Northern Ireland	non-ministrial govt. dept.	privatisation: 1992/93. EU directive 1.7.99	T, D, S	bilateral contracts	1.33 GWh p.a.	T/D: 1 public	yes (fr. 2002)	DEA and regression using a sample of GB utilities	full discretion	no
Hungary	indep., subord. to Min. of Econ. Affairs	Jul. 2001 (expected)	all activities currently regulated	no	tbd	T: 1 state-owned D:6 75-90% private	limited	some comparisons by independent consultants when auditing costs	large degree of freedom	discretion of independent consultants
Ireland	independent	reform: feb. 2000	T., D., and S. to capt. consumers (rev. cap, X for all firms 1%	spot & forward market for trade w. NI	28% (2000), 40% (2002), 100% (2005)	T: 1 D: 1 95% (public)	proposed - as a contributory factor	-	large degree of freedom	COC, CAPEX, OPEX, tech. eff., qual. of serv.
Italy	independent	reform: 1999	T, D, S	bilateral (existing) spot & forward mkt. (fr.2001) balanc. mkt. (under consideration)	consortia/groups of firms w. demand p.a. >30 GWh 1999 >20 GWh 2000 >9 GWh 2002	T: 1 national. grid (pub.) & 13 grid owners. D: 200 (priv. & municip.) – Enel (94%) u. privatisation	yes	comparisons	large degree of freedom	Euro. countries and int. firms examined in setting X factor, ROR, risk factor
Netherlands	independent, subord. to Min. of Econ. Affairs	reform: 1999: partial lib. benchm.: 2000	T, D , S (captive customers)	spot (APX), balancing and bilateral contract mkt. (near future)	full liberalisation from 2004	T: 1 public D: 19 public region. networks (T&D to be part privatised)	yes	DEA, yardstick regulation after a transition period	large degree of freedom	yes, for setting transm. tariffs

Norway	semi-autonom., subord. to Min. of Petrol. & En.	reform: 1991 benchm.: 1997	T, regional networks, & D (rev. cap)	spot, futures (no physical deliv.), bilat. cont., bal. mkt.	full liberalisation since 1995	T: 1 state D: c.200 (77% public, 23% priv. & mix)	yes	DEA for 190 D units and 90 reg. netw.	large degree of freedom	T: w. Swedish T (Value Chain Method)
Spain	indep., subord. to Min. of Econ.	Jan. 1998	T, D, S (captive consumers) rev. cap	voluntary pool (day, intra-daily, constraints, ancillary ser.) & bilateral contract mkts.	gradual liberalisation - to be completed by 2007	T. grid 74.2% priv. D. private (4 large and many small)	yes	theoretical efficient model/reference firms for revenue retribution among utilities	discretion	-
Sweden	independent, subord. to Min. of Trade & Ind.	reform: 1996	T, D, light handed regulation (no ex ante tariff approval)	spot and forward markets (Nord Pool)	full liberalisation for all customers in from 2000	T:1 central grid (state) D: 20 plus 6 regional Ts (mixed ownership)	intends to use a GIS-based model to compare revs. to a benchmark rev.	the regulator has used DEA and SFA for follow-up but not tariff or revenue regulation	large degree of freedom	no
Other OECD										
Australia ***- New South Wales***	independent	reform: 1996 benchmk.: 1994	T, D S (franchise customers)	compulsory spot mkt. financial contracts between S and G	Jan. 01: 100-160 MWh Jun. 01: 40-100 MWh Jan. 02: 0-40MWh p.a.	T: 1 (government) D: 6 (government)	yes	DEA, TFP, SFA, industry benchmark., partial indicator analysis	full discretion	yes, DEA/TFP and industry benchmarking
- Queens-land	present: Min. of Mines & En. from Dec. 2000: indep. regulator	reform: 1995 benchmarking: (DEA) 1996	T, D S (franchise customers)	national spot mkt., financial contracts	July 99: consumers w. demand > 0.2 GWh p.a.	T: 1 D: 2 all state govt. owned	yes	previously: DEA, currently: econometric, partial & total productivity factors	full discretion	US & Australian distribution utilities (T: 1996)
- Tasmania	independent	1997-98 rev. cap & unbundling of services	T, D as well as G and S for franchise customers	no competitive mkts., seeking to join the national spot mkt..	-	T: 1 (state-owned) D: 1 (state-owned)	yes	independent consultant reports	full discretion	yes
- Victoria	independent	reform: 1995 benchmk.:	T (nation. regul. 2001) D (price cap) S (max. retail tariff)	compulsory wholesale spot mkt, contract mkt.	6o MWh p.a., fr. mid-2001 full liberalisation	T: 1 D: 5	yes	OPEX: statistical industry (partial) benchmarking	full discretion	yes, internat. industry benchmarking
Canada ***- Ontario***	independent quasi-judicial tribunal	reform: 2000 price cap (IPI - utilities TFP+Z)	T, D (IPI–TFP+Z)	spot & bilateral mkts. fr. mid-2001. In the future: emissions & T rights trading	-	T: 1 province-owned D: c.250 municip., 1 province, 4 priv. owned	yes	2000-02: hist. dev. Of TFP for 47 utilities next rate period: yardstick regulation	discretion	possible - for system reliability indicators in the future
Japan	Min. of Int. Trade & Ind.	reform: 1995 – gen./wholesale benchm.: 1995	T, D, & low-volume retail (ROR regulation)	-	March 2000 retail customers w. demand >2000kw & >20000V	10 private vertically integrated	yes	yardstick regulation – 3 perform. groups for setting allowable costs/rate-base	-	-
United States ***- California (SCE)***	independent	reform: 1993 benchmark: 1997	T (ROR), D (PBR) S (bundled customers)	spot market	full liberalisation	private	yes	ROR-base profit sharing	full discretion	no
Non – OECD										
Brazil	independent	reform: 1995	T, D S (partial)	spot market (Sept. 2001)	-	T; 15 (state-owned) D: 65 (private)	fr. 2001	DEA	full discretion	-
Chile	government agency	reform: 1982 benchm.: 1986	T, D S (captive customers)	centralised marg. cost based dispatch pool	demand>2 MW (0.2 MW proposed)	T: 2 D: c.35	yes	yardstick regulation w. reference/model firms	full discretion	-
Colombia	indep., subord. to Min. of Mines & Energy	reform: 1995 benchmark.: 1997	T, D, S (captive customers) PPI-1% price cap regul.	spot 30%, & contracts 70% mkts. Futures mkt (anticipated)	custom. w. demand > 0.1 MW & 55 MWh per month	T: 12 (90% pub. /10% priv.) D: 35 (40% pub. /60% priv. - planned)	yes	DEA for S & T construction costs	full discretion	yes, for T construction costs
India ***- Orissa***	independent	reform: 1995	T, D, S (captive customers) ROR reg.	bilateral long-term PPAs	-	T: 1 (state) D: 4 (state & private)	yes	ROR reward for T/D loss reduction	full discretion	-

Table 4: Benchmarking process

	BENCHMARKING – PROCESS									
	11. Regulatory lag	**12. Iterations / consultations**	**13. Separate OPEX/CAPEX**	**14. Service quality benchmarking**	**15. Incentives for service qual.**	**16. Incentives for optim. invest.**	**17. Incentives for env. impact**	**18. Info. required stand. / audited**	**19. Published information**	**20. Influence of indepen. studies**
OECD–Europe										
Austria	-	-	-	-	-	-	-	not stand. - proven by a consultants	consulting reports	1 study by the ministry, others under discussion
Belgium	1 year	annual 3-month long discussions under preparation	total controllable costs	tbd	-	use of tot. costs in rate-setting, project return analysis	obligation to supply min. 3% green energy by 2004	std. format under preparation, approved auditors	initial consultation documents and informal meetings	yes
Denmark	4 years	yes, 1-2 years	total controllable costs	no	-	tbd	-	standard reporting format audited by utility auditors	yes, statuary orders	indirect through consultants
Finland	annual assessments	yes	DEA study of OPEX (planned)	to be included in the DEA study	by including service quality in the DEA	no	no	questionnaire, some account. info indep. audited	key technical and financial figures	yes
France	-	-	-	-	-	-	-	-	-	-
Great Britain ***England & Wales (T/D), Scotland (D)***	5 years	consultant. papers T: 4 D: 2	yes	no	compensation, loss of licence, fr. 2002 +/- 1% rev. reward	shared savings in investments	no	questionnaire, no explicit audit, some accounting info subj. to audit	consultation docs, & company business plans & submissions	no
- Northern Ireland	5 years	ca. 5 iterations	no	-	-	-	-	-	consultation documents and price reviews	through consultants
Hungary	4 years (1997-2000)	yes, ad-hoc	-	-	-	-	-	cost audit in standard. format	limited to info in annual report	limited
Ireland	likely 3-5 years	open consultation intended	tbd	tbd	tbd	based on RPI-X model and CAPEX assessment	tbd	tbd	tbd	to be established
Italy	4 years (2000-2003)	4 consultation documents	-	penalties for non-attainment of standards	uniform targets after trans. period reducing national /intern. gap	-	-	standardised (in the future also independent audit	-	-
Netherlands	4 years (2000-2003)	3 consultation & guideline documents	no, total controllable costs	from 2001	-	yes	-	standard format & company auditor	consultation docs. & info meetings	New Zealand 1993 study, DEA research
Norway	min. 5 years 2002-2007	1 draft and final proposals	no	-	rev. cap from 2001	½ of expected % growth in delivery added to rev. cap	-	standard format, utility auditors, check by regulator	utility submissions, annual financial, techn. reporting	joint research - ministry, regulator, research orgs.
Spain	not fixed. current period 1999-2002	none	no	tbd – standards and compensation	tbd	rev. cap linked to productivity & demand growth	tbd	info. audited by the regulator	unpublished	research into model networks

Sweden	-	consultations with the industry	has used physical data for capital. intends to use replacement value	-	-	-	an incentive system for renewable energy under study	standard reporting format, audited annual accounts	-	indirect
Other OECD										
Australia ***- New South Wales***	5 years	several iterations	yes	possible in future reviews	-	medium term caps, CAPEX prudency tests, optimisation of asset base	D required to consider DSM in lieu of CAPEX, retailers have targets for renewables & GH emissions	standard format reports, accounts subject to independent audit	efficiency studies, consultant's reports, financial projections	yes
- Queensland	min. 3 years	issue papers / draft determinations	O & M study & CAPEX-OPEX trade-offs	fr. 2001consistent measuring of indicators & complaints reports	under preparation	benchmarking & DORC asset valuation method	-	independent audit – std. reporting formats under development	issue papers and determinations public	limited
- Tasmania	min.3 max 5 years	consultations, issue papers, draft reports	OPEX: benchm. CAPEX: DORC method	intended use of Australian benchmarks	-	'market benefits test' for inclusion of CAPEX in rate-base	-	audited info in specified format and guidelines	price determine. limited consulting reports	no
- Victoria	5 years	several iterations	yes	proxy benchmarks	reward and penalty	yes, with efficiency carry over to next regulatory period	-	utility auditors, standard reporting format planned	issue/consultation papers, draft decisions	indirect
Canada ***- Ontario***	3 years (current regulatory period)	two-year consultation period	-	1st PBR period: min. quality standards 2nd.: benchmark. of collected data	2nd PBR period	through price cap mechanism	incentives for DSM in the 2nd. rate period	standard format & audited by the regulator	consultation papers & information	-
Japan	upon submission of proposal for price revision	-	-	-	-	-	-	-	-	-
United States *- California* (SCE)	5 years	several iterations	yes	yes	yes, quality standards	-	-	-	PBR guidelines, applications, decisions	-
Non - OECD										
Brazil	4 years	at least 1	-	MCDA	penalties	-	-	standard format reporting, audit by the regulator	-	research sponsorship
Chile	4-5 years	yes	separate	standards	penalties, revoking license	yes	-	standard format, company auditors	-	-
Colombia	5 years	at least 1 consult. doc. 1 year prior to application	benchm. total controllable costs	international benchm. of product & techn. service in S	compensation to customers	yes	-	standard format & no formal auditing	no	yes
India ***- Orissa***	variable	variable	-	performance standards	-	-	-	standard reporting format, audited utility accounts	-	-

Abbreviations - D: distribution T: transmission S: supply tbd: to be decided w.: with fr.: from mkt.: market SCE: Southern California Edison

5.2.3 From Benchmarking to Price-Setting

The previous sections discussed the diversity of the benchmarking methods adopted by regulators. This section outlines the differences in the regulators' approach to translate benchmarking results into X-factors and price-setting. In liberalised power sectors the distribution function is often separated from supply or retailing. However, where there is no separation of distribution and supply, the X-factor for the distribution function can be applied to a rate base which excludes power purchase costs. Specific targeted incentive regulation schemes can then be designed to promote efficiency in power purchasing. Tables 5 and 6 summarise the main features of this process for distribution and transmission utilities respectively in selected countries.

As shown in Table 5, the Norwegian regulator uses a rather formalised approach involving a linear conversion of the efficiency scores from DEA into efficiency requirements. Also, the regulator uses the total controllable costs in benchmarking. These features may be explained in the light of the large number of distribution utilities in the sector which makes an equitable and consistent treatment of capital expenditures and X-factors of individual utilities rather difficult. In the Netherlands, England and Wales, and New South Wales where there are fewer utilities the regulators limit the scope of benchmarking to operating expenditures and treat capital expenditures individually. In New South Wales with just 6 distribution utilities there is no formalised procedure for conversion of efficiency scores into X-factors.

Chile represents an exception in this regard and as discussed previously the 35 utilities are benchmarked against efficient model firms. In California, Performance Based Regulation schemes are negotiated individually, the regulator uses rate of return regulation based on profit sharing which does not require direct comparisons. This approach is also consistent with the US legal environment which favours the use of utilities' actual costs rather than that of the most efficient technology and configuration available.[18]

Table 6 shows setting the X-factor for the central transmission grids in the Netherlands and Norway the two countries in our sample which make their benchmarking process clear. The Dutch regulator has used DEA and a large international sample of transmission utilities in order to overcome the lack of comparators in the domestic power sector. In Norway, in contrast to benchmarking of distribution utilities, the regulator has chosen a one-to-one benchmarking relative to the Swedish transmission utility. This approach appears to a large extent to be motivated by the view that the topography of the Statnett's operating environment is a crucial factor. The choice of the one-to-one benchmarking method of Value Chain Method which recognises and allows for such differences also reflects this view.

The following section highlights three cases of price setting and regulation involving different approaches to incentive regulation and benchmarking.

[18] See for example USCA (2000) for a ruling against the use of predictive pricing methodologies.

Table 5: Benchmarking and incentive regulation of distribution utilities in selected countries (latest price review)

Country	Benchmarking/regulation method	Benchmarking sample	Inputs and outputs	From benchmarking to X-factor/reward
Great Britain	COLS analysis of OPEX Revenue cap	14 RECs in Great Britain	Input: OPEX Output: Composite variable (50% no. of customers, 25% electricity distributed, 25% network length)	High-cost utilities must move 75% of the distance to efficient frontier by 2001/02.
Netherlands	DEA: total controllable costs Revenue cap	19 Dutch utilities	Input: OPEX Output: units, peak demand high voltage, peak demand low voltage, network length, customers small, customers large	Benchmarking analysis and analysis of OPEX. X=8 to -2 for individual companies. Assume all inefficiency for companies below the maximum cap of 8 eliminated by year 3 and a frontier shift of 2% per annum (some companies could have been given up to X=17).
Norway	DEA: total controllable costs Revenue cap	Ca. 180 national regional networks and distribution utilities	Inputs: Capital (book value & repl. cost), goods/services, losses, labour Outputs: No. of customers, energy deliv., length of lines & sea cables	Utility's revenue cap for the 1998-2001 is reduced with 38.2% of the distance of utility's eff. score from the frontier: A 70% score means 11.5% rev. cap reduction or 3.5.% p.a. plus a 1.5% p.a. general eff. requirement.
Australia ***- New South Wales***	DEA, SFA, TFP Revenue cap	219 utilities – New South Wales, other Australia, New Zealand, England & Wales, and US	Inputs: Tot. O&M costs, transformer cap, network size Output: Electricity sold, no. of customers, peak demand	Various forms of benchmarking are used but there is not a single 'preferred' benchmarking technique or an automatic translation of the results of quantitative benchmarking analysis into the pricing determinations.
California ***- Southern California Edison***	ROR-based profit sharing Price cap	-	-	$P_0=P_{1996}$, $X_{1997}=1.2\%$, $X_{1998}=1.4\%$, $X_{1999\text{-}2001}=1.6\%$ -/+50 bps -> shareholders receive all revs./losses -/+50-300 bps -> shareholders' marg. share 25 to 100% -/+300-600 bps -> sharehlders receive the gains/losses >600 bps -> triggers rate review
Chile	Efficient theoretical reference / model firm Yardstick regulation	-	Input: CAPEX, O&M, losses, and customer related costs (low, medium, and high voltage) Output: Added distribution value (ADV) for efficient model firms	The estimated ADV (tariffs) for the model firms are applied to comparable real distribution utilities.

Table 6: Benchmarking and incentive regulation of transmission utilities in selected countries

Country	Benchmarking/regulation method	Benchmarking sample	Inputs and outputs	From benchmarking to X-factor/reward
Netherlands	DEA Revenue Cap	40 international utilities (Sweden, Spain, UK, Germany, US, Norway, Finland)	<u>Input</u>: Total Cost <u>Output</u>: Units Transmitted (kWh); Maximum Simultaneous Demand (MW); +220kV Circuit Lines (km); and Transformers (number) Efficiency: 70% (2000)	X=4.2% including an assumed frontier shift of 2% p.a.
Norway	Value Chain Method (VCM) Revenue cap	One-to-one benchmarking against the Swedish transmission company - Svenska Kraftnät	<u>Input</u>: CAPEX & OPEX costs (C) , Units/No. of cost drivers (net length, transformers, connectors, stations) multiplied by assigned weights (CD) <u>Output</u>: C/CD used to compare relative efficiency ● CAPEX eff. = 71.6% ● OPEX eff. = 79.2% ● Total eff. = 74.0%	Utility-specific efficiency requirement = 2.36%p.a 1997-01. (same conversion method as for the distribution utilities, some costs not included in the revenue cap) General efficiency requirement = 1.50%p.a. 1997-01

5.3. Selected Benchmarking Cases

Southern California Edison (SCE)

The state of California began in 1990 to study replacement of the cost-of-service regulation for gas and electric utilities with performance based regulation. Since 1993, the California Public Utility Commission (CPUC) has adopted various PBR schemes for generation and dispatch, base rate, gas procurement, and other operating revenues.[19] The SCE PBR was adopted in 1997 for transmission and distribution. In 1998, due to restructuring of the sector, this PBR was limited to distribution only. The SCE PBR incorporates: (i) a rate-indexing or RPI-X price cap formula, (ii) a revenue sharing mechanism, (iii) a cost of capital trigger mechanism, (iv) a Z-factor, (v) service quality performance incentives, and (vi) a monitoring and evaluation programme.

The initial rate (P_0) was derived from 1996 tariffs and for subsequent years, the X-factor was set at 1.2% (1997), 1.4% (1998), and 1.6% (1999-2001). The revenue sharing mechanism is based on a benchmark return on equity (ROE) established by the Commission and three rate bands surrounding the return. In the inner band (-/+50 basis points) the shareholders receive all net revenue gains or losses. In the middle-band (-/+ 50-300), the shareholders marginal share rises from 25 to 100%. In the outer-band (-/+300-600) shareholders receive the gains and losses. Outside the 600 basis points, the PBR scheme is re-evaluated. The cost of capital trigger mechanism makes provision for adjustment of the allowed return on equity based on half the change in a AA bond index value. The authorised ROE for 1997 to 1999 has been 11.6 % while the actual return has been 13.55% in 1997 (adopted), 11.16% in 1998 (reported), and 11.31% in (1999-reported). The high ROE in 1997 resulted in a ratepayer revenue share of $40.6 million or 6.7% and 3.8% of the utility's total net and operating income respectively. The Z-factor makes allowance for costs incurred due to extraodrdinary events such that are beyond the control of the utility's management such as changes in tax laws and natural disasters.

The service quality incentives comprise service reliability, customer satisfaction, and employee health and safety. Service reliability comprises outage duration and outage frequency benchmarks. The outage duration benchmark is 59 minutes average customer outage in 1997 and declines by 2 minutes in subsequent years. A dead-band of 6 minutes surrounds the benchmark. No penalty is payable if the utility achieves an average of 55 minutes for the 1997-2001 period. The reward or penalty is $1 million per minute for two-year averages with an upper limit of $18 million for outage and frequency. The frequency benchmark is 10,900 annual interruptions with $1 million reward or penalty for each 183 interruptions.

Customer satisfaction is measured by independent surveys and the satisfaction benchmark is 64%. The main reward and penalty is $2 million for each percentage below or above a 3% dead-band. The employee health and safety benchmark in brief is a ratio index of the number of accidents and illnesses. The benchmark value is 13 with a dead-band of 0.3 and $555,000

[19] See CPUC (2000) for reviews of this and other PBR cases adopted in California.

reward or penalty for 0.1 deviation increments beyond the band. The monitoring and evaluation programme includes procedures such as change of prices and cost of capital as well as revenue sharing and performance results.

Norway

The Norwegian power sector liberalisation began in 1991 as one of the first market-oriented attempts to reform the sector. The reform involved restructuring of the state-owned utility Statkraft, unbundling of services, and introduction of competition into electricity generation and supply. Unlike the England & Wales model, the Norwegian reform did not affect the ownership structure of the sector which is predominantly state, municipality, and county-owned.

Until 1996, the transmission and distribution activities were subject to cost of service regulation. Since 1997, an incentive-based revenue cap regulation was adopted for the central transmission grid, 40-50 regional transmission utilities, and ca. 200 distribution utilities. The central grid is owned by the state-owned company Statnett while the regional transmission and distribution utilities are owned by municipalities and counties. The utility profits are the difference between the revenue cap and actual costs and can vary in the range of +/-7% around the normal rate of return (currently 8.3%). The length of the current regulatory period is 5 years. The revenue cap for the initial year is shown in Equation (9).

(9) *Initial revenue cap = Expected network loss * Expected spot price + Revenue cap before network losses*

The revenue cap before network loss was based on average costs in 1994 and 1995. Also, the expected network loss is equal to average physical loss in 1994 and 1995. The initial revenue cap is then adjusted using Consumer Price Index, average spot price on the Nordic Power Exchange (Nord Pool), and 50% of the expected percentage increase in supply growth. The revenue cap is then further adjusted using an efficiency factor X that comprises a 'general' and a 'utility-specific' component.

The utility specific X-factor is calculated from DEA analysis of the distribution utilities while for Statnett the X-factor is calculated from Value Chain Method and comparison with the Swedish utility Svenska Kraftnät (see Magnus and Midttun 2000). From 2001 the revenue caps will be adjusted for quality of supply. The amount of reward or penalty equals the increase or decrease in the cost of interruptions to customers.

In 1997, a general efficiency requirement of 2% applied to all utilities and no utility-specific X-requirement. In 1998, the general X-factor was set at 1.5% while the weighted average of utility-specific X-factors was 0.6%. The corresponding figures from 1999 to 2001 are 1.5 and 1.1% respectively. In 1999, the total revenue cap for the utilities amounted to 14,360 million NKr.[20] In comparison, the total efficiency improvement requirement for the same year was 370 million NKr. The utility-specific efficient requirement amounted to 157 million NKr, of

[20] $1≈NKr 9.

which 70 million NKr applied to distribution utilities and 87 million NKr to regional networks.

Great Britain

The power sector reform in Great Britain began in 1990. The reform has involved restructuring of the industry, introduction of competition into generation and supply, and large-scale privatisation. The regional distribution utilities in England and Wales, which jointly owned the national transmission grid, were privatised in 1990 followed by most of generation capacity in 1991.[21] The regulated segments of the sector are the transmission grid National Grid Company (NGC), and distribution utilities. In addition, the domestic supply activities of the distribution utilities is subject to price cap regulation.

Some form of benchmarking is used in regulation of all regulation activities. The benchmarking of transmission grid for the current 4-year price control period (1997-01) involve TFP, DEA, and an international survey of 15 transmission utilities (OFFER 1996).[22] In setting the price caps for domestic supplies the regulator has used comparison and benchmarking of total operating supply costs. There is no regulation of independent suppliers (OFGEM ,1999c).

In regulation of the distribution utilities, the regulator considers the operating costs, value of existing assets, cost of capital, need for new investments, expected productivity growth, and competition conditions in setting the revenue caps (OFGEM, 1999). The regulator uses a high level benchmarking of total OPEX as well as an activity level benchmarking of specific types of operating costs such as engineering, information technology, and human resources. In addition, the regulator has used benchmarking of capital expenditures for average replacement costs across the companies for a particular asset age profile.

In setting the revenue caps for individual distribution utilities, the present value of the total revenue cap for the duration of the rate period is calculated. The revenue cap for each year is then determined based on utility-specific initial price levels P_0 and X-factors which are set simultaneously. There is therefore an infinite number of possible combinations of P_0 and X-factor. The regulatory period for distribution utilities is 5 years. For each period, prices for the initial year(s) P_0 vary across the utilities while they share the same X-factors. For example, for the rate period 1995/6-1999/00, the X-factors for 1996/97 and 1997/98 averaged 14 and 11.5% respectively and 3% p.a. for the 1997/98-1999/00 period. Similarly, for the current period 2000/01-2004/05, the average X-factor for the initial year 2000/01 is 23.4% (some of which accounts for transfers to the supply business) and 3% p.a. for the 2001/02-2004/05 period.

The price control review for the regulatory period 1995-2000 assume that the less cost efficient distribution utilities “move three quarters of the way to the efficient frontier by 2001/02 and retain that position relative to the frontier” (OFGEM, 1999a, p.21). Also, the

[21] The 2 Scottish public electricity suppliers were also privatised in 1990 but remained as vertically integrated companies.

[22] The next price control period is extended to 5 years (2001-06).

three utilities that are closest to the efficient frontier were rewarded with 1% of their price control revenue.

There have also been several incentive schemes that involve adjustments to price control revenues in respect of performance in the previous regulatory period. For the first year of the current rate period for distribution (2000-01), these 'within the range adjustments' could potentially amount to up to +2.0/-2.25% of the revenue. The actual maximum revenue adjustments however amounted to -1.25%. For example, efficiency in capital expenditure could be rewarded with up to +/-1% of the revenue. In addition, reward and penalty schemes were tied to customer satisfaction, quality of supply, energy efficiency, and accuracy of forecasts (penalty only) (OFGEM, 1999a; OFGEM, 1999b). From 2002 to 2005 quality of supply is due to be annually benchmarked using utility-specific quality targets that are tied to financial rewards and penalties. The maximum amount of revenue which will then be exposed to 'within the range adjustments' will be +/-2% p.a.

6. Conclusions

In closing we summarise the international experience to date from countries that have used benchmarking in incentive regulation. We then outline the main outstanding issues associated with the use of benchmarking and draw some lessons for best-practice implementation by regulators.

The incentive regulation and benchmarking in most countries is in the first or second regulatory period. Our survey showed that a number of regulators are using or considering benchmarking in the regulatory process. Most reforms have involved establishing independent regulatory authorities. New regulators seem to be less bounded by path dependency of institutional constraints to adopt new regulatory tools such as benchmarking. Therefore, benchmarking is likely to become more common as more countries implement reforms.

The time lag between implementation of reforms and establishing new regulatory agencies and adoption of benchmarking appears to be decreasing. As the number of regulators increases, there is more scope for exchange of experience with regulators in other industries and countries. Most incentive regulations use price and revenue caps. As we saw, the Southern California Edison’s PBR is essentially a price cap regulation with profit sharing. Sharing mechanisms are uncommon although the UK also uses such a scheme for new investments. We did not find benchmarking cases with explicit treatment of environmental impacts. There is however a desire in the United States for the inclusion of DSM programmes in PBRs.

Further, we found that benchmarking is mostly practised in countries with well-developed upstream competition, spot market, and a high degree of market liberalisation. Finally, to the extent that consultation between the regulator and industry and high degree of published information are regarded as indicators for transparency of the regulatory process, most benchmarking countries exhibit such transparancy.

Outstanding Issues

Although a number of regulators have used benchmarking and more are likely to do so, some theoretical issues are still open to debate. Frontier approaches are susceptible to shocks and errors in data. This is especially the case when cross-sectional data is used and there is no allowance for errors. In order to minimise problems due to data errors there should be very careful handling of data accuracy. For example, Norway and UK have made considerable effort to improve data standardisation and accuracy.

Firm specific efficiency scores are sensitive to the specification and assignment of the outputs, inputs and environmental variables. This raises questions as to the robustness and accuracy of calculated X-factors based on unstable rankings. The UK regulator has adopted a simple regression model with one dependent (cost) and one independent variable (composite output) to increase data robustness while Norway, perhaps due to a large sample size, has been able to adopt a more elaborate DEA model.

A problem with frontier methods is that it is not clear whether the frontier provides a valid comparator even in the absence of data errors and shocks. For instance in DEA models that assume constant returns to scale, a firm may be compared to a part of the frontier defined by firms of radically different scale. To reduce these problems some regulators such as in the UK just use national samples in benchmarking.

Separate analysis of capital and operating costs encourages intermediation between these cost categories. For example, firms may attempt to argue for higher capital costs to reduce operating costs. While benchmarking should ideally apply to total costs, this is difficult given the heterogeneous nature of capital. As a result, regulators in the UK and Norway have struggled with how to handle the possibility of intermediation. International comparisons are often restricted to comparison of operating costs because of the heterogeneity of capital but this may limit their applicability.

The calculation of the likely future rate of movement of the frontier is problematic. Measures of past productivity growth usually include both frontier shift effects and movements towards the frontier. However, the problem of estimating this is minimised if firms are compared to world best practice as, the range of variation in estimates of world best practice frontier shifts (given international benchmarking) is small (1-2% p.a.).

Once efficiency scores are calculated the crucial assumption in deciding the X-factors is the rate at which efficiency gaps can be closed. Therefore, national regulators will need to make allowance both for this and for in-country heterogeneity. In international comparisons, firms in some countries will be able to close the gap faster than others.

A major reservation against assigning firm specific X-factors has been that the cost saving incentives are blunted if companies are not allowed to retain efficiency savings beyond the next price review. Benchmarking may result in firms having to run to stand still and hence there may be strong incentives to subvert the regulatory process.

International benchmarking raises particular difficulties. The most notable issue is that of comparability and quality of data which may only be improved in time and requires co-operation among the regulators. In addition, when comparing monetary units the correct handling of currency exchange rates is of particular importance. The relative differences in input prices (e.g. wage rates, taxes, and rates of return on capital) beyond the control of the firm may have to be taken into consideration.

Finally, design and implementation of incentive regulation schemes in developing countries may have to take certain political issues and concerns into consideration. In some Latin American countries, the governments, in order to guarantee regulatory commitment and to the secure success of privatisation programmes, have directly negotiated the terms (e.g. price caps) of the initial post privatisation rate periods with utilities and thus limited the regulators' discretion. Another concern is that of price subsidies in place which often serve social and political objectives. In other countries, it is important to maintain national uniform final electricity prices.

Lessons for Best Practice Implementation

Based on the results of the survey and the above theoretical and empirical concerns we can draw some lessons for implementation of benchmarking in regulation.

The regulators should use cost-linked benchmarking to calculate X-factors in the early period following power sector reforms. Benchmarking exercises should be viewed as just a transitional regime until competition can be introduced into the sector or international best practice arrives.

International benchmarking is more useful for comparison of transmission utilities as there is often a lack of domestic comparators. In addition, countries with a small number of distribution firms can benefit from international comparisons. Also, international benchmarking is generally advantageous in the case of non-US firms, as these are likely to be behind the frontier.

It is important that the regulators collect national and international data through formal co-operation and exchange. New regulators need to pay ample attention to developing good data collection and reporting systems. A precondition for international comparisons is to focus on the improving the quality of data collection process, auditing, and standardisation within and across countries.

The issue of choosing the most appropriate benchmarking methods and model specification can not be settled on theoretical grounds. Therefore, benchmarking should not be confined to a particular technique. In each case, regulators should use the latest techniques such as DEA, COLS, SFA, and partial benchmarking as well as sensitivity analysis to examine the consistency of results and robustness of the rank orders.

The regulator should also use benchmarking in order to estimate the scope for efficiency improvement subject to error bounds. In keeping with transparency criteria for regulatory governance regulators should publish data, method, and results and as an information revelation device and invite comments and solicit more information.

Further, benchmarking methods and their raw results should not be regarded as replacements to decision-makers and their judgements. Rather, the primary function of benchmarking methods is to serve as decision-aid tools that can help decision-makers overcome bounded rationality in a complex decision environment. Therefore, as in any area of public policy, regulatory decisions should ultimately be based on decision-makers' judgements and discretion.

Finally, it is important that the regulator has full discretion with regard to several aspects of the data, models, and methods used in benchmarking. The regulator should be free to decide specification of the important factors for national utilities and in weighting the results from different techniques. The regulator should exercise discretion through assessing the scope for future frontier shift, predicting the rate of demand growth and crucially in the estimation of the rate at which efficiency gaps should and can be closed. Benchmarking methods are an important decision-aid. However, they do not mean that regulators can not or should not use their informed judgment in setting prices and performance targets.

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