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International Benchmarking of Electricity
Transmission by Regulators: Theory and
Practice

Aoife Brophy Haney and Michael G. Pollitt

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Abstract Benchmarking of electricity networks has a key role in sharing the benefits of efficiency improvements with consumers and ensuring regulated companies earn a fair return on their investments. This paper analyses the theory and practice of international benchmarking of electricity transmission by regulators. We examine the literature relevant to electricity transmission benchmarking and conduct a survey of 48 national electricity regulators. Consideration of the literature and our survey indicates that electricity transmission benchmarking is significantly more challenging than electricity distribution benchmarking. New panel data techniques aimed at dealing with unobserved heterogeneity and the validity of the comparator group look intellectually promising but are in their infancy for regulatory purposes. In electricity transmission choosing variables is particularly difficult, because of the large number of potential variables to choose from. Failure to apply benchmarking appropriately may negatively affect investors' willingness to invest in the future. While few of our surveyed regulators acknowledge that regulatory risk is currently an issue in transmission benchmarking, many more concede it might be. New regulatory approaches – such as those based on tendering, negotiated settlements, a wider range of outputs or longer term grid planning - are emerging and will necessarily involve a reduced role for benchmarking.

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International Benchmarking of Electricity Transmission by Regulators: Theory and Practice

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Abstract

Benchmarking of electricity networks has a key role in sharing the benefits of efficiency improvements with consumers and ensuring regulated companies earn a fair return on their investments. This paper analyses the theory and practice of international benchmarking of electricity transmission by regulators. We examine the literature relevant to electricity transmission benchmarking and conduct a survey of 48 national electricity regulators. Consideration of the literature and our survey indicates that electricity transmission benchmarking is significantly more challenging than electricity distribution benchmarking. New panel data techniques aimed at dealing with unobserved heterogeneity and the validity of the comparator group look intellectually promising but are in their infancy for regulatory purposes. In electricity transmission choosing variables is particularly difficult, because of the large number of potential variables to choose from. Failure to apply benchmarking appropriately may negatively affect investors' willingness to invest in the future. While few of our surveyed regulators acknowledge that regulatory risk is currently an issue in transmission benchmarking, many more concede it might be. New regulatory approaches – such as those based on tendering, negotiated settlements, a wider range of outputs or longer term grid planning – are emerging and will necessarily involve a reduced role for benchmarking.

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Section 1: Introduction

Electricity transmission utilities provide electricity transport services across high voltage wires. They often, but not always, combine their core function of the maintenance of transmission system availability, with real time system operation to synchronise electricity supply and demand within their control area. Energy Regulators across the world regularly engage in benchmarking of the transmission and distribution network utilities that they are responsible for regulating (see Jamasb and Pollitt, 2001). In many jurisdictions, benchmarking is an integral part of periodic price/revenue reviews during which regulated prices/revenues are determined for a fixed period. The benchmarking of electricity transmission presents a particular challenge for regulators because, unlike in distribution, there is usually only one or a very small number of transmission utilities operating within the jurisdiction of one regulator. This reduces the scope for national comparisons of efficiency between firms with identical accounting and technical standards. This necessarily makes benchmarking transmission more challenging than benchmarking distribution and suggests that international benchmarking is something that regulators need to consider.

International benchmarking of transmission utilities implies the comparison of very different entities, performing a wider range of functions than distribution utilities, while operating at a wide range of scales and in contrasting operating environments. While there are a significant number of international electricity companies that operating generating plants, distribution systems and retail businesses in a number of regulatory environments (e.g. the dominant EU players - EdF, RWE, EoN, Vattenfall, ENEL and Iberdrola) there are only a handful of international transmission companies (in Europe only TenneT, elia/50 Hertz and National Grid operate in more than one country). This suggests that utilities themselves have little direct experience of international benchmarking of transmission, in contrast to their experience in distribution.

This paper discusses the use of international benchmarking, including the use of frontier efficiency techniques (such as data envelopment analysis and stochastic frontier analysis), of electricity transmission by regulators. We attempt to draw attention to the methodological issues around benchmarking transmission and to suggest what we can learn from previous studies. We also make use of a survey of national electricity regulators to contrast the lessons from the literature with the actual experience and practice of energy regulators with benchmarking. A key aim of the paper is to suggest where transmission benchmarking within regulation should be heading in the future.

The paper proceeds as follows. In section 2 we discuss what international benchmarking is trying to do within economic regulation. We then go on to look at the previous literature on electricity transmission benchmarking in section 3. Section 4 looks at the difficulties of collecting and comparing data on transmission companies. Section 5 introduces the methodological issues in frontier benchmarking with particular application to transmission utilities. Section 6 makes some suggestions on what should be done to benchmark electricity transmission. Section 7 suggests what regulators should actually do about transmission, drawing on a recent international survey of **48** national energy regulators. Section 8 offers a conclusion.

Section 2: What is the role of (international) benchmarking within regulation?

It is important to situate international benchmarking with the regulatory price review process. International benchmarking is itself only a particular form of regulatory benchmarking. The role benchmarking within regulation is by no means uncontroversial.

Some authors are critical of ad hoc nature of benchmarking as practiced by regulators. For instance Weyman-Jones (2006, p.25) suggests that ‘The overwhelming impression of regulatory and governance case studies is that sample size, variable choice, model

specification and choice of methodology has been governed by different objectives from those in the theoretical literature.'

However other writers recognise that the purpose of benchmarking is not the accurate measurement of efficiency. Thus Waddams (1999, p.11) states that '[m]uch of the political debate now centres around [] distributional issues, focussing on allegations that consumers have not received a sufficient share of the benefits.....Because the...system depends on independent regulators who have used their ... discretion to develop a variety of regulatory review procedures, they display considerable variation in using productivity studies...'

Weyman-Jones seems to be suggesting that the rationale behind what regulators actually do is difficult to explain and that there is an unwelcome divorce of theory from practice. By contrast, Waddams is pointing out that there is a national context for regulation (in her case in the UK) which does explain what might be going on: namely regulation occurs because of concerns about consumer welfare (not efficiency per se) and that regulators have a large amount of discretion in the techniques they adopt (and hence could adopt the most sophisticated ones if they wished, but often choose not to).

The basic financial context of benchmarking for a fixed period is illustrated in Figures 1A and 1B below.

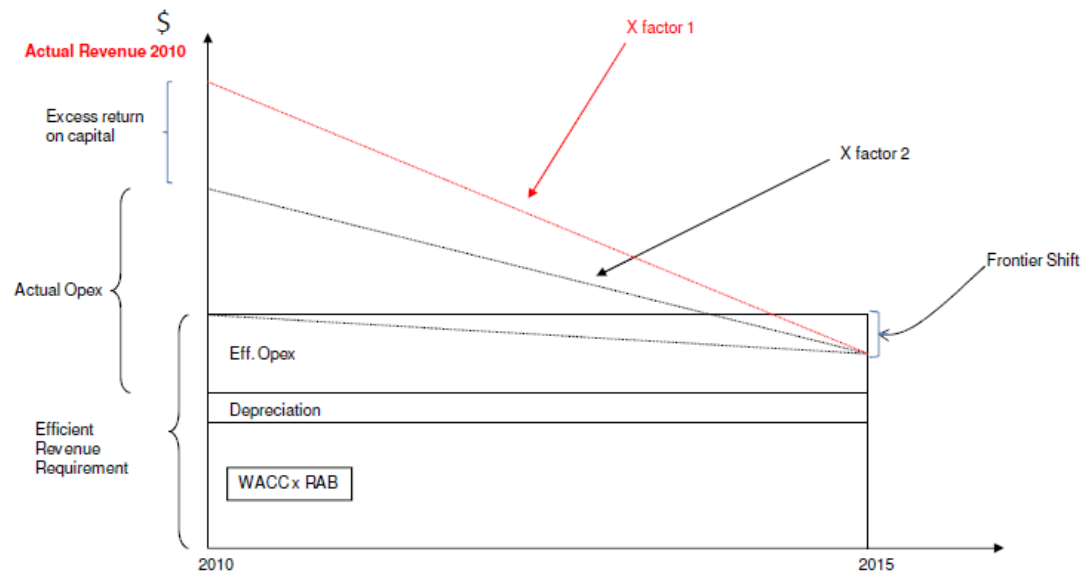


Figure 1A: Regulated revenue over a price control period with constant asset base

Figure 1A shows the actual and efficient revenue of a regulated network company over the period of a price control from 2010 to 2015. The efficient revenue requirement for 2010 is shown on the left as comprising of the sum of efficient opex + depreciation + weighted average cost of capital (WACC) \times regulatory asset base (RAB). However given that actual 2010 revenue is higher than this, it is up to the regulator to determine an X factor pathway which reduces to the efficient level by 2015 (assuming that the regulator wishes to ensure convergence to the efficient level of revenue by this date). The actual level of revenue in 2010 is higher than the efficient level of revenue due to a combination of high operating costs and excess return on the regulatory asset base. Over regulatory control period there might be some further improvement in the efficiency of an efficient firm (shown by the amount of frontier shift). This leaves the regulator to choose between various combinations of initial revenue adjustments and X factors which determine a pathway to the efficient level of revenue by 2015. X factor 1 (in red) is a regulatory settlement which involves a constant (in absolute terms) annual reduction in revenue. X factor 2 (in black) also ensures convergence to the efficient level of revenue by 2015, but because it reduces the first year

revenue sharply (followed by a lower annual absolute rate of revenue reduction) involves substantially less overall revenue for the regulated company. Benchmarking enters into the revenue control process as a way of determining the efficient level of revenue to which a given regulated company should be expected to converge.

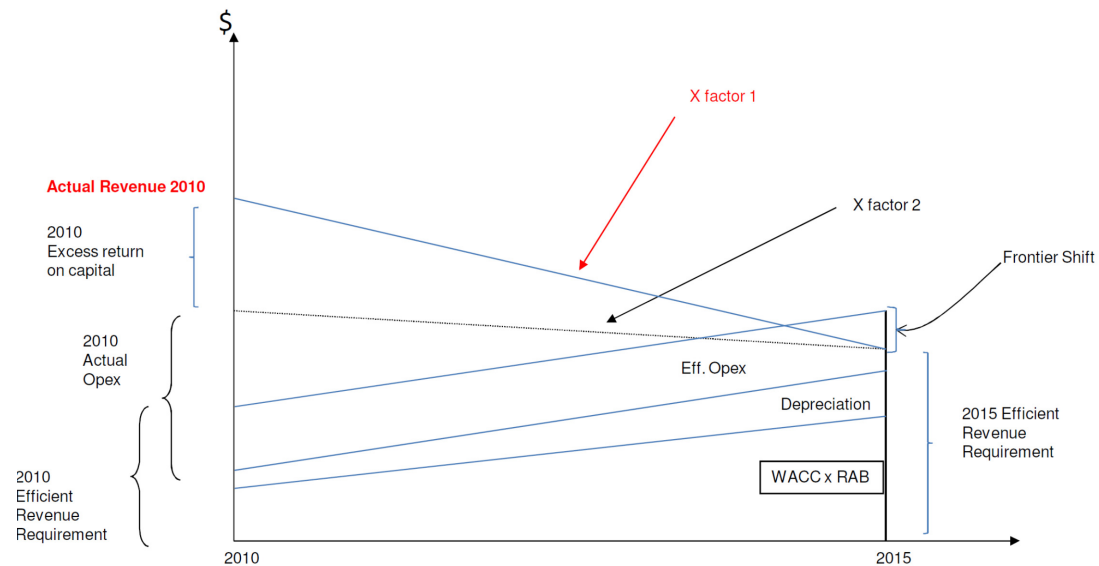


Figure 1B: Regulated revenue over a price control period with rising asset base

Figure 1B illustrates the regulated revenue requirements for a regulated utility with a rising regulatory asset base over the price control period. Over the price control period the regulatory asset base significantly increases, increasing associated depreciation. There is some frontier shift over the period. Two potential pathways of regulated revenue are shown. X factor 1 gradually eliminates both the excess return on capital and the excess expenditure on operating costs over the period to reach the efficient level by 2015. X factor 2 immediately eliminates the excess return on capital and assumes that the excess operating expenditure will be eliminated gradually over time. Both these X factors indicate less sharp declines in revenue than in Figure 1A due to the rising efficient revenue requirements due to net new investment over the period.

It is important to establish that efficiency analysis happens within a process (see Mulder, 2012). That process is interactive, does involve negotiation and is subject to external ex post scrutiny. That scrutiny asks the 'so what' and 'prove it' questions and is potentially very significant in any context. As such it would be wrong to condemn simple benchmarking models as 'wrong' or 'ineffective' per se. They may be useful negotiation devices to be employed by the regulator for public benefit to discover best practice. If their results bear little relation to reality then there is room for challenge within the process.

It is important to emphasise that Figures 1A and 1B implicitly assume that the regulatory asset base is given. This is because would be wholly inappropriate for regulators to agree to an initial level of RAB and then to appropriate part of it at a subsequent price review. In this sense efficiency assessments and the frontier shift should not be applied to all of the revenue required to finance existing assets within the regulatory asset base. It is legitimate for regulators to incentivise efficient new investments within a regulatory price control period (e.g. via menu regulation of capital expenditure) and, potentially, disallow the addition of some capex to the RAB. However once the starting RAB has been established for each price control period it should be allowed to earn at least its WACC + depreciation. It is important that regulators do not confuse the revenue requirements of an efficient return to the RAB (which reflects past inefficiencies), with an efficient RAB (which ignores historical regulatory decisions).

A regulatory price or revenue review sets X factors set for a period (3-5 years)². The fixed path of prices or revenue provides both an incentive mechanism and a device for distribution between customers and the regulated firm. It is the fixity of the price control

² Ofgem have recently increased their review period to 8 years.

period that provides the incentives to cost efficiency.³ Thus the X factor is primarily about distribution. However some cost endogeneity observed, in that subsequent cost reductions do seem influenced by the size of the X factors.

Why might the size of X matter for productive efficiency? This might be because X reveals information to the regulated firm; affects investment; and may effect stakeholder bargaining, e.g. with unions or suppliers (Dalen et al, 2003). Does the size of X matter for allocative efficiency? Yes, it certainly does in the short run. However, in the long run it depends on the extent to which X is sustainable. X factors which are set too high to begin with may lead to regulated firms being left with too little revenue and therefore not be sustainable. Regulated prices which are below the economically efficient level are allocatively inefficient (leading to over-consumption of the regulated good). There is also a related issue of whether the regulated revenue reflects the replacement value of the capital (rather than simply the historic cost). Regulated prices which lie below the replacement cost may result in allocative inefficiency due to prices being below long run marginal cost. However traditionally regulators and governments have found raising prices to reflect the replacement value of capital rather difficult when replacement costs are much higher than historic costs (as they often are in network industries).

The theory of incentive regulation appears to lie behind regulatory benchmarking. This is only partially true. Regulators could do no benchmarking and simply fix an arbitrary price (for five years) and this might have the same incentive properties as X factors set on the basis of sophisticated frontier benchmarking. Hence the actual value of X is largely about the distribution of surplus between companies and consumers.

³ Menu regulation of capital expenditure which shares savings relative to planned capital expenditure does not rely on the length of the review period for its incentive property, but instead on the percentage of any savings which can be retained by the firm.

In reality only a small percentage of costs are benchmarked. For example consider the GB electricity distribution price control for the period 2005-2010, beginning in 2005-06 (discussed in Pollitt, 2005). In establishing a baseline efficient regulated revenue level for this price control period only operating costs were benchmarked. Thus for one of the regulated firms, United Utilities:

- £67.1m (in 2002-03) represented the normalised operational costs to be compared.
- £54.8m (82% of the normalised operational cost) represented the efficient costs.
- £67.0m represented the allowed costs (the difference being mainly local taxes).
- £220.9m was the total allowed revenue in 2005-06.
- £205.2m was the actual revenue in 2004-05.

There are a number of interesting things to note about this example. First, only normalised operational costs were benchmarked because this was the amount of regulated revenue that was deemed to be comparable among the comparator group of 14 distribution companies. This implies that only 33% of revenue was benchmarked. Second, the dates are significant. Benchmarking could only be done on historic data (for 2002-03) for a price control starting in 2005-06. This suggests the significant lag between analysis and implementation that exists in any regulatory benchmarking exercise. Third, the small share of revenue subject to benchmarking implies that benchmarking is only one factor substantially affecting the regulated revenue in the next price control period. We can observe this by noting the effect on regulatory revenue of varying some key parameters:

- +/- 5% on efficiency score: +/- £3.4m
- +/- 1% p.a. on frontier shift: -/+ £2.7m (by year 5)
- +/- 1% on rate of return: +/- £9.2m

- +/- 10% on capital expenditure: +/- £11.2m

This implies that from the perspective of the regulated firm there might be significant room to accept crude, and possibly overly harsh, benchmarking of operating cost (opex), if one has got a better deal on other elements of revenue. However it does not mean that the basis for the benchmarking is valid or sustainable in the long run, simply because it has been accepted by the firm to date.

Lovell (2006) suggests where we might look for best practice in efficiency analysis. First, he suggests that benchmarking should involve frontier efficiency methods (DEA / SDEA / COLS / SFA). This is considered to be an improvement on a simple unit cost approach, because it involves more variables and the potential for internally consistent trade-offs. Second, he advocates the use of a large and high quality dataset involving panel data. This has the advantage of improving the robustness of the estimates of efficiency. Third, Lovell advises that frontier efficiency results should demonstrate consistency with the underlying engineering and give rise to well behaved functional forms (i.e. that the form of any estimated cost function should reflect the properties of the underlying production process it is assessing). Fourth, he suggests that bootstrapping / confidence interval analysis should be employed to provide some statistical confidence bounds around individual efficiency scores. A difference of 10 % between two efficiency scores may not actually be statistically significant given the degree of variance in efficiency scores. Fifth, Lovell advocates looking for the consistency of results with those of non-frontier methods (i.e. that there should be consistency with industry insiders own assessments of relative efficiency). Sixth, he advises that appropriate quality / environmental / input price variables should be included in the analysis, as they are relevant determinants of efficiency. And finally Lovell, argues for a clear demonstration of the value added in the efficiency analysis, i.e. that sophisticated techniques of efficiency measure should clearly add something to the simpler analysis

typically carried out by industry analysts and consultants. All of these elements of best practice would seem to be significantly more challenging to implement in the context of transmission where there is a shortage of data of the right quality, relative to electricity and gas distribution. We pick up on these elements of best practice in our survey of regulators in section 7.

Observing the wide variety of approaches to benchmarking adopted by national energy regulators, Brophy Haney and Pollitt (2011) ask the question: why do regulators do what they do in terms of the use of benchmarking? They examine a sample of 43 regulatory jurisdictions across the world. They suggest a number of drivers of national approaches to regulatory benchmarking based on the idea of differing governance traditions (following La Porta et al., 1999). In the area of benchmarking these drivers include: the technical tradition favoured by regulators (law, economics or engineering); the specific powers of the regulator to innovate the use of benchmarking techniques; whether regulated firms are privately or publicly owned; the availability of national comparators and the attitude to international comparison; the time elapsed since utility reform and the introduction of incentive regulation; the capacity of the regulator for organisational learning; the technical ability of the regulator to process data and understand advanced benchmarking techniques; and the degree of political support for the activities of the regulator. The use of frontier efficiency benchmarking for electricity transmission by a regulator would require: a technical tradition in economics rather than in engineering; the ability to make use of appropriate frontier techniques; a positive attitude to making international comparisons since this would be required when the number of national transmission companies was small; sufficient time since utility reform to develop the use of the benchmarking methodology; the right skill set within the regulator to implement or commission associated benchmarking studies; and political support for the regulator in implementing the results from the benchmarking analysis on what is likely to be one nationally significant transmission company. Brophy

Haney and Pollitt (2011) found some evidence for electricity distribution that there was evidence that more experienced regulatory agencies tended to use more sophisticated benchmarking techniques.

Section 3: The previous literature on electricity transmission benchmarking

There has been relatively little analysis of electricity transmission benchmarking in the academic literature, compared to the large literature on electricity and gas distribution.

There has also been no academic analysis of the effect of benchmarking on electricity transmission companies' performance. In an early review, Jamasb and Pollitt (2001) found only two jurisdictions (the Netherlands and Norway) had undertaken noteworthy international benchmarking of electricity transmission. In a recent review of benchmarking of energy network ACCC (2012) reviews 22 DEA studies and 16 SFA of the efficiency of energy networks, all of which are on distribution utilities.

Table 1 – Academic Studies of Transmission

	<i>Dataset</i>	<i>Inputs (I), Outputs (O), Environmental (E) Variables</i>	<i>Methodology</i>	<i>Hypothesis Tested</i>	<i>Results and average efficiency (AE)</i>
Pollitt (1995)	129 US utilities in 1990	I: Number of employees, circuit km*KV, energy losses O: energy delivered, maximum demand, route km	DEA	Public and Private utilities different	Public and private utilities equally efficient AE: 0.80
Nemoto and Goto (2006)	9 Transmission- Distribution Japanese utilities 1991- 98	O: weight sales I: No of employees, capital expenditure	SFA	Evolution of firm efficiencies over time	Time invariant efficiency = 0.78-0.94
Von Geymueller (2007)	7 EU utilities, 1999-2005	I: Employees O: Domestic Demand Quasi-fixed	DEA	Significant difference if some capital inputs	Dynamic models better than static. AE:

		input: Transformer capacity		assumed fixed	0.75-1.00
Von Geymueller (2009)	50 US utilities 2000-2006	I: materials and supplies costs, labour costs O: transmission of electricity for others Quasi-fixed inputs: transmission miles, transformer capacity	DEA	Significant difference if some capital inputs assumed fixed	Dynamic models better than static. AE: 0.7-0.85

There have been a number of consultancy studies of electricity transmission benchmarking using data from groups of collaborating transmission companies, including Sumicsid (2009). This study examined the totex efficiency of construction, maintenance, planning and administration (CMPA) of European electricity TSOs. The publicly available summary of the Sumicsid study contains only limited information on the detailed results (because not all the participating companies/regulators were willing to publish their efficiency scores), however it makes use of a data envelopment analysis (DEA) approach assuming non decreasing returns to scale (NDRS). The Sumicsid study analyses the performance of 22 European transmission utilities using for the period 2003-2006. The reported average efficiency after adjusting for outliers is 87%. The outputs in the analysis were a normalised grid size measure ('normalized grid metric'), population density and the amount of connected renewable capacity. The normalised grid size measure was calculated starting from 1200 different grid characteristics⁴ using assumed weights. This study involved a substantial data collection and standardisation exercise involving the cooperation of national regulatory agencies and

⁴ These characteristics cover eight asset classes: lines, cables, circuit ends, transformers, compensating devices, series compensations, control centers and other assets (such as HVDC). For a discussion see Sumicsid (2009, pp.65-68).

regulated transmission companies with the report authors. The scale of the data exercise and the number of engineering judgements and standardisations required to arrive at a 'normalized grid metric' suggests the extreme difficulty of making international comparisons between electricity transmission companies.

Indeed, the use of assumed weights is precisely what a frontier efficiency technique such as DEA is designed to avoid. In DEA input and output weights are chosen, by the technique, for each firm individually in such a way as to give the firm the highest efficiency score possible. The arbitrary imposition of common weights for all firms to create one of the key outputs within the Sumicsid study, combined with the subsequent use of this output within DEA is contradictory.

In sum, the lack of academic studies, and the fact that all but one are on the data from one country, suggests the difficulty of doing comparisons of electricity companies.

Section 4: Data Issues in Benchmarking Transmission Systems

International benchmarking of electricity transmission systems is challenging, because the need to collect data on a consistent basis from a number of countries.

What is being compared?

A key initial requirement is to clarify the boundary of transmission and other activities.

Transmission voltage levels vary between different countries, both in terms of the standard high voltage levels (400 vs 500 kV) and in terms of the extent to which lower voltages are classified as transmission rather than distribution (in the UK 132 kV is the highest distribution voltage, in the Netherlands 110 kV is the lowest transmission voltage, while in the US 66 kV is the lowest transmission voltage). These transmission / distribution boundaries have very significant implications for the size and configuration of the networks being compared. Standard adjustments such as just reducing the comparison to the

common voltage levels or comparing all the lines using weights for each voltage level (as in Pollitt, 1995 or Sumicsid, 2009) are very arbitrary. Clearly, the underlying weights in a particular country may reflect local investment cost conditions (outside of the control of the firm) and the use of a fixed weight across an international sample may not be a valid approximation to the economic reality facing each firm being compared. Transmission systems may also be defined as including or not including step down transformers to the distribution system, implying that adjustments need to be made for different asset ownership boundaries across countries, but again any adjustments to allow comparability imply common assumptions across the dataset that are somewhat arbitrary.

Transmission companies may or may not have responsibility for system operation and system planning. National Grid in the UK is a system operator and a transmission operator. However most US transmission businesses have delegated system operation to a regional transmission organisation (RTO), which is a form of independent system operator (ISO) (see Pollitt, 2012). Even in the UK National Grid's system operation covers a different area to its transmission asset operations and the activities are functionally integrated. Comparisons can be made which focus on transmission operation or system operation and system planning but these require somewhat arbitrary common cost allocations between the three and may be very difficult to get comparative information for across countries. System operation is a complex business which may or may not involve the running of associated market operations (for balancing power, day ahead power, capacity, transmission rights) in addition to real time grid control. A typical RTO in the US has around 50% of its costs in running markets as opposed to control centre costs. System operators in the US additionally run sophisticated locational marginal price software, not used in Europe.

Which price indices should be used in international comparison?

International comparison immediately raises issues of how to adjust for exchange rates: should market exchange rates or purchasing power parity (PPP) exchange rates be used? PPP exchange rates are appropriate for wholly domestically incurred costs, while market exchange rates are appropriate for pricing internationally traded goods. In electricity transmission some costs are wholly domestic (e.g. transmission line operation expenses) but some costs are internationally determined (e.g. the price of copper in transmission cables). The value of capital assets in the regulatory asset base at any point in time reflects the time profile over which the assets were accumulated, thus careful adjustment is required for the role of inflation over the long run. Simply converting the current value of capital assets at the current exchange rate may have the effect of locking in the effect of inflation on those assets, producing biases in the results. This is particularly true where the only available, and broadly internationally comparable, measure of current capital assets is an historic cost figure. High inflation countries will have a low current valuation of historic costs, while low inflation countries will have a higher current valuation of historic costs. This would lead to a particular problem in comparing say central and eastern European countries with certain western European countries.⁵

Labour costs in a particular country reflect the supply and demand situation of national labour markets. They may be relatively high in high wage countries or may be inflated by the degree of unionisation, pension requirements or differing social insurance costs. These costs may also be accounted for differently in different countries with respect to whether they are expensed in the year they are incurred or whether they are separately charged to individual business units of integrated companies (e.g. they are general costs in the US). Thus in

⁵ Using annual historic investment costs and inflating these by a general measure of inflation such as the CPI is also likely to be unsatisfactory, given differences between the CPI and the relevant transmission investment inflation index in individual countries (as for example in Sumiscid, 2009). For instance, if transmission investment inflation is higher than the CPI in western Europe but lower than the CPI in central and eastern Europe, using the CPI would wrongly reduce the measured real value of capital in central and eastern Europe relative to that in Western Europe.

comparing transmission company costs, care needs to be taken to adjust for pension and social insurance costs imposed in particular countries on their firms and some recognition may need to be made for the role of unions in setting pay rates and limiting the ability of firms to cut wage costs.⁶

Shared costs, local taxes and capitalisation policies

There are a number of features of transmission costs which mean that the financial costs of transmission services may vary substantially between two different jurisdictions even where the underlying use of inputs – capital, labour and materials – is identical.

These include how overheads shared between activities within transmission and system operation are allocated, or how overheads between generation, transmission, distribution are allocated within financially integrated utilities.⁷ Two standard ways of doing this are to allocate on the basis of salary costs (if these are allocated to different functions) or on the basis of assets.⁸ Even for samples of similar companies in the same jurisdiction (e.g. in the US) this gives very different shares of overhead costs allocated to transmission.

A second key issue is the treatment of input taxes such as property taxes or public land use rights. These are potentially significant for network utilities. Some countries have clearly identifiable local property taxes (e.g. in the UK), but there are other charges that may be extracted from transmission companies or their suppliers which can add to costs in ways that are difficult to adjust for, given the given the unclear incidence of taxation.

⁶ Such necessary adjustments to labour costs may also need to be reflected in comparing capital costs, because some companies may capitalise some of their pension and social security costs (as part of their investment costs). This further adds to the difficulty of making ex post adjustments to incurred capital costs in order to make efficiency comparisons.

⁷ This may be an issue even though the Third Energy Package within the EU requires legal separation of transmission companies from the rest of the electricity system. Such separation is based on an initial allocation of shared overheads. Kwoka et al. (2010) suggest that the initial over-allocation of shared costs to separated distribution businesses in the US may explain why distribution efficiency appears to go down following divestiture of generation.

⁸ For instance, Kwoka and Pollitt (2010) allocate shared operation and maintenance costs on the basis of wages and salaries shares and shared capital costs on the basis of total asset shares.

A third significant difference within and between countries is the accounting treatment of capital assets. This is very significant for transmission where most of the total cost is associated for depreciation and the return on capital. Capitalisation policies vary significantly between firms and across countries meaning that the allocation of costs between operating (opex) and capital expenditure (capex) differs significantly. This clearly affects an opex only benchmarking exercise. However it may affect a total expenditure (totex) benchmarking exercise, because the annual efficient revenue requirement varies according to the capitalisation policy. This suggests that total cash costs (rather than either opex or capex on their own) are the only broadly comparable measure of expenditure between companies in different countries. Capitalisation policy effects the current financial value of assets employed and the requirements for depreciation and return on capital. Depreciation policies may also vary between countries for different types of assets leading to further differences in the current accounting value of assets with the same initial cash cost. These accounting differences are compounded by the fact by regulatory asset values (RAV) are arbitrarily defined usually by capping initial profitability and letting the RAV be determined in relation to this rather than with reference to the incurred capital cost of the assets. This implies that any comparison of the costs of transmission companies which makes use of financial measures of current capital assets is likely to be biased systematically (up or down by individual and national treatments of capital expenditure). The benchmarking model would have to take this into account by aligning RAVs and Investment costs used.⁹ In practice national regulators often put a lot of effort into checking and adjusting for capitalisation policy differences in order to produce comparable data on national regulated network companies (e.g. for UK electricity distribution firms). While this can be done for a given year (or recent years) for a sample of international electricity transmission companies, it is

⁹ Equally, regulators then need to translate efficiency scores back into efficient revenue requirements, while reflecting established RAV, to avoid appropriation of shareholder assets.

practically impossible to estimate the effects of historic capitalisation policies on historic capital costs or on the regulatory asset base implying that there is likely to be a difficulty in comparing efficiency using either historic capital costs or regulatory asset bases. In summary, measuring capital on a consistent basis through time, in order to arrive at a number that can meaningfully be used in efficiency comparisons of companies is extremely difficult.

Which inputs, outputs and environmental variables might be relevant?

Transmission service provision involves a complicated relationship between inputs and outputs. This gives rise to a long list of variables in Table 2 that either should be considered as outputs (or inputs) in the production process or as explanatory (or environmental) variables for efficiency. The Table also considers the extent to which the variables are under the control of the regulated transmission company. Each on their own has the capacity to raise costs, *ceteris paribus*. Ideally they should all be measured directly or indirectly in assessing transmission system performance. If not all variables are considered and if regulators decide to choose certain variables, the measured efficiency can change significantly.

Table 2 – Possible outputs and Environmental variables in electricity transmission (depending on the regulatory framework)

Variable (s)	Output variable	Environmental variable	Input variable	Degree of company control
<i>Length transmission network</i>	X		X (sometimes used as input)	Virtually none in short run
<i>maximum demand and load density (average utilisation)</i>	X			Some via load management
<i>demand growth in units sent out and growth of route length</i>	X			Virtually none in short run
<i>network density (e.g. long or short lines)</i>		X		None

<i>from generation sources to load centres)</i>				
<i>flow patterns (amount of wheeled energy), interconnection with other systems</i>		X		Some in long run via increased interconnection
<i>whether lines are uni- or bi-directional and the topology of network (whether security standards are n-1 or n-2)</i>		X		None in short run
<i>availability/reliability requirements</i>		X		Often imposed by regulation
<i>extent of tree cutting requirements</i>		X		Partially under company control
<i>terrain (e.g. how mountainous the service area is)</i>		X		None
<i>weather effects of peak wind strength, temperature at time of peak demand</i>		X		None in short run, could re-site some assets in long run
<i>requirements for the provision of ancillary services</i>		X		None
<i>number of circuits and substations, voltage levels of transmission lines, amount of underground lines, mix of AC and DC lines, number of angle towers</i>		X		None in short run, network can only be reconfigured in long run
<i>age and condition of network</i>		X		None in short run

Other variables may be relevant to a benchmarking exercise. Thus the incentive properties of regulation (e.g. under rate of return vs CPI-X), the maturity of the regulatory framework and the nature of ownership (e.g. public vs private)¹⁰ may explain cost differentials and need

¹⁰ If ownership type is a determinant of efficiency, but it is not fully under the control of the company then direct comparisons of firms with different ownership forms may not be valid. For example if

to be taken into account in deciding how to set targets for transmission companies shown to be inefficient as a result of a benchmarking exercise.

Conclusions on data requirements

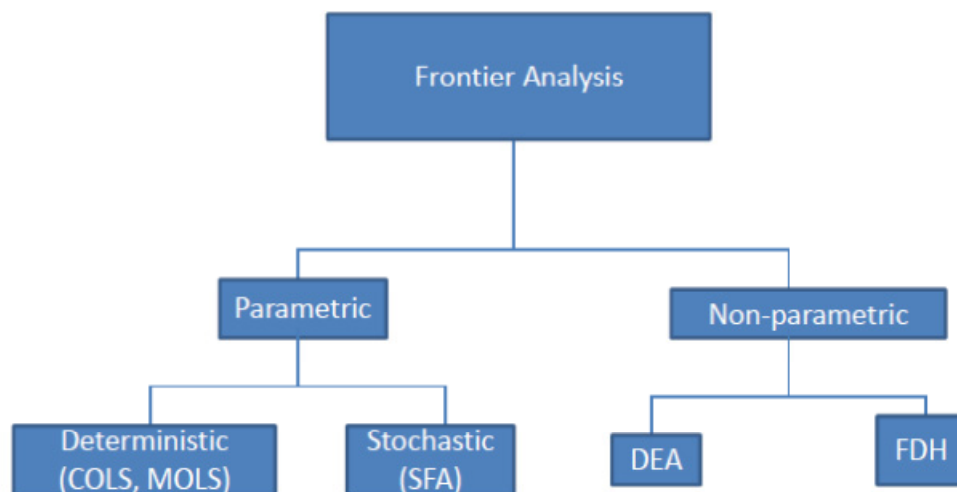
The results of benchmarking models and hence efficiency scores are sensitive towards the choice of model input and output parameters. The above discussion makes clear that data on the outputs and the environmental factors associated with a sample of international transmission companies is extremely challenging to collect on a consistent basis. While some of this data would be available on a reasonable consistent basis for a sample of US electricity transmission companies very little of it is available on a consistent basis for an international sample of transmission companies. Data problems are acknowledged as being important in explaining the benchmarking actually undertaken by national regulators (see Brophy Haney and Pollitt, 2011, and section 6 below). Even if all the relevant data for a sample of transmission companies were available it would be questionable whether it would be possible to get enough degrees of freedom to estimate meaningful efficiency differences within a sample of transmission companies, given the likely large number in outputs and environmental factors which would need to be included relative to the number of companies in the sample. A standard way round this is to combine multiple factors into a single output / environmental variable to save degrees of freedom. The Sumicsid (2009) study starts from 1200 different assets and uses ‘techno-economic’ weights to combine them into a single output measure. This is an extreme example of saving degrees of freedom – all firms would likely have been 100% efficient if all 1200 variables had been allowed to be separate outputs - that itself raises the issue of where the ‘weights’ came from.

Section 5: Methodological issues in frontier benchmarking relevant to electricity transmission

publicly owned firms have access to cheap finance and local rights of way this may give them a cost advantage, not available to private firms. If however publicly owned firms are not free to merge or reorganise efficiently this may place them at a cost disadvantage relative to private firms, which the actions of their managers could not be expected to eliminate.

In this section we discuss approaches to frontier efficiency and their application to electricity transmission. We acknowledge excellent discussions of frontier methodologies in Filippini (2012) and Farsi and Filippini (2009). There are two main approaches to frontier benchmarking based on either non-parametric analysis (using linear programming techniques) or on parametric analysis of efficiency frontiers (using econometrics). These are illustrated in schematic below:

Figure 2: Approaches to Benchmarking (from Filippini, 2012, slide 13)



Non-parametric approaches

Non-parametric approaches usually involve the use of data envelopment analysis (DEA). This has been widely used in electricity distribution. For transmission, two of the academic studies we discussed in section 3 did make use of it and it has been used by regulators in Sumscid (2009). A sub-branch of the non-parametric approach, known as FDH ('freely-disposable hull') assumes that instead of enveloping the frontier firms by means of straight lines (i.e. that any linear combination of two frontier firms is possible) the enveloping involves horizontal lines with steps down to frontier firms (i.e. that linear combinations of frontier firms are not possible, merely restrictions of them which involve free disposability of

at least one input). This leads to a frontier which is likely to show less inefficiency than conventional DEA. This approach has been championed by some authors for some sectors, such as hospitals (see Thanassoulis et al., 2008), where assuming any linear combination of units of analysis is possible produces virtual units of comparison a long way from any unit actually observed in practice. For large samples of broadly similar firms, DEA has a more intuitive appeal and is likely to produce very similar results to FDH. Essentially DEA can be thought of as providing an aggregate measure of single factor productivities for a multiple output – multiple input technology. This closeness to simple measures of performance explains DEA's appeal within a regulatory setting where transparency and simplicity are important features of a regulatory regime which aims to protect private property rights for investors as well as promote consumer welfare (Bauer et al., 1998). DEA is very flexible in terms of the nature of production function it assumes (simply assuming that it is convex). However DEA can involve the imposition of differing scale assumptions, such as constant returns to scale (CRS), non-decreasing returns to scale (NDRS) or variable returns to scale (VRS). Assuming CRS gives rise to higher measured inefficiency and implicitly assumes sample companies are free to vary scale up or down. The NDRs assumption¹¹ assumes that larger companies may scale their size down to a more efficient, smaller level. This may be significant imposition for a national transmission utility which may not be free to merge or reorganise itself locally to replicate a smaller more efficient firm, in contrast to distribution utilities which can be much more easily merged or reorganised to exploit optimal scale.

Incorporating environmental variables into DEA increases the degrees of freedom in the analysis, raising efficiency scores¹² (which might be considered undesirable by regulators).

There are a number of multi-stage approaches for incorporating environmental variables in

¹¹ Used in Sumiscid (2009).

¹² Efficiency scores cannot be reduced when variables are added to the analysis, thus while not all scores are effected, average efficiency scores are expected to rise. One way to reduce the number of variables in the analysis is to use composite variables. These can be useful as demonstrated in Yu et al. (2009), but come with their own statistical assumptions as discussed in Jamasb et al. (2010).

DEA (see Yang and Pollitt, 2009), the most popular one being a second stage which performs OLS or Tobit regression on the raw DEA scores. This approach has been widely used by regulators to interpret or adjust efficiency scores. This has been heavily criticised by Simar and Wilson (2007) who suggest that this approach is not statistically robust and advocate more robust 'stochastic' DEA approaches (SDEA). These have not been widely used in regulation due to their capacity to increase efficiency scores, the difficulty of explaining how the methodology works and the lack of widely available software for its implementation (and indeed the wide variety of 'stochastic' approaches to DEA).

One 'stochastic' approach involves the use of bootstrapping methods to test the robustness of DEA scores and essentially provide error bounds on DEA scores (see Thanassoulis et al., 2008). This approach involves re-estimating the DEA score based on a re-sampling approach to test how much the score for an individual firm varies if the sample against which it is being analysed changes. Such an approach does produce a confidence interval around a DEA score, which suggests that there is a higher efficiency score for a given firm which we can be 95% confident the firm does not exceed. Bootstrapping is difficult to justify with small samples of regulated firms and produces wide confidence intervals, but it does highlight the fact that a given efficiency score is a point estimate of the 'true' of efficiency score. It is increasingly popular in academic papers (e.g. Triebs et al., 2008 on the efficiency of US gas transmission companies) but is not widely used by regulators.¹³

Parametric approaches

Parametric approaches can either make no allowance for stochastic factors (corrected ordinary least squares (COLS) or modified ordinary least squares (MOLS)) or split observed deviations from the frontier into an efficiency and a stochastic component (stochastic

¹³ This is because bootstrapping tends to show that a significant number of apparently inefficient firms (i.e. those with raw efficiency scores less than 1) cannot be demonstrated to have efficiency scores which are *significantly different* from 1.

frontier analysis, SFA). In parametric approaches a cost or production function is estimated using OLS or Maximum Likelihood methods. With COLS, this is shifted to envelope all of the data (so only one firm is 100% efficient) or under MOLS the OLS equation is shifted by the mean of the measured residuals so that most of the observations are now enveloped by the frontier (but some will be observed to have efficiencies of more than 100%). A MOLS type approach is widely used by regulators in electricity distribution. Ofgem have used a COLS/MOLS approach shifting an OLS cost function down to upper quartile of UK electricity distribution firms and using this to measure efficiency scores (in the 1999 and 2004 price control reviews – see Pollitt, 2005). Stochastic frontier analysis, by allowing some of the deviation from the estimated cost/production function to be due to stochastic factors, results in lower measured inefficiency. Parametric approaches do have the advantage that they produce standard errors for frontier parameters and they can easily include environmental variables (e.g. as z variables in SFA, see Coelli et al, 2008). This does allow hypotheses about what variables to include to be consistently tested in a parametric context.

However parametric approaches may give rise to estimated frontiers which do not make engineering or economic sense and sometimes SFA software does not converge to sensible solutions. Regulators tend to estimate a heavily reduced form of cost and production functions which often leave out key variables (such as input prices within cost functions or capital within opex only cost functions). This has produced a significant difference between the estimates of cost functions used to test hypotheses (such as whether private ownership is more efficient than public ownership), where most writers would suggest that readers should not pay much attention to individual efficiency scores, and the reliance on the scores for individual firms by regulators (see Cronin and Motluk, 2007, for a critique of regulatory benchmarking practice). While DEA can be implemented for small samples straightforwardly, parametric approaches do require more data. Thus in Brophy Haney and

Pollitt's 2008 survey of regulatory benchmarking, only 2 regulators out of 43 used SFA for electricity distribution benchmarking and only 1 used SFA for transmission, against 8 who used DEA for distribution and 8 who used DEA for transmission.

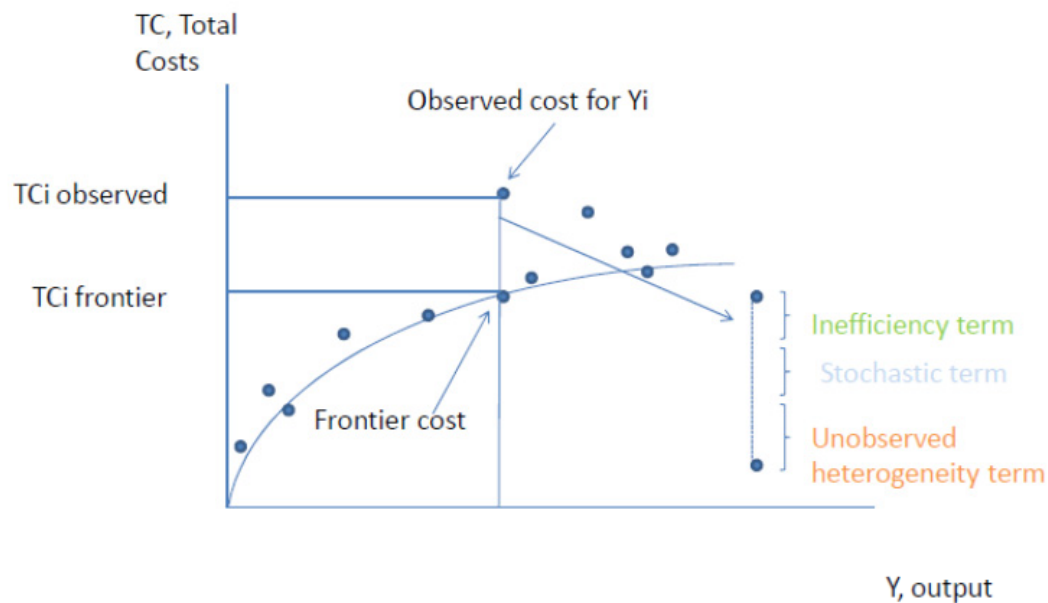
New approaches to efficiency measurement

It is worth discussing two of the latest developments in frontier efficiency techniques to see how these might apply to electricity transmission and what how best practice in frontier efficiency measurement of transmission might evolve.

A key methodological problem for efficiency analysis is **unobserved heterogeneity** between firms in a sample. This arises because there may be unobserved outputs or environmental factors which are having a significant effect on the performance of the firm. This is distinct from a genuinely stochastic effect (such as a random measurement error or the effect of a 'good' or 'bad' year). In DEA (or in COLS or MOLS) the presence of such heterogeneity will cause deviations in the measured efficiency score away from its 'true' value (similarly to a stochastic effect). Even in SFA, the presence of unobserved heterogeneity may wrongly be attributed to inefficiency. Greene (2005) thus proposes a 'new' set of panel data techniques which essentially divide deviations from the frontier into three components – an inefficiency component, a stochastic term and an unobserved heterogeneity term. These techniques are known as true random effects ('TRE') and true fixed effects ('TFE') models. This is illustrated in the Figure 3 below.

Figure 3: New Panel Data techniques (Green, 2005, TRE and TFE)

(following Filippini, 2012, slide 23)



Essentially what these models do is look for time invariant effects on output or cost and attribute these as unobserved heterogeneity. This can be done because panel data is available (to which standard random and fixed effects models can be applied). TRE/TFE based SFA models produce lower measured inefficiency than conventional SFA models (see Farsi and Filippini, 2009). However it is worth saying that by attributing all time invariant deviations from the frontier to unobserved heterogeneity they probably overstate the efficiency of companies relative to its 'true' value. As Fillipini (2012) observes the 'truth' (at least from an SFA point of view) lies somewhere between the SFA and the TRE/TFE value. Given the large number of variables (noted in section 3 above) that would seem to be relevant to transmission system efficiency (at least some of which don't change much over the length of any available sample), it would seem to be the case (conceptually at least) that unobserved heterogeneity is likely to be a serious problem for a sample of transmission companies. Thus TRE/TFE models would seem to be at least worth looking at to provide upper bounds on efficiency scores.

A second development in frontier efficiency techniques addresses the problem of making a valid comparison by attempting to partition the sample in a statistically valid way. The

creation of a valid set of comparator companies is one that has troubled regulators and led many to only use broadly similar domestic comparators where these exist. It has been well known that the simplest way to deal with environmental differences within a sample has been to split the sample according to key environmental criteria (e.g. firms above or below a certain size threshold) and only measure efficiency by using the data within a sub-sample (see Yang and Pollitt, 2009). **Latent class models** attempt to allocate firms to clusters on a statistical basis. This technique begins by imposing a maximum number of potential classes (i.e. different sub-groups) and then tests using a maximum likelihood approach whether clusters of firms have significantly different cost or production functions based on the value of the classifying variables. This gives rise to the identification of sub-samples firms that can be legitimately compared. These sub-samples can then be analysed using COLS, SFA or DEA in the conventional way (though there may be a problem in implementing the techniques on small subsamples). Filippini (2012) finds significant clusters within a sample of Swiss electricity distribution utilities, this gives rise to significantly higher efficiency scores relative to a pooled sample.¹⁴ This sort of approach is clearly important for transmission utilities where it is quite possible that clustering into statistically valid comparator groups would be an important first step before undertaking efficiency analysis.

Comparing approaches

Parametric and non-parametric approaches exist and have their strengths and weaknesses. SFA has made significant methodological progress but its direction of travel has made it less useful to regulators. This is because the drive of econometric approaches is to explain deviations in performance, not to leave them unexplained. A strong argument can therefore be made for the appropriate use of DEA by regulators, on the grounds that it is more in line with sort of benchmarking that companies undertake for their own private purposes (see

¹⁴ See also Cullmann (2009) for an application to German distribution utilities.

Nillesen and Pollitt, 2010) and that it has less onerous data requirements (see Frontier Economics, 2010, who recommend it to Ofgem for electricity transmission). Useful improvements to both SFA and DEA may lie in more and better data that would allow the more sophisticated techniques to be implemented robustly, better attention to issues of unobserved effects and the creation of statistically valid comparator groups of firms. However in the end measured frontier efficiency is limited by the current performance of sample firms.

Another approach to calculating efficiency scores is to use a norm or reference network model approach. This compares the actual cost of the regulated firm to a constructed ideal network which replicates the supply and demand links, subject to constraints, on the basis of reference costs. This approach has been used in Chile, Spain and Sweden. It is an approach which is dependent on a significant amount of technical parameters and has been severely criticised as a tool for use in independent regulation (e.g. by Jamasb and Pollitt, 2008). This is because the efficiency score depends on the specification of the reference network which is usually 'a black box', rather than on the basis of a frontier estimated from existing firms using parametric or non-parametric techniques.

Two final points are worth making about efficiency scores. First, efficiency scores only measure the efficiency of the part of the production process that they analyse at a particular point in time. They offer no guidance as to how quickly any measured efficiency gap can be eliminated or how it might evolve over the years of a price control period. Thus they need be combined with an assumption of the speed at which the efficiency gap should be eliminated and with a projection of the likely future trend in efficiency (Figures 1A and 1B assume a linear elimination of the efficiency gap and a linear underlying improvement in efficiency). As noted earlier, efficiency scores do not offer a justification for appropriation of the pre-existing RAB. Second, there is a question about whether efficiency scores produced

by different methods should be combined. Clearly, simply averaging a set of efficiency scores for the same firm (produced for example by DEA, COLS and SFA or different specifications of the same measurement technique) produces a score which itself does not correspond to the result of any one method. It makes more sense to pick the result of one set of estimates, on the basis of the argument that this was the most appropriate method for measuring the efficiency of the sample of firms in question, and consistently use that.

Section 6: The future of international benchmarking of electricity transmission

Benchmarking electricity transmission aims to facilitate yardstick competition among benchmarked transmission utilities to drive efficiency improvements and to share these with consumers. This gives rise to a number of issues.

Is benchmarking a short term phenomenon? It was envisaged that CPI-X price control would be a short term solution until competition arrived (Littlechild, 1983). This has not happened yet in electricity transmission, however it does beg the question as to whether benchmarking to calculate X is a short run phenomenon until something better arrives. Benchmarking is good at measuring the relative performance of broadly similar entities. With emergence of more renewables and smarter grids it is clear that transmission systems may develop in increasingly radically different ways in the future (indeed in Spain and Germany this future is already upon us). This will make comparability of networks more difficult in the future. As Agrell and Bogetoft (2010, p.6-7) point out the ‘effectiveness [of the current regulatory system] depends on the tasks and externalities it is supposed to control, past performance is only representative of future success insofar as these are of equivalent nature’. This implies that benchmarking will be an increasingly poor measure of the current performance of transmission entities with increasingly divergent objectives. A better future approach might be to build in efficiency at the beginning of the creation of

new assets via a procurement tender process. This would reduce reliance on ex-post benchmarking of capex performance.¹⁵

Does benchmarking introduce unwelcome distortions? There is a question as to whether benchmarking introduces regulatory risk. This has not been a particular issue when network companies have been initially inefficient at the start of the liberalisation period. However given the reduced ability of firms to cut costs over time under an incentive regulation regime, there is the potential for inaccurately low efficiency assessments to damage the credit rating of regulated transmission companies. In assessing the credit rating of network utility companies, Moody's do include a weight on regulatory benchmarking risk (see Moody's, 2009). While there would seem to be no evidence of a company ever having been downgraded as a result of a regulatory benchmarking exercise (see Oxera, 2010) this is a possibility. Indeed in the context of US utilities more generally Sanyal and Bulan (2011) find that 'deregulation' has deleveraged utilities sending up the weighted average cost of capital (WACC). Increased risk does increase the cost of capital for utilities. Sanyal and Bulan measure regulatory risk as being associated with the passage of reform acts and the presence of incentive based regulation (known as performance based rate making (PBR) in the US). Together these regulatory risk factors reduce leverage by 15% (though there is no significant effect of PBR on its own). Another risk faced by regulated network utilities is the way in which regulators assess their weighted average cost of capital. Interestingly, Morana and Sawkins (2000) show that the reverse is true for water companies in England and Wales: that a predictable regulatory regime leads to reduced share price volatility and equity betas over time. Schaeffler and Weber (2010) find that 21 regulatory authorities use a CAPM approach to calculate the weighted average cost of capital (WACC) in spite of the flaws in the CAPM methodology. A major flaw being that estimated equity betas do not refer solely

¹⁵ However, there may still be substantial scope for benchmarking in jurisdictions where it has not been effectively applied in the past, or in benchmarking comparable bits of transmission businesses.

to the regulatory part of the business and may not accurately pick up risk volatility. Indeed, if regulatory risk is one-sided and discrete this may not be reflected at all in estimates of beta – and not show up as increasing beta and therefore the cost of capital within CAPM - even though it does effectively increase the cost of capital. Kobiałka and Rammerstorfer (2009) find evidence of a lack of persistence of regulatory risk impacts for German utilities within CAPM. They explain this by the minor significance of the of network business within vertically integrated utilities. Of the 21 regulators, only one (Ofgem) also uses an alternative approach (the dividend growth model). This suggests that regulators may collectively use inappropriate capital cost benchmarking methods.¹⁶

Is there a longer run regulatory solution? A number of new ideas relevant to benchmarking have emerged recently as part of Ofgem's RPI-X@20 review of their system of price control regulation (see Ofgem, 2010). These include the idea that there should be more use of procurement tendering for new network assets to determine that the assets were efficiently procured. Such tendering would provide prima facie evidence of cost efficiency and reduce the need for whole firm benchmarking. There have been moves towards more customer engagement to ask network users what they are willing to pay for in terms of network services. In the US such engagement can lead to negotiated settlements whereby users and network providers agree on a price control plan which specifies what investments will be funded at what price (see Doucet and Littlechild, 2009), what the quality incentives and penalties are and takes account of the scope for efficiency improvement. In this process benchmarking simply informs the price control negotiations, within the context of performance based rate-making, as the WACC is specified by the regulator and there is revenue sharing should profitability rise/fall because of efficiency improvement/detriment.

¹⁶ For instance, it is worth noting that estimates of equity betas are backward looking. If investment risks are set to rise in the future these won't necessarily be reflected in estimated betas. Nor will firm specific risks which do not apply to equity betas estimated on other firms (e.g. beta estimates based on listed companies being applied to non-listed transmission businesses).

There has also been a move to streamline the process with a longer price review period (8 years), with a short review at 4 years, and an effort to incentivise companies to cooperate via more rapid price determination should they provide better evidence of revenue requirements.

Looking further off, Rosellon and Weigt (2010) suggest that - as in telecoms - it might be possible to fund transmission via a price basket cap on nodal prices based on financial transmission rights. The transmission price basket would initially allow for recovery of full economic costs (i.e. include a fixed charge as well as nodal element) and would be capped for the regulatory control period but there would be incentives to optimally balance charges across the network. Periodic adjustment could be done on the basis of a targeted regulated rate of return. This would suggest combining benchmarking (to ensure full economic costs are covered) with optimal transmission charging. The approach would, however, differ fundamentally from the current European electricity market design. A practical implementation of this theoretical approach therefore seems doubtful in the medium term.

Benchmarking is already a fairly small part of what is determining the regulated revenue of a network utility (which is mostly made up of return on the rolled forward regulatory asset base and non-benchmarked costs, see Pollitt, 2005, 2008). In future the focus will increasingly be on the efficient delivery of capacity – via asset utilisation and new investment – rather than on the least cost operation of the existing network. More renewables and associated dynamic demand will put new and different pressures on national transmission systems, according to local circumstances (see Agrell and Bogetoft, 2010). Transmission networks will be increasingly difficult to compare at the sort of high level that they have been compared in the past.

This suggests that the emphasis can and should move to the benchmarking not of the outturn costs of the network but to the efficiency with which new investments are decided

on, procured and managed. Simpler incentive regimes such as those under performance based rate making in the US might deliver the same sort of incentives as CPI-X while reducing the reliance on fairly unreliable estimates of relative efficiency and work well in controlling the total costs of existing transmission systems. An example of a PBR type incentive regime is given in Jamasb and Pollitt (2001) for Southern California Edison over the period 1996-2001. Prices were capped at the previous level in 1996, then X factors specified for 1997-2001 ($X_{1997}=1.2\%$, $X_{1998}=1.4\%$, $X_{1999-2001}=1.6\%$). However prices could be adjusted according to the profitability of the regulated business according to a profit sharing arrangement around a target rate of return, such that for $-/+50$ basis points (bps) around the target, shareholders receive all profits/losses; for $-/+50$ to 300 bps, shareholders share of the excess profits/losses rises from 25 to 100%; while for $-/+300$ to 600 bps, shareholders receive all the gains/losses; however at greater than $+/- 600$ bps, a price (rate) review is triggered. Under such an arrangement, direct benchmarking of costs can have a role in regulatory revenue determination but it would, likely, be a smaller one than in the past (Pollitt, 2005 and Pollitt, 2008), because the initial X factors are of reduced importance relative to the incentive properties of the profit sharing mechanism.¹⁷

Section 7: Survey of current practice in regulatory benchmarking of electricity transmission

To explore some of these issues further, we conducted a survey in both English and Spanish of energy regulatory agencies in Europe, Australasia and Latin America and the Caribbean. The survey was initially sent out to a total of 48 agencies who were invited to participate in the survey online using a dedicated survey website. The full list of countries is available in Table A1 at the end of this paper.

¹⁷ It is not actually necessary to do any benchmarking within such a mechanism. The only reason to do benchmarking initially would be to check that the regulated company was not going to too easily make an excess profit of 600 bps, potentially discrediting the mechanism for being too lenient on the company (relative to the current regime).

This survey follows up on a similar survey conducted in the same regions in 2008 (Haney and Pollitt 2009). This time, we have a specific focus on electricity transmission. In the 2008 survey, the questions covered electricity and gas for both transmission and distribution.

The survey is divided into three main sections. The first section focuses on the choice of benchmarking techniques. The second section narrows its focus on the set of countries that have chosen to use benchmarking techniques to regulate their electricity transmission companies. Questions in this section investigate the details of the benchmarking analysis process. Finally, in the third section, all regulators are asked a series of questions about the current state as well as the future of benchmarking for electricity transmission¹⁸.

7.1: Survey results - Choice of benchmarking techniques

We received 25 responses to the survey. Table 3 summarises the responses to the first section of the survey on the choice of benchmarking techniques.

Of the regulators that have responded, 13 out of 25 use some form of benchmarking to regulate their electricity transmission companies. Of these 13, four refer to the use of frontier benchmarking (Netherlands, Finland, Portugal and Brazil). The others mainly use either unit cost approaches (Great Britain, Ireland, Australia, Dominican Republic, Peru, Guatemala) and/or reference network analysis (Ireland, Latvia and Guatemala).

A total of 12 regulators do not use any benchmarking techniques to regulate their electricity transmission companies. Of these, five have stated that they are considering the use of different forms of benchmarking in the future (Austria, Lithuania, Poland, Spain and Costa Rica). Both Austria and Poland are considering the use of advanced techniques such as DEA, SFA, MOLS and a Bayesian stochastic frontier model in the case of Poland. The remaining

¹⁸ Table A2 in the appendix provides a full list of survey questions

seven regulators have however stated they do not have any intentions to use benchmarking in the future.

The most frequently cited reason for not using benchmarking techniques up to this point is the limited number of transmission operators and associated lack of comparators. In the case of Mexico, the main reason is due to limited regulatory powers in this domain. Costa Rica also mentions the need for more information and also for specialist training.

The length of review periods varies across the respondents. Nine regulators have review periods greater than 3 years in length (Great Britain, Hungary, Italy, Ireland, Iceland, Brazil, Dominican Republic, New Zealand and Australia). Seven of these nine regulators also use benchmarking techniques. We will return to this variation when we discuss views regarding possible changes in regulatory regimes in the final section of the survey.

7.2: Survey results - Benchmarking analysis process

Table 4 summarises the responses of the regulators that use benchmarking for electricity transmission regulation. There are 11 detailed responses to the questions on benchmarking analysis process. Hungary and New Zealand use alternative benchmarking techniques to the ones listed in our survey. As a result, they were not asked to complete the detailed analysis process questions. As we can see from the table, most of these use the results of the analysis directly in their decision-making. Only three of the 11 regulators use the results indirectly, i.e. as the basis for negotiation (Great Britain, Peru and Portugal). Finland uses a number of frontier benchmarking methods but only applies the results of their negotiation-based method to regulation.

There is some evidence of regulators adjusting for uncertainty in their application of benchmarking. Six out of the eleven regulators make some sort of adjustment for uncertainty (Ireland, Latvia, Netherlands, Portugal, Australia and Brazil). Brazil and Portugal

are the only regulators that make assumptions about returns to scale in their analysis. Both assume non-decreasing returns to scale. Five of the respondents use international data (Ireland, Latvia, Portugal, Guatemala and the Netherlands) and four use panel data (Great Britain, Brazil, Guatemala, Latvia and Portugal). Comparability issues are mentioned as a concern in the use of international data. For example, the difference in industry structure between Ireland and other European countries is a problem referred to by the Irish regulator¹⁹. Access to data is also an issue mentioned by the British regulator.

¹⁹ Ireland's transmission and distribution networks are owned and managed by ESB Networks, a separate company within the ESB group which is Ireland's main utility company. The ESB group is active in generation, transmission, distribution and supply of electricity. Since 2006, however, a separate state-owned company, Eirgrid plc, has acted as Transmission System Operator.

Table 3: Choice of benchmarking techniques

	Number of regulated companies	Start date; length of review in years	Benchmarking used in regulation?	Techniques used in most recent price review	What was benchmarked?	Other methods used?	Plans to use benchmarking in future?	Why not part of formal process?
<i>EU</i>								
Austria	3	2012; 1	No				Yes (DEA, SFA, MOLS)	Limited number of transmission operators – only international benchmarking possible
Denmark	1	n/a; 1	No				No	Limited number of transmission operators – participates in international benchmarks when possible but benchmarking is not a part of TSO regulation
Estonia	1	2011; 3	No				No	No suitable comparators
Ireland	2	2011; 5	Yes	Unit cost approach (firm), reference network analysis (firm)	Total expenditure (opex and capex)			
Finland	1	2012; 1	Yes	DEA (firm), COLS, (firm) SFA (firm), unit cost approach (firm)	Total expenditure (opex and capex)	Negotiation method, benchmarking on TSO's historical/budgeted costs – controllable OPEX and outage cost benchmarked		
Great Britain	3	2007; 5	Yes	Unit cost approach (process/activity)	Capex only (costs of transmission assets and their installation)			

	Number of regulated companies	Start date; length of review in years	Benchmarking used in regulation?	Techniques used in most recent price review	What was benchmarked?	Other methods used?	Plans to use benchmarking in future?	Why not part of formal process?
Hungary	1	2009; 4	Yes	None of above		Overall average benchmarking results of the last European survey of transmission operators (coordinated by BundesNetzAgentur) – capex, depreciation, duration of use (partly energy losses)		
Italy	1	2012; 4	No				No	
Latvia	1	2011; 2	Yes	Reference network analysis (firm)	Total expenditure (opex and capex)			
Lithuania	1	2011; 3	No				Yes (operating expenses to be benchmarked against other transmission operators)	For the moment we have a complex of several techniques used for regulation, i.e. cost incurred + return on investment + factor-of-efficiency
Netherlands	1	2011; 3	Yes	DEA (firm), SFA (firm)	Total expenditure (opex and capex)			
Poland	1	2012; 3	No				Yes (Bayesian stochastic frontier model, DEA, SFA, unit costs, COLS)	
Portugal	1	2012; 3	Yes	DEA (process/activity), COLS (process/activity), SFA (process/activity), Reference network analysis (firm)	Total expenditure (opex and capex) – construction, maintenance, planning and administration			

	Number of regulated companies	Start date; length of review in years	Benchmarking used in regulation?	Techniques used in most recent price review	What was benchmarked?	Other methods used?	Plans to use benchmarking in future?	Why not part of formal process?
Spain	2	2012; 1	No				Yes (unit costs of facilities and then compare half the total with what is actually reported by companies)	
Sweden	1	2012; 1	No				No	The model we use (from 2012) is an ex-ante revenue cap model there the capital cost is based on replacement value of the assets. We set the reasonable rate of return but the TSO set the tariffs themselves.
<i>Rest of Europe</i>								
Iceland	1	2011; 5	No				Yes	Will become part of regulation but choice of methods unclear
<i>Latin America</i>								
Brazil	11	2009; 4	Yes	DEA (firm)	Opex only			
Costa Rica	1	2012; 1	No				Yes (Cost plus)	Lack of information and need for staff training
Dominican Republic	1	2012; 4	Yes	Unit cost approach (process/activity)	Total expenditure (opex and capex)			
Ecuador	1	2011;1	No				No	In Ecuador, by law there is only one transmission company

	Number of regulated companies	Start date; length of review in years	Benchmarking used in regulation?	Techniques used in most recent price review	What was benchmarked?	Other methods used?	Plans to use benchmarking in future?	Why not part of formal process?
Guatemala	6	2011; 2	Yes	Unit cost approach (process/activity), Reference network analysis (process/activity)	Total expenditure (opex and capex)			
Mexico	1	April 2010 transmission charges published, updated monthly	No				No because currently the regulator doesn't have any powers to implement benchmarking techniques	Due to the lack of powers of the regulator in this matter
Peru	4	2011; 1	Yes	Unit cost approach (firm)	Total expenditure (opex and capex)			
<i>Australasia</i>								
Australia	7	2012; 5	Yes	Unit cost approach (process/activity and firm)	Opex only; Capex only (Unit costs used to assess planned network capital and operational expenditure)			
New Zealand	1	2011; 4	Yes	None of the above		Unit costs, OLS (average rather than frontier), scatter plots with use of quadrants to identify strong and weak performance – opex, IT related capex, grid reliability, transmission line and substation service levels		

Table 4: Benchmarking analysis process

	How were the results used?	Uncertainty techniques	RTS assumptions?	Data used (Int'l or panel?)	Problems with data	Environmental factors	Quality of output measures; other variables	% revenue benchmarked	Ex-post adjustments?	Selection of efficiency	Inefficiency reduction
<i>EU</i>											
Ireland	Directly	Specific adjustment	No	Int'l	Comparability issues – industry structure different to other European countries	No	No	30% for TSO and 15% for TAO	No	Subjective judgement	2% per year on most controllable opex costs (5 years)
Finland	Only results from negotiation method applied to regulation	No	No	No		No	Yes (cost of customer outages)	n/a	No	Negotiation procedure main method applied, results from E3GRID study found TSO efficient in comparison and were no further applied	n/a
Great Britain	Indirectly (basis for negotiation)	No (although fixed percentages allowed for some uncertainties)	No	Panel and data from consultants on other transmission companies	Yes (comparability problems, confidentiality clauses around potential sources of data)	Yes – considered in agreeing on volume of assets to be replaced	No	About 40%	No	Subjective judgement	1%
Hungary											

	How were the results used?	Uncertainty techniques	RTS assumptions?	Data used (Int'l or panel?)	Problems with data	Environmental factors	Quality of output measures; other variables	% revenue benchmarked	Ex-post adjustments?	Selection of efficiency	Inefficiency reduction
Latvia	Directly	Tests for functional form	No	Int'l and panel		Yes	Yes		No		
Netherlands	Directly	Confidence interval analysis; tests for functional form; specific adjustment (10% margin to outcome of efficiency)	No	Int'l	Correcting for country-specific factors	Yes – z variables in SFA	No	About 80%	No	Average scores of number of selected models	Efficiency parameter was 47% which was increased by 10% to 57% (15 years)
Portugal	Indirectly (basis for negotiation)	Yes (confidence interval analysis and specific adjustment – with and without outliers, sensitivity analysis using external factors e.g. interest rates, asset weights, life time)	Yes – non-decreasing returns to scale	Int'l and panel and reference costs		Yes – in the second phase of the analysis, considered companies' claims	No	Almost 100%	No	Lowest efficiency score	0.5% in first period (2009 to 2011); 2.5% in second period (2012 to 2014)

*Latin
America*

	How were the results used?	Uncertainty techniques	RTS assumptions?	Data used (Int'l or panel?)	Problems with data	Environmental factors	Quality of output measures; other variables	% revenue benchmarked	Ex-post adjustments?	Selection of efficiency	Inefficiency reduction
Brazil	Directly	Confidence interval analysis	Yes – non-decreasing returns to scale	Panel	No	Yes – second-stage analysis in DEA	No; voltage level, wage in the region of operation, network density	60%	Yes – two stage estimation using adjusted DEA model (Simar and Wilson 2007)	Maximum efficiency	
Dominican Republic	Directly	None of above	No	Neither		No	No		No		
Guatemala	Directly	No	No	Int'l and panel	Yes with panel data – less availability of costs for first-of-a-kind technologies	Yes – all processes and procedures considered	Yes – quality standards defined by the regulator		Yes – adjustments for inflation	Comparison with technology available in market to provide same service	Difficult to indicate a time-frame due to methodology used
Peru	Indirectly (basis for negotiation)	None of above		Neither		No	No		Yes (region and terrain)		
<i>Australasia</i>											
Australia	Directly	None of above – adjustments based primarily on engineering judgement	No	Neither	Issues with legal framework	Yes – engineering judgement	Yes – a service target performance incentives scheme applies	Capex – 100%, opex – 100%; RAB – 0%; roughly 50% overall	No		2.60% (5 years)

Environmental factors have been incorporated into the analysis by 7 regulators (Great Britain, Latvia, Netherlands, Portugal, Brazil, Guatemala and Australia). Only 3 have included quality of output measures (Finland, Latvia, Guatemala and Australia). Ex-post adjustments are made in three Latin American Countries (Peru, Guatemala and Brazil). In the Peruvian case, these adjustments are based on region and terrain. Generally, we would consider that some element of subjective judgement should be used in the application of benchmarking results, however so far only two regulators have mentioned this as a factor in selecting between results (Great Britain and Ireland).

7.3: Survey results - Regulatory changes and the future of benchmarking for transmission

In the final section of the survey, we asked regulators to rate how strongly they support each of four potential regulatory changes: longer price control periods; more use of tendering; greater engagement between companies and customers; and a refocus of incentives on a broader range of outputs. Figure 3 summarises the responses.

The regulatory change with the strongest support so far is longer price control periods. A total of 13 regulators out of 25 either strongly agree or agree that longer price control periods would be useful in their jurisdictions and only 2 disagree. The level of support of course depends on the length of the existing price control periods in the different countries. All of these regulators, except Great Britain, have existing price control periods of 3 years or less.

Thirteen regulators also agree that greater customer engagement would be useful going forward.

Thirteen also support a refocus of incentives on a broader range of outputs (10 who agree and 3 who strongly agree). The lowest level of overall support is for tendering (9 in total who agree or strongly agree). More tendering, however, is strongly supported by 8 of these 9 regulators (Ireland, Costa Rica, Peru, Mexico, Great Britain, Guatemala, Brazil and Spain).

Support for these changes does not necessarily translate into a greater likelihood of implementation. Figure 4 summarises how likely the same regulators are to introduce each of these

regulatory changes. Although 13 regulators agree that greater customer engagement would be useful, only two of these same regulators consider changes in this direction as likely (Ecuador, Guatemala and Great Britain). With the other three changes, there is a greater correspondence between support and likelihood of implementation.

Figure 4: Do you agree that each of the following regulatory changes would be useful in your jurisdiction?

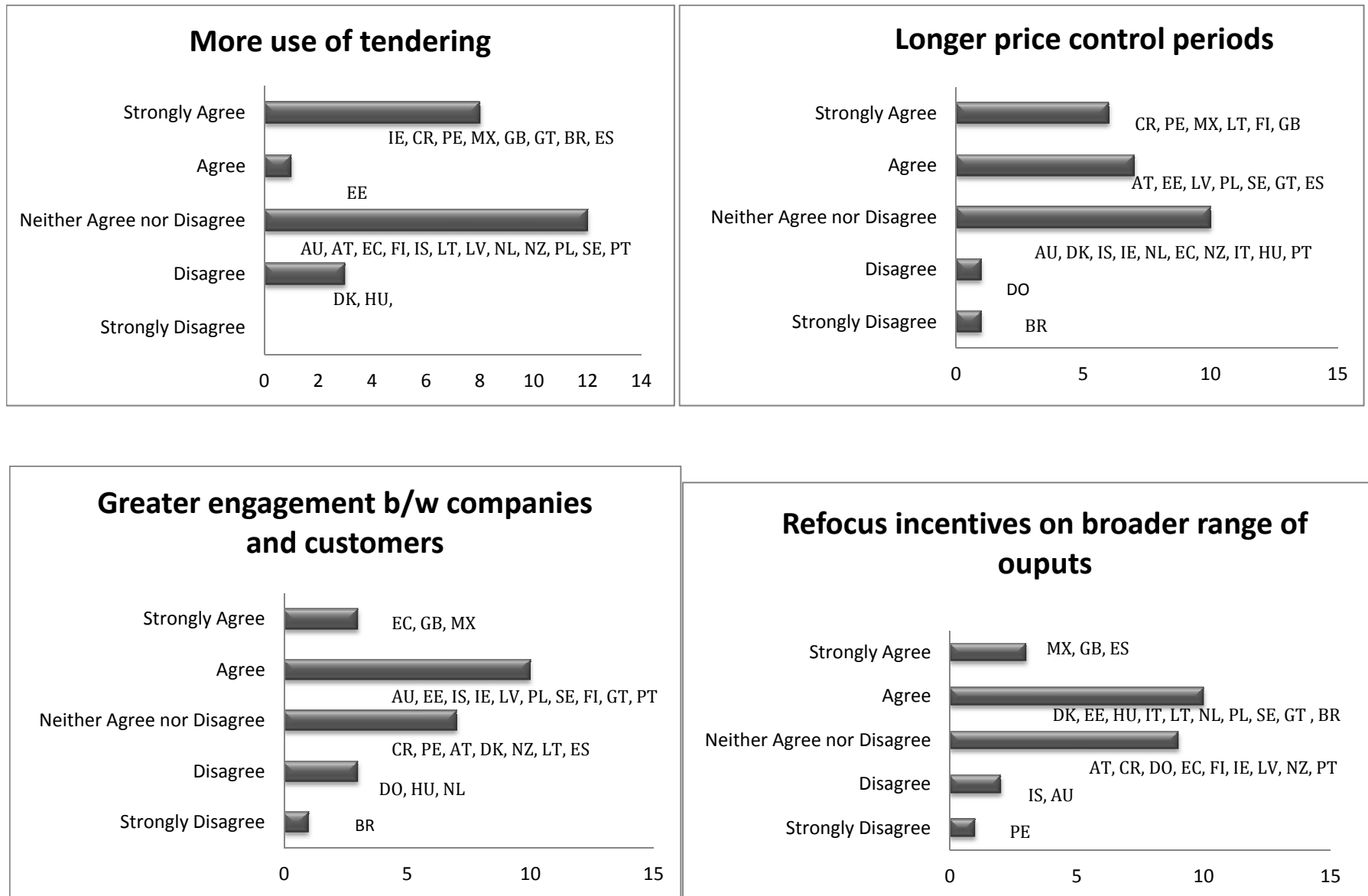
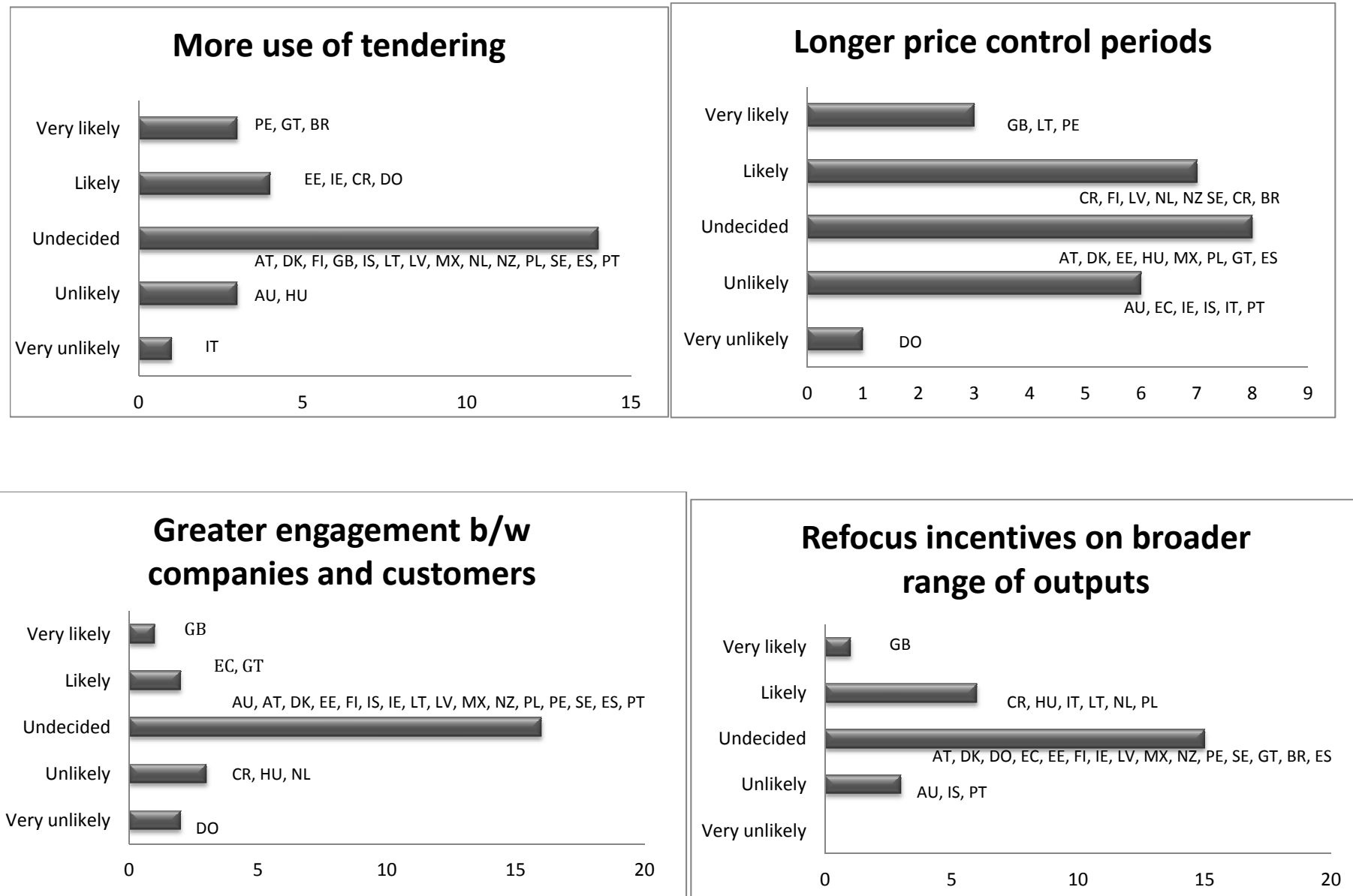


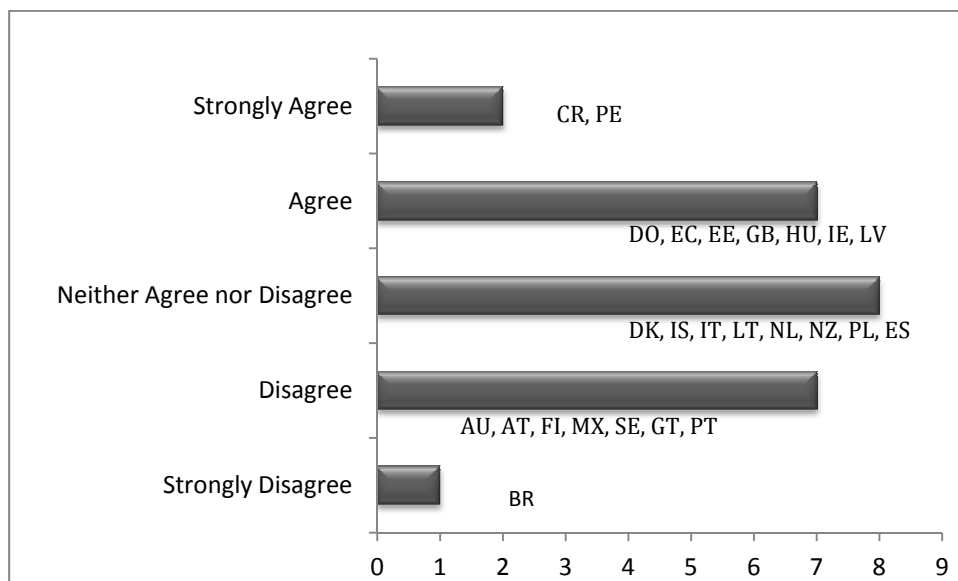
Figure 5: How likely are you to introduce these changes into your regulation?



The final set of survey questions asks regulators to respond to two statements to investigate firstly whether regulators think that transmission benchmarking is becoming more difficult over time and secondly whether benchmarking has any negative financial impacts on transmission companies.

Figure 6 and *Figure 7* summarise the responses to these questions. The accompanying text boxes provide some more insights into the rationale for different country responses. The comments represent the opinions of individual representatives of the regulatory agencies but are nonetheless illustrative of differences in attitudes across jurisdictions.

Figure 6: "Benchmarking of transmission is becoming more difficult over time"



"Benchmarking of transmission is becoming more difficult over time"

For

"There is greater uncertainty in cost and price issues over time"

"The development of the technology being introduced increasing differences, also the use of networks for communication purposes"

"There are only a few companies providing transmission service and this does not allow a good level of comparison. In the case of international benchmarking, access to information is a limitation"

"Accessing comparable datasets is becoming increasingly difficult"

"There are quite different regulatory approaches, there are considerable gaps between the financial potentials of the different countries/control areas. Last but not least: there are incompatible geographical differences within Europe (transit countries, exporting countries, importing countries, loop flows etc.)"

"Industry structures across jurisdictions are rarely the exact same so it provides an avenue for the regulated utilities to constantly question regulator results or positions during the price review"

"Bidding is more convenient"

Neutral

"As we don't benchmark it is difficult to know, but personally I doubt it"

"With the appropriate external support and a suitable base of knowledge within the regulatory time is a critical variable"

"So far there was no practice in my state, therefore I cannot provide reliable opinion"

"Econometrically, our experience and knowledge have increased, but are also more aware of the drawbacks of this method"

"Insufficient experience of benchmarking transmission to comment"

"No experience in area of TSO benchmarking (only participation in one project of international TSO benchmarking)"

Against

"It is always difficult as few peers exist with readily comparable geographic, climatic and operating environments"

"Challenges for benchmarking exercises are changing, but not becoming more difficult"

"Learning can only facilitate this kind of technique"

"More recent studies and experience on benchmarking"

"The fact that data from the transmission companies is used to define tariffs means that there is a great incentive for companies to provide these data to the regulator"

"I disagree with the assertion that benchmarking becomes more difficult over time due to the fact that data availability increases with time, and if you have variables that have not captured a technological change or other functions, these can generate variables that contribute to make a comparison efficiently even with investments made in different periods of time and considering advances in technology"

"Due to European Directives that promote costs comparison more countries are interested in joining international benchmarking studies"

"I do not see any difficulty to benchmark TSO on quality, but there are difficulties on economic indicators"

In summary, opinions about the difficulty of benchmarking over time are equally split between support, neutrality and disagreement. Just over one third of the regulators that responded to the survey agree or strongly agree that benchmarking is becoming more difficult over time.²⁰ One of the reasons cited for this is changing industry structures (Ireland). Comparability issues are raised by Ecuador, Hungary and Great Britain. In this regard, the British regulator specifically mentions access to data as something that is becoming more difficult over time. The countries that do not agree with the statement (one third of respondents) do not necessarily dispute the fact that benchmarking of transmission companies is difficult. In fact, they suggest that there are always challenges along the way but they are not becoming more difficult (Australia and Austria). As one of four countries to have implemented frontier benchmarking, the Netherlands takes a neutral stance. Although experience with econometric methods has been a plus for the Dutch regulator, this experience over time has revealed some methodological drawbacks. By contrast, the Finnish regulator (also a user of frontier benchmarking) disagrees with the statement due to the increase in the number of studies and experience in benchmarking over time. Similarly, the Brazilian regulator strongly disagrees suggesting that learning will always make application of benchmarking techniques more straightforward.

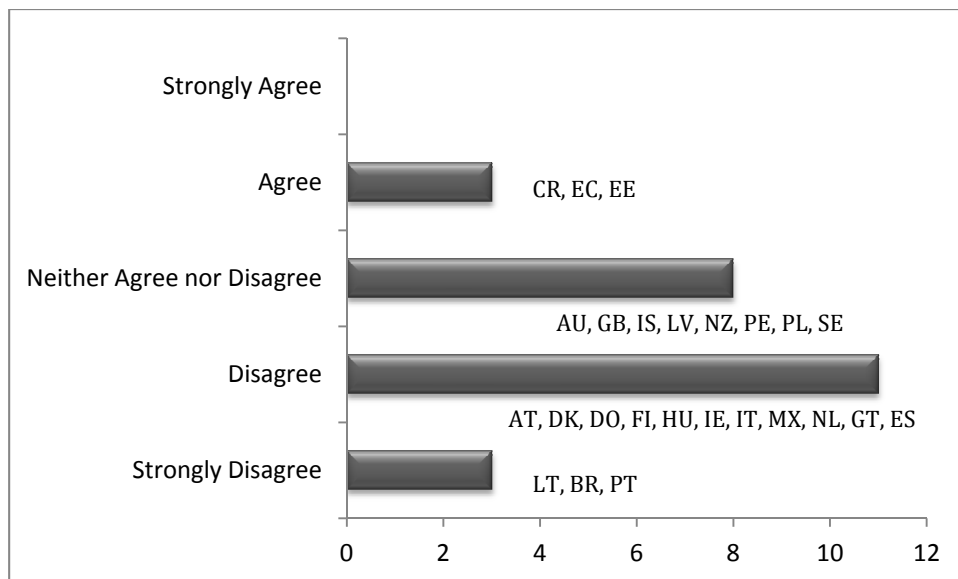
Only three regulators out of 25 agree that benchmarking negatively affects the financial rating of transmission companies. Costa Rica explains that if the benchmarking results cast doubt on the efficiency of business operations, this will indeed have a negative impact on financial ratings.²¹ Those that disagree (14 out of 25) suggest that because benchmarking encourages greater efficiency, this should give investors greater confidence. The remaining regulators (8 out of 25) are

²⁰ The distribution of results is not much different if we only looked at countries which actually use benchmarking.

²¹ This comment indicates that benchmarking may simply play the role of revealing poor underlying performance to the market. As such it is an informational device which may cause efficient market adjustments to equity valuations. If benchmarking played this role it could not be characterised as contributing to regulatory uncertainty, but market efficiency.

undecided and cite the lack of evidence, and the change in impacts of benchmarking over time as the main reasons behind their opinions. This suggests that there is room to explore this issue further.

Figure 7: "Benchmarking of transmission induces investment uncertainty and negatively impacts the financial rating of transmission companies"



"Benchmarking of transmission induces investment uncertainty and negatively impacts the financial rating of transmission companies"

For

"Yes, if there is doubt about the efficiency with which businesses operate"

"Depending on how you set the cost of regulated firms based on the benchmarking companies for which there will be an increase in the risk of investment recovery and therefore a reduction in ratings"

Neutral

"Financial market analysts in Australia have a far stronger influence than the small variations in outcomes achieved in Australian regulatory decisions"

"Initially it might introduce some level of uncertainty but this uncertainty will be removed over time"

"No evidence either way"

"Changes in investment flows depending on the method would create problems by reducing or increasing revenues"

"On the one side benchmarking usually reduces TSO revenues (which can have negative impact on financial rating) but on the other side benchmarking is connected with longer regulatory period (which should improve financial rating)"

"Planned investments should not be included in benchmarking. The TSO should be robust to ensure high reliability of supply"

Against

"It depends on the outcome of the analyses, and benchmarking has to be seen in context with the overall regulatory framework"

"Benchmarking will generally help to improve TSO efficiency. That should in itself not have negative effects on investments and financial ratings. Quite the opposite"

"The comparison allows the introduction of incentives for cost reduction and efficiency improvements that result in benefits for society and for the transmission company"

"Benchmarking makes investors aware of how efficient transmission companies are"

"I can see no (strong and direct) relation between investment uncertainty and benchmarking of transmission companies"

"If debt funding institutions believe utilities are moving towards a particular efficiency frontier recognized across other notable jurisdiction they should be more confident in the ability of that utility to repay debt"

"We do not see a link between benchmarking and rating"

"Benchmarking of transmission does not induce uncertainty in investment because an investor before building or developing any electric transmission facility should analyze and compare the costs incurred by companies with similar characteristics nationally or internationally. They would therefore be in a position to reduce their costs based by using the experience of other companies and thus, when the regulator does its benchmarking they would obtain similar ratings for both companies and this would not affect investment or the company's financial rating"

"Benchmarking in itself does not affect financial position, but the way the regulation deals with the outcome of the benchmarking process"

"It can be an external incentive to those companies to reduce costs"

Section 8: Conclusions

We need to think about the purpose of regulation in order to consider what best practice in regulatory benchmarking looks like. Benchmarking has a key role in sharing the benefits of efficiency improvements with consumers.

Relative to electricity distribution, electricity transmission systems are much more difficult to benchmark consistently and in a way that regulators can defend to their stakeholders in the industry and in government. Our survey of regulators indicates that they are aware that electricity transmission benchmarking is significantly more challenging than benchmarking distribution. A significant number of regulators also think that transmission benchmarking is not getting any easier. Fundamentally, this is because transmission companies are much more idiosyncratic entities than distribution companies, particularly when transmission must be compared internationally.

As a result, there have been few academic studies of transmission benchmarking and regulators are reluctant to use frontier efficiency techniques such as DEA and SFA to benchmark their transmission utilities. The data requirements to sensibly benchmark transmission are significant and sophisticated benchmarking methods are required. New panel data techniques aimed at dealing with unobserved heterogeneity and the validity of the comparator group look intellectually promising but are in their infancy for regulatory purposes.

The choice of variables used in benchmarking affects the results of any benchmarking exercise. In electricity transmission choosing variables is particularly difficult, because of the large number of potential variables to choose from. Variables are often arbitrarily chosen and combined, while the degree of control the company has over them may be limited. Efficiency scores arising from transmission benchmarking need to be carefully translated back into regulated revenue allowances in order to avoid appropriation of normal returns to investments which have been previously

approved by the regulator. Failure to apply benchmarking appropriately may negatively affect investors' willingness to invest in the future.

Our survey suggests that regulators make relatively little use of frontier efficiency techniques for benchmarking electricity transmission and are interested in new approaches to regulation (though many see these approaches as some way from being implemented). It also suggests that regulators need to pay attention to the potential for regulatory risk implicit in the use of transmission benchmarking. While few acknowledge that regulatory risk is currently an issue in transmission benchmarking, many more concede it might be. If benchmarking induces uncertainty as to whether large transmission investment programmes will be adequately remunerated this will significantly raise the capital cost of financing new investments and could be counterproductive.

The reliance of regulators on benchmarking seems set to decline. Future networks will be even more bespoke and idiosyncratic than now, making the high level comparisons used by regulators today even less meaningful. New regulatory approaches – such as those based on tendering, negotiated settlements, a wider range of outputs or longer term grid planning - are emerging and will necessarily involve a reduced role for benchmarking. New approaches will be necessary if the ambitious European plans for transmission network expansion – of up to €104 bn²² - over the next ten years are to be, even partially, realised.

²² See <https://www.entsoe.eu/system-development/tyndp/tyndp-2012/> Accessed on 10 July 2012.

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Appendix

Table A1: List of countries surveyed

		Country	Country code	Survey response
1	<i>Europe</i>	Austria	AT	!!
2		Belgium	BE	
3		Bulgaria	BG	
4		Cyprus	CY	
5		Czech Republic	CZ	
6		Denmark	DK	!!
7		Estonia	EE	!!
8		Finland	FI	!!
9		France	FR	
10		Germany	DE	
11		Great Britain	GB	!!
12		Hungary	HU	!!
13		Iceland	IS	!!
14		Ireland	IE	!!
15		Italy	IT	!!
16		Latvia	LV	!!
17		Lithuania	LT	!!
18		Luxembourg	LU	
19		Malta	MT	
20		Netherlands	NL	!!
21		Norway	NO	
22		Poland	PL	!!
23		Portugal	PT	!!
24		Rumania	RO	
25		Slovak Republic	SK	
26		Slovenia	SI	
27		Spain	ES	!!
28		Sweden	SE	!!
29		Turkey	TR	
30	<i>Australasia</i>	Australia	AU	!!
31		New Zealand	NZ	!!
32	<i>Latin America and the Caribbean</i>	Argentina	AR	
33		Bolivia	BO	
34		Brazil	BR	!!
35		Chile	CL	
36		Colombia	CO	
37		Costa Rica	CR	!!
38		Ecuador	EC	!!
39		El Salvador	SV	
40		Guatemala	GT	!!
41		Honduras	HN	
42		Mexico	MX	!!
43		Nicaragua	NI	
44		Panama	PA	
45		Peru	PE	!!
46		Dominican Republic	DO	!!
47		Uruguay	UY	
48		Venezuela	VE	

Table A2: Survey questions

Question	Options
1. In which country or region does your agency regulate electricity transmission?	
2. How many regulated electricity transmission companies is your agency responsible for?	
3. What was the starting year for the most recent price/revenue control review?	
4. Please state the length of the most recent price/revenue control review (in years).	
<i>Choice of benchmarking techniques</i>	
1. Do you use any benchmarking techniques to regulate your electricity transmission utilities	Yes No
2. In your most recent set of electricity transmission price reviews, which of these benchmarking techniques did you use as part of the process? (You can choose more than one)	DEA COLS SFA Unit cost approach Reference Network Analysis None of the above
3. Was this at the level of the process/activity and/or the firm	Process/activity Firm
4. What was benchmarked?	Opex Capex Totex Not applicable
5. Have you used any other benchmarking techniques for electricity transmission?	Yes No
6. What was benchmarked? (e.g. operating expenditure, capital expenditure, system services, losses, individual processes or activities)	
7. If no, please explain why you do not use any benchmarking techniques to set regulated prices/revenue for your utilities.	
8. Do you plan to use any of these techniques in the future? If yes, which techniques are you considering?	Yes No
<i>Analysis process</i>	
9. Were the benchmarking results used for the most recent set of price reviews?	Yes No
If yes please answer the following questions:	
10. How were the results used?	Directly Indirectly (as a basis for negotiations or further discussion)
11. Did the analysis in the most recent set of price reviews involve	Confidence interval analysis (e.g. bootstrapping for DEA) Specific adjustment for uncertainty (e.g. comparison against upper quartile) Tests for well-behaved functional form

	(e.g. monotonicity of cost function)
12. If you made a specific adjustment for uncertainty (e.g. comparison against upper quartile), please briefly describe the nature of the adjustment.	
13. Did you make any assumptions about returns to scale in the analysis? If yes, please explain.	Yes No Not applicable
14. Did the analysis include	International data (more than 1 country) Panel data (more than 1 year) Other, please specify Not applicable
15. In light of the previous question outline any problems you face with using the following type of data for benchmarking.	International data (e.g. comparability issues, legal restrictions etc.) Panel data (e.g. lack of comparability through time, lack of data etc.) Not applicable
16. Have you incorporated environmental factors (e.g. weather, age of assets, customer density) into your assessment of the efficiency of regulated companies?	Yes No
17. How did you incorporate environmental factors into your assessment of the efficiency of regulated companies?	Second stage analysis in DEA Z variables in SFA Supplementary revenue adjustments Other, please specify
18. Did you include quality of output measures in your analysis? If yes, please describe.	Yes No
19. Approximately, what percentage of regulated companies' revenue is benchmarked?	
20. Where more than one benchmarking technique was used to assess efficiency how was the efficiency for the purposes of regulated prices/revenue selected (e.g. highest efficiency score, subjective judgement etc.)?	
21. Please list any other variables that were included in your analysis	
22. Were any ex-post adjustments made due to special cost factors? (e.g. region-specific or company-specific terrain or technology)	Yes No
23. How was the efficiency for the purposes of regulated prices/revenue selected (e.g. highest efficiency score, average of scores from different techniques, subjective judgement etc.)?	
24. For the final benchmarked efficiency score, how much was the inefficiency expected to be reduced	%
25. For the final benchmarked efficiency score, over what period was the measured inefficiency expected to be reduced?	In years

General

26. Do you agree that each of the following regulatory changes would be useful in your jurisdiction? (Likert scale: Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree)	Longer price control periods Greater engagement between transmission companies and customers of their services Increased use of tendering for transmission investments Refocus incentives on a broader range of outputs
27. How likely are you to introduce these changes into your regulation? (Likert scale: Very Unlikely, Unlikely, Undecided, Likely, Very Likely)	Longer price control periods

Greater engagement between
transmission companies and customers of
their services

Increased use of tendering for
transmission investments

Refocus incentives on a broader range of
outputs

28. If you have comments on these or any other useful regulatory changes,
please enter them here.

29. "Benchmarking of transmission is becoming more difficult over time". Do
you agree with this statement? Please explain your answer.

Strongly Disagree
Disagree
Neither Agree nor Disagree
Agree
Strongly Agree

30. "Benchmarking of transmission induces investment uncertainty and
impacts the financial rating of grid companies". Do you agree with this
statement? Please explain your answer.

Strongly Disagree
Disagree
Neither Agree nor Disagree
Agree
Strongly Agree
