Reference Models and Incentive Regulation of Electricity Distribution Networks: An Evaluation of Sweden's Network Performance Assessment Model (NPAM)

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September 2007

CWPE 0747 & EPRG 0718

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19 September 2007

Acknowledgements

We acknowledge the support of the ESRC Electricity Policy Research Group. Authors are grateful for constructive comments from an anonymous referee. All remaining errors remain the responsibility of the authors.

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ABSTRACT

The world-wide electricity sector reforms have led to a search for alternative and innovative approaches to regulation to promote efficiency improvement in the natural monopoly electricity networks. A number of countries have used incentive regulation models based on efficiency benchmarking of the electricity network utilities. While most regulators have opted adopted parametric and non-parametric frontier-based methods of benchmarking some have used engineering designed 'reference firm' or 'norm' models for the purpose. This paper examines the incentive properties and other related aspects of the norm model NPAM used in regulation of distribution networks in Sweden and compares these with those of frontier-based benchmarking methods. We identify a number of important differences between the two approaches to regulation benchmarking that are not readily apparent and discuss their ramifications for the regulatory objectives and process.

Key words: Electricity, regulation, benchmarking

JEL: L51, L94, L97

1. Introduction

Regulatory reform of natural monopoly networks is an important part of the liberalisation of the electricity supply industry (ESI). Effective regulation of distribution utilities can improve their cost efficiency and facilitate competition in the sector. Distribution network charges roughly stand for one-third of final electricity prices and have shown significant potential for efficiency improvement. Therefore, many electricity regulators have sought to replace the traditional and ineffective cost-plus regulation with incentive regulation models and benchmarking to improve the efficiency of the networks. Moreover, they have introduced third-party access to distribution networks in order to promote competition in the wholesale and retail electricity markets.

At the same time, regulators are concerned with the effectiveness and long-term effects of incentive regulation regime on distribution networks. This concern is well placed as the profit incentives of regulation schemes can have important implications for investments and reliability of the networks. The incentive structures are also important for the active networks of future characterised by: responsive industrial and household demand, micro-generation technologies, industrial CHP, decentralised renewable sources, smart meters, and advanced information and communications technologies.

In principle, the purpose of the benchmarking techniques in incentive regulation is to aid the regulator in a transition period to reduce the performance gap among the companies. After this interim period, as the performance gap narrows, the regulation can gradually be based on yardstick regulation models, which mimic competitive conditions (Jamasb and Pollitt, 2001a). Thus the use of frontier-based benchmarking methods should generally be with a view to use in an interim period. Reducing the performance gap may take longer than initially anticipated e.g., in the UK the regulator Ofgem has only recently noticed clear indications of reduction in the efficiency gap among the distribution utilities (Pollitt, 2005). However, this does not change the nature of this long-term objective.

One of the approaches to benchmarking of electricity distribution utilities, as part of incentive regulation scheme, has been the use of reference firms or norm models.[1] The use of norm models as an alternative to frontier-based approaches to benchmarking and regulation is appealing to some regulators. Regulators in Spain, Chile, and Sweden have

1 See Jamasb and Pollitt (2001b) for a brief description of alternative approaches to incentive regulation and benchmarking.

developed different forms of reference firm approach to regulatory benchmarking while the German regulator has considered the use of such models.[2] Turvey (2006) suggests such models are superior to the frontier models in use in jurisdictions such as the UK.

In this paper we evaluate the Network Performance Assessment Model (NPAM) adopted by the Swedish energy regulator (EMI) as a benchmarking tool in the incentive regulation of electricity distribution companies. The Swedish electricity sector was deregulated in 1996. At the time of reform, there were over 250 distribution utilities operating under a light-handed and/or self-regulation regime.[3] The EMI has, in recent years, developed the NPAM to oversee and benchmark the performance of electricity distribution utilities against efficient reference networks. The reference model is then applied within an ex-post regulation framework to evaluate the performance of distribution utilities based on a revenue cap approach and to identify those that exhibit significant inefficiency. These firms will then be selected for further regulatory scrutiny and may be subjected to efficiency improvement requirements.

However, the regulatory approach based on reference models combined with ex-post assessments has led to serious conflicts between the regulator and a number of utilities resulting in lengthy legal proceedings involving court rulings and appeal cases. Therefore, the use of reference firm models in network regulation in Sweden offers an opportunity to examine the merits of this alternative approach to benchmarking and incentive regulation of natural monopolies in network industries. In this study we present an assessment of the NPAM as an incentive regulation tool.

The main focus of this paper is on the incentive properties of the NPAM and the regulatory framework within which the model is implemented. The performance of incentive regulation and its associated benchmarking regime is highly dependent on the incentive properties and the wider regulatory context within which these are implemented. Section 2 discusses some important and relevant features of the model and related aspects of the incentive regulation process within which the NPAM is applied. Section 3 addresses the main questions and the related issues associated with the implementation of the model by way of a set of evaluation criteria as reference points for an efficient incentive regulation model. Section 4 is conclusions and policy recommendations.

2 See Agrell and Bogetoft (2003) for a review of the reference firm models in these countries.

3 The number of utilities has been declining in recent years as a result of many mergers and acquisitions.

2. The Swedish Reference Model Approach and Network Regulation - Features and Application

From a methodological point of view, the NPAM is an engineering approach to develop an economic model of electricity distribution networks. The model is based on designing a fairly efficient model of each distribution network based on a number of standard technical and economic information. A separate reference model is then developed for the service area of each real distribution network. The resulting models then serve as a reference or benchmark for assessing overall efficiency (cost and quality of service) of the real networks on which they have been modelled. Real networks whose efficiency will deviate more than a pre-defined degree will be subject to regulatory scrutiny and can be required to achieve specific performance targets. The development of the NPAM for each real network consists of a set of specific steps as summarized in Box 1 (Stem, 2004).

An overall benchmarking model should reflect the main costs and other significant aspects of operation of networks. Broadly, the NPAM is an integrated or "all-in-one" incentive model incorporating operating and maintenance expenditures (Opex), capital expenditures (Capex), quality of service, and network losses in a single model. Aggregation of these important elements into a single model has useful efficiency and incentive properties. Firms can adjust their inputs and outputs more efficiently by weighting the incentives and trade-offs between them while taking own individual costs and circumstances into account.

Although pursuit of profit offers strong cost saving and efficiency improvement incentives these must be sought through suitable regulation frameworks (Domah and Pollitt, 2001). The incentive regulation model in Sweden based on benchmarking using norm models in annual ex-post reviews could be viewed within the context of its institutional setting. The predominant state and local ownership of the networks in Sweden could have been influential in adopting a somewhat modest departure from the self-regulation mode that was in place prior to the reform.[4]

The NPAM does not measure relative inefficiency of firms using real reference firms as in conventional incentive regulation and benchmarking. Rather, the NPAM develops an efficient, though not optimised, design of real firm as individual benchmarks. In this respect, NPAM differs from frontier benchmarking approaches that use Data Envelopment Analysis (DEA), Corrected Ordinary Least Squares (COLS), and Stochastic Frontier Analysis (SFA) techniques that measure relative efficiency of firms relative to a

[4] Also the Norwegian electricity sector has a long tradition of local ownership. However, since the 1980s, there has been a shift in emphasis to economic approach (relative to technical) to regulation, a trend that is evident in the post reform regulation in Norway (see e.g. Thue, 1993).

best practice or efficient frontier made of real firms. Also, the NPAM does not explicitly mimic market competition among real firms. In effect, NPAM assigns individual benchmarks to each firm. Therefore, NPAM differs from a conventional yardstick regulation based on a common benchmark. It also represents an efficient benchmark based on a new network while making allowance for the age of the actual network.

i. Information on the geographic co-ordinates of all customers for each network company is obtained.

ii. Information is collected on customers: numbers, energy, and power.

iii. The model creates a reference network based on technical and legal requirements and with high service quality standards.

iv. Using the reference network NPAM derives an installation register for:
   - Meters of line per bleeding point
   - A density measure to every meter of line
   - Number of transformer stations
   - Capacity for every transformer station
   - A density measure for every transformer

v. The model then calculates the investment cost of a reference firm based on standard costs of equipment from the Swedish Electricity Building Rationalisation (EBR) catalogue.

vi. Costs of building and operating an efficient network today and related costs are derived from a number of cost functions for:
   - Capital expenditures (real cost of capital) - compensation for depreciation, equity, debt (risk free and risk premium)
   - Cost of operation and maintenance
   - Network administration costs
   - Cost of network losses
   - Financial costs
   - Return on capital

vii. Deductions from revenues are made for quality of service using supply interruptions data of actual companies and customer willingness-to-pay (WTP) values.

viii. Costs of the reference network are then compared against those of the actual networks to obtain a "charge grade" (as ratio of cost of real firms over the reference firm) as performance measure of the real network.

ix. The benchmarking exercise is to take place every year *ex-post* and relative to the previous year. Firms with charge grades exceeding unity by a certain margin can then be subject to detail investigation and efficiency requirements by the regulator.

Box 1: The main steps in developing reference networks using the NPAM

Frontier benchmarking approaches are based on within-sample observed performance. The use of relative efficiency in relation to a reference design bears some resemblance to yardstick regulation or performance standard. In NPAM, inefficiency of an individual firm is measured independent of the performance of other firms in the sector. Instead of identifying a common frontier made up of observed best practice, the regulator uses NPAM to identify a separate benchmark or comparator for each firm. In addition, standard asset and component costs for the industry are used to calculate the costs of individual reference firms (see also Section 3.1).

The reference firm is designed as if a new network would be built instantaneously. The model is developed using a stylised optimum design and standard assets. The measured inefficiency of the actual network relative to the reference firm may be due to different factors such as inherited design and assets, management performance, or environmental factors beyond the control of the management or management performance (such factors may since have changed). There may be firms and special cases that do not readily conform to the standard technology and design as in NPAM. For example, some firms may have large sunk investments in vacant capacity in anticipation of demand growth that has not materialised or have only few but large customers. The model's methodology can therefore be unfavourable to some firms.

An important question that arises is to how an incentive regulation framework based on reference models and ex-post price control reviews compares to incentive regulation with frontier-oriented benchmarking and ex-ante price control reviews. Some key considerations in this regard are:

- ***Ex-ante vs. ex-post regulation.*** Ex-ante regulation is the preferred model by the majority of regulators. As a regulatory contract, ex-ante regulation involves less uncertainty on issues such as the benchmarking model used, efficiency targets set, and the review process. *Ex-ante* regulation requires adjustments for demand growth and price changes but these are fairly easy to incorporate. *Ex-ante* incentives to achieve and retain efficiency gains are stronger and more certain than ex-post determination of gains/penalties or avoidance of regulatory intervention. Ex-post regulation is, therefore, more likely to lead to conflict between the firms and the regulator. It should be noted that, in principle, it is possible to use NPAM in ex-ante regulation.

- ***Forward-looking vs. backward looking.*** An *ex-post* regulation is in effect a backward looking exercise. The main reservation against this is that the regulated firm is compared to a stylised design determined by the model that may not be accurate and cannot be verified. In addition, the design and operation of the real firms can be influenced by the way they have been allowed to evolve and improve relative to best practice of real firms rather than with reference to the NPAM model.

- ***Short-term vs. long-term***. Price control reviews based on annual assessments of firms using NPAM increase uncertainty with regard to regulatory framework and reduce the incentive to engage in long-term efficiency improvement measures. As mentioned, they can also reduce the likelihood that firms can retain the efficiency gains achieved. This aspect will be discussed in more detail in the next sections.

- ***Design.*** The design of the NPAM is based on that of a new network also described as the "greenfield" approach and based on New Present Purchase Value (Turvey, 2006). It is desirable that, in the long-run, utilities reach an optimum network design. In the short-run, however, some firms may deviate significantly from optimum design. Given the right incentives, asset valuation based on "brownfield" approach - i.e. the existing network configuration - can be also be effective in promoting greater design efficiency. While information on efficient design is available to the firms, flexibility and freedom of choice to move towards better design is likely to be more effective. In addition, reference models implicitly assume that firms are the sum of their constituent components, for example, in the form of configuration of model parameters for different voltage levels. However, the organisation and structure of real firms may deviate from those suggested by their reference models. Real firms can have synergies among their activities and assets and the efficiency with which these are combined and managed. Econometric and non-parametric approaches to benchmarking can capture such effects from observations of real firms.

- ***Replacement cost asset valuation.*** The justification for the use of replacement costs in utility regulation is not conclusive. This is particularly the case for valuation of existing assets and to a lesser extent though less so for new investments (see Johnston, 2003). The bottom-up structure of the NPAM almost requires the use of replacement cost and makes difficult to use other asset valuation methods in reference models. However, frontier-benchmarking techniques can accommodate different asset valuation basis. For example, the Norwegian regulator has used both book value and replacement values in benchmarking. Incorporating such flexibility in the NPAM, if methodologically sound, could require considerably more resources and costs. The key issue is, however, correct representation of investments going forward.

A peripheral but noteworthy point is that there is a distinction between high distribution charges that may simply be due to high costs and those that are due to low costs but high profits. A company with high costs is deemed inefficient from an economic point of view. However, for a locally owned firm with low-cost but high charges, the implication of ineffective regulation may be mainly a question of local welfare distribution. Municipality-owned utilities are effectively user-owned and their excess profits may be compared with a local tax. Direct consumption taxes such as levies on fuels are often efficient ways of raising local revenues than most tax forms due to low administrative burdens and collection costs.[5]

3. Criteria for Evaluating NPAM in Benchmarking and Regulation

Evidence from leading liberalised electricity sectors such as the UK and Norway shows that strong and independent incentive regulation is effective with unbundled distribution networks combined with benchmarking. In contrast, in New Zealand, the light-handed approach based on self-regulation and information disclosure resulted in distribution companies being the major beneficiary of the gains from liberalisation (Bertram, 2005). Moreover, in Germany, lack of effective regulation and regulated third-party access to networks helped maintain high network charges and slowed down the development of effective competition in the generation and retail markets (Jamasb and Pollitt, 2005).

The effectiveness test of an incentive regulation and benchmarking model is whether the regime has proper incentive properties for efficient outcomes. For the purpose of this paper, we distinguish between two approaches that use some form of incentive regulation and benchmarking: (i) Network Performance Assessment Model (NPAM) which constitutes an engineering approach to benchmarking based on developing efficient networks as reference, and (ii) frontier-based benchmarking methods - i.e. those based on techniques such as Data Envelopment Analysis (DEA), Corrected Ordinary Least Squares (COLS), and Stochastic Frontier Analysis (SFA) - and constitute an economic approach to benchmarking using real firms.

This section specifies a set of criteria for best-practice incentive regulation based on theoretical merit and the accumulated practical experience. The criteria are then used to evaluate the incentive properties of the NPAM in an ex post regulatory setting and to compare this with incentive regulation with frontier-based benchmarking. The evaluation criteria discussed here, therefore, reflect the experience with and desirable features of best practice to latter type of regulation. Nevertheless, these criteria serve as a useful platform and reference point for assessing the NPAM and its regulatory context.

5 While it is possible that municipal firms are less efficient than private firms discussing the ownership aspect is beyond the scope of this paper.

3.1 Benchmarking models should include the necessary variables

The primary building blocks of the NPAM are the number of customers and the capacity at which they are connected to the network. The geographical co-ordinates of customers are used to determine the physical assets (e.g. type of cable and transformer capacity) as a function of location and type of customers. These assets form the basis of the model, which is subsequently enhanced and detailed. In comparison, frontier-based benchmarking models tend to use number of customers and units of energy delivered as outputs and often network length as proxy for customer dispersion.

The NPAM takes into account the required capacity when designing a network. As Turvey (2006) suggests, the units of energy delivered are the throughput rather than the output of a network. The main service of distribution networks is to provide and maintain connection at adequate capacity to customers' premises. Moreover, the amount of energy transported over the network is not a real cost driver but mainly serves as proxy for maximum demand for network capacity and can be measured accurately. Likewise, maximum demand may be used as proxy for network technical capacity which may not be measured accurately. Therefore, in this respect, the NPAM has an advantage over other benchmarking methods.

The NPAM contains the necessary variables to capture the main feature of networks and representation of benchmark models. However, there is a risk that too many parameters may be built into such models which increases the complexity of the models but do not increase their accuracy. This in turn leaves less flexibility for the utilities to improve their efficiency in ways that may deviate from the structure of the benchmark model.

There is, however, an important structural difference between the NPAM and frontier-based benchmarking models. Several of the critical parameters of the NPAM are derived using hyperbolic tangent functions that are entirely based on customer density and five constant terms to resemble empirical data (Equation 1). The parameters dependent on customer density include: geometrical adjustment, back-up lines, back-up transformers, lines, cost of land for transformers, energy losses, interruption cost, and expected interruption cost (Stem, 2004). For each parameter at each voltage level, the functions are estimated using a number of "reference values".

$$\text{ModTanh}(x) = (k_1 + k_2 * \tanh(k_3 * (x - k_4)))^{k_0} \quad (1)$$

Where:

x density (meters of line/customer)

$k_0, \ldots, k_4$ constants

The high degree of conditioning on customer density distinguishes the NPAM from frontier based models. This may be compared to inclusion of customer density in a deterministic production function. In frontier-based benchmarking, this would be the same as including customer density directly in the parametric (SFA) or non-parametric (DEA) production function, implying that customer density influences the efficient frontier. In frontier-based benchmarking, customer density would generally be considered as an environmental variable - i.e. a variable over which the firm's management has no control. The efficiency scores can be corrected for the effect of the environmental factors through second stage regressions in DEA or specifying these as environmental (z) variables in SFA. The importance of customer density in the NPAM and its sensitivity to this parameter is a strong assumption that needs to be justified with empirical analysis.

The NPAM implicitly assumes that there is a standard design and efficient operation for a distribution network and aims to approximate this. There can be important structural and cost differences across utilities caused by design, organisational, and environmental factors. For example, in the UK, after two full five-year distribution price control reviews with incentive regulation and benchmarking, there were still significant variations in the cost structure of the 14 distribution network operators (see Ofgem, 2004a). It is also conceivable that there may be multiple ways of combining network designs and resources to achieve the same end in a given distribution area. It is difficult to establish the extent to which the standardised procedures of the NPAM can be aligned with the diversity of cost structure and design of real networks.

As a long-term benchmarking model, the NPAM incorporates the main inputs and outputs of regulatory concern such as operating and maintenance expenditures (Opex), capital expenditures (Capex), service quality, and network energy losses. It is generally accepted that there is some scope for trade-offs between these factors and that firms can use them to adopt to their operating environment. If there are real firms that have a cost structure different from that of the reference network but are more or as efficient of them, this may indicate that such trade-offs can exist. However, the deterministic structure of the reference models does not take the possible trade-offs between these factors into account. In benchmarking against real firms, such trade-offs are reflected in the performance of the sector's best-practice firms. Indeed there may be considerable innovation in the way such trade-offs are handled in real firms.

A comparison of the methodology of the NPAM with that of regression-based benchmarking methods is noteworthy. In regression-based benchmarking models the left-hand-side (LHS) variable (e.g. total cost) and right-hand-side (RHS) variables (e.g. energy and customer numbers as outputs) are each measured independently. There is also an underlying assumption about the production function built into the model through its specification. The "estimated" coefficients of RHS variables can signal whether a variable may be included in or excluded from the model. The values, signs, and significance of coefficients are therefore driven directly from the specific sample at hand.

In the NPAM, the total cost variable is not measured independently from the LHS variables but is "calculated" directly from the RHS variables and density factors (and the industry's average unit costs based on the EBR catalogues). In effect, the accuracy of the NPAM is dependent on the relevance of the pre-determined production function and standard factor costs (both decided prior to benchmarking).

As mentioned, the costs used to calculate the asset base of the reference network in the NPAM are based on EBR (Electricity Building Rationalisation) catalogue. EBR is a voluntary collaboration between the Swedish distribution companies to improve cost efficiency through technical and material standardisation (Olsson and Ahs, 2001). While EBR reduces the regulator's cost of information search to the regulator it cannot be regarded as an independent source of information in the long-run as it is dependent on the firms that the regulator oversees.

Environmental variables

Apart from customer density, the NPAM does not explicitly take other types of environmental variables into account. In frontier-based benchmarking methods such as SFA and DEA based on actual firms, such factors can more easily be incorporated in the benchmarking model. However, inclusion of too many environmental variables will add considerably to the complexity of the model. Moreover, controlling for such factors outside of the model may need to be made on a case-by-case approach using subjective judgements.

Filippini and Wild (2001) show that in addition to customer density, other environmental factors such as unproductive land, forestation, and agricultural land influence the networks' efficiency. A recent examination of the environmental factors of electricity and gas and distribution companies in the Netherlands found that factors such as soil quality, salty air, procurement of energy and capacity, load factors, and population and connection density did not show significant effect on their costs (Brattle Group, 2006). The study found that only the cost of water crossings longer than one kilometre and local taxes amounted to significant environmental effects. In addition, a study of various environmental factors on quality of service in Norwegian distribution companies found that, with the exception of maximum wind speed in coastal regions, other factors did not appear to have a strong influence (ECON, 2000).

It is also conceivable that, in the long-run, utilities are able to adapt to most aspects of their operating environment and the effect of environmental factors on cost and efficiency diminishes. Also, some positive and negative effects of environmental factors may cancel each other out. However, there is a need for further examination of their environmental factors and to develop the techniques for taking these factors into account. In addition, the extent and nature effect of environmental factors on firm performance may not be the same everywhere and they still need to be determined on a country to country basis.

3.2 Select and or create efficient comparators

Similar to frontier-based benchmarking methods, the NPAM identifies a single measure of overall efficiency of the real firm in relation to the reference network. In the NPAM, this measure is in the form of a performance ratio. The NPAM develops 'an' efficient model using a set of key parameters in a specific way. However, the NPAM's methodology implies that there is a unique or standard efficient design for each real network.

Moreover, a model is, by definition, only a simplified representation of a real system. A question is, therefore, how detailed a model should be. At one extreme, the design and operationalisation of an optimally designed model will be, at least, as complex as the real system that it attempts to represent. It can then be argued that any entity able to design the perfect model of a real network should, in principle, also be able own, maintain, and operate the network efficiently. The answer to the above questions is, therefore, that the NPAM is unlikely to identify and reflect a "true" or single possible efficient design and operation of a real network. For example, Griffel-Tatje and Lovell (1999) show that, in terms of operation and maintenance, the real Spanish electricity distribution utilities were more efficient than those of the theoretical firms.

Another issue is whether the resulting reference model is useful as a benchmark. When designing a modern and efficient structure and operation, the NPAM cannot reflect the historical development of the companies, which span over many years. The existing assets of actual firms are largely sunk costs and may represent the needs of a rather different demand structure and forecasts two or three decades ago. In the short-run, many firms have limited ability to alter their design. A clear advantage of using real firms as benchmark is that to the extent that real firms share have similar historical developments, the effect of such factors on measured relative efficiency diminishes.

Moreover, following the discussion of perfect models of real systems, the NPAM does not appear to reduce information asymmetry between the regulator and the firm. On specific complex and technical issues, the accuracy of physical measurements, reference networks (e.g. GIS-based measurements) can have a comparative advantage over other methods. However, the reference networks will not capture and reflect the complexity, dynamics, and synergies within all real firms in a sector.

However, the use of reference models can be justified where important technical data on actual firms are not available, or are of very poor quality. However, in the Swedish distribution networks, availability and quality of data is not a significant issue. Therefore, the benefits of the extra information from the NPAM can be out-weighted by the burden of information and required resources for making purposeful use of reference models. The large number of reference models to which the regulator and the firms must relate demands considerable resources. In Chile, where there are 36 distribution utilities, the regulator has taken a pragmatic step by dividing these into six categories and developing a reference model based on a representative firm from each category. Therefore, the regulator and the firms, collectively, only need to relate to six reference firms.

Furthermore, the NPAM and its implementation exhibit some characteristics of yardstick regulation regime. If firms perform better than the minimum threshold in relation to the reference network, they avoid being subject to regulatory scrutiny. This is in contrast to the conventional wisdom that advocates the use of frontier-based benchmarking methods until the performance gap among the firms has narrowed down. In Chile, where reference models have been used for a long time, considerable differences in the performance of the companies can be observed (see Sanhueza and Rudnick, 2004). This reinforces the argument that, initially, the frontier-based benchmarking should be used to narrow down the performance gap among the firms. In the UK, the X-factors have been instrumental in improving the efficiency of distribution companies (Jamasb and Pollitt, 2007).

In Germany, where there are many companies of a diverse nature and greater issues with data quality than in Sweden, the regulator has made progress toward setting up a framework for the use of benchmarking methods such as SFA and DEA together with possible use of reference firms in setting the revenue caps.[6]

An implication of the application of the NPAM within the current regulatory framework is that each firm has only one specific reference model as benchmark to which it should relate. This transforms the process of benchmarking and the incentive regulation process into a one-to-one relationship between the firm and the regulator. This framework may therefore be characterised as "individual benchmarking". This has certain implications for

[6] The regulator BnetzA also intends to make supplementary use of GIS-based reference networks as part of the benchmarking exercise.

the dynamics of the relationship and the regulatory contract between the firms and the regulator. For example, if a firm is able to influence the terms of its model or regulatory contract this does not have direct consequences for the other firms i.e. it is not a zero-sum game. On the other hand, frontier-based benchmarking method identifies a common frontier for all the firms in the sector. Therefore, the frontier-based methods can be viewed as "collective benchmarking" methods. Within this framework, an attempt by a firm to influence the terms of regulatory contract (for example, model variables or specifications) has also implications for other firms (see Jamasb et al., 2003; 2004).

3.3 Consistency of benchmarking results

It is difficult to identify the most appropriate and superior benchmarking techniques based on only theoretical grounds. The disciplinary origins of the parametric techniques, non-parametric techniques, and reference models are very different. The inherent differences also result in different outcomes. Therefore, in order to gain confidence in the robustness and representativeness of the outcomes of the NPAM, it is important to expect a reassuring degree of consistency between the results of the model and those obtained from frontier-based benchmarking techniques.

However, there is not a systematic study of reference models where their results are compared to those of other techniques. Some consistency criteria have been proposed to test how the results of different benchmarking techniques compare with those of others. The same consistency requirements can also be extended to those of the NPAM. Bauer et. al. (1998) have proposed the following consistency criteria for cross technique comparisons that can also be used in such an exercise:

- Similar distributions and means to DEA/COLS/SFA models
- Ranks orders should be reasonably correlated
- Similar least and most efficient firms differences
- Reasonable stability of results over time
- Results consistent with market conditions given gains subsequently achieved
- Some consistency with single factor productivity measures

In benchmarking models with real firms, the results are, to a larger extent, data driven. Therefore, the position and composition of the frontier, and consequently the efficiency requirements for each firm can change from one price control period to the next. NPAM, in effect, benchmarks a firm against some updated version of itself. As a result, the use of reference firm as comparator as in the NPAM offers a degree of long-term stability and consistency with regards to the frontier applicable to each firm.

3.4 Ensure sufficient investments in the long-run

In the NPAM, the value of the reference firm's asset base is the new present purchase value of the required assets for an efficient network. The use of (depreciated) replacement costs in the regulation of regulated utilities has been criticised as being generous to companies (see Johnstone, 2003). The Norwegian regulator has used both the book value and the replacement value of assets in benchmarking of electricity distribution utilities using DEA. We do not attempt to settle the debate on the merits or shortcomings of using replacement value in utility regulation here. However, it is useful to note the application of this valuation method in a reference firm-based utility benchmarking framework.

Reference firms, by the virtue of being more modern, would be expected to have higher capital costs and lower operating expenditures than real firms. Therefore, in principle, when the allowed revenues of the actual firms are benchmarked against those of the reference firm, this is not expected to result in under-investment in the long run. However, some related regulatory factors can influence the investment decisions:

- ***The asset base of reference network may be difficult to match -*** If, the real firms are, in practice, unable to achieve the implied level of asset base as the reference firm they incur high capital costs for their "sub-optimum" design.

- ***The standard asset values may not apply -*** Real firms may, due to their inherited, sub-optimum design, or environmentally challenging service areas require non-standard assets or for other reasons require more costly assets than those of the reference firm and EBR catalogue.

- ***Asset depreciation -*** If assets are depreciated and are in need of replacement more rapidly than assumed in the model, the real firms will attempt to keep their depreciated assets in service longer, or incur higher capital expenditures in relation to the reference firm.

- ***The risk-free rate of return and risk premium -*** If the risk premium of the real firms (currently 2 percent), more likely for low performance firms, exceeds the rate allowed by the NPAM, the cost of capital and the total capital cost of the firm will increase. For example, if the firms' investment plans are not approved by the regulator *ex-ante*, their risk premium may increase.

An optimised reference firm cannot reflect the historical development of the real firm. When benchmarking based on frontier approach using real benchmark firms, to the extent that these have evolved through comparable time periods and economic conditions, the effect of historical development diminishes. In addition, existing networks can, in a transition period, have limitations in adopting current asset-based and operating costs to an efficient design. Moreover, there is some trade-off between operating and capital expenditure. It is difficult to see how the NPAM can reflect the flexibility that real firm have in running, maintaining, upgrading, and extending the networks.

The investment efficiency incentive scheme adopted by Ofgem as part of the 2005-2010 distribution price control review exhibits some flexibility for firms to perform better than their allowed and expected investments needs. This approach also enables the firms, when possible, to take the trade-offs with operating expenditures into consideration. For the 2005-2010 price control period, the regulator has allowed a substantial increase in capital investments aimed at modernisation of the networks. The more than 40 percent increase in capital investments by network companies has resulted in a positive average X-factors for the sector as a whole. The increase in allowed investments is then accompanied by an incentive scheme that allows higher returns on actual investments in return for improving efficiency in achieving investment targets (Ofgem, 2004b).

An increase in investment allowance of this magnitude reminds us that conventional benchmarking approaches do not send timely signals to the regulator about the need for asset renewal and increased capital investments across the whole sector. Limiting the benchmarking exercise to Opex has given Ofgem the flexibility to respond to the cyclical nature of investments in distribution networks and the need for an increase in investments for network modernisation, quality of service, and distributed generation (Ofgem, 2006).

Dalen (1998) examines investment incentives of firms under yardstick competition while distinguishing between industry-specific and firm-specific investments. The paper suggests that under yardstick competition, industry-specific investments with spill-overs that benefit all firms are reduced while, firm-specific investments that only improve the relative efficiency of the individual firm will increase. An example of industry-specific type of investments is research and development (R&D) spending, which is the subject of the next section. Despite their relatively small share in total spending, R&D can have significant long-term efficiency benefits for the sector as a whole.

The NPAM is a long-term efficiency benchmarking model that includes not only capital and operating costs but also network energy losses and service quality in relation to an optimum design. However, the model is used within a short-term performance assessment setting - i.e. in the form of yearly applications of the model to firms. The current regulatory framework characterised by frequent and ex-post price reviews contradict the lead times necessary for the firms to achieve a new design and asset structure.

Achieving long-term efficiency improvements can involve short-term increases in Capex and/or Opex expenditures that may not generate immediate efficiency improvements. Expenditure increases can deteriorate the firms' short-term relative performance. This can prevent firms from embarking on efficiency improving investments that have long-term gains. Setting long-term efficiency improvement targets and benchmarks for the firms should be accompanied with the incentive to keep the benefits of efficiency gains. In *ex-ante* regulation, long regulatory periods can reduce uncertainty with regards to long-term investments and retaining their benefits. Moreover, the mismatch between the long-term horizon of investments and short price control periods can have a negative effect on terms and cost of financing of investments (see Ofwat/Ofgem, 2006).

3.5 Quality of service

In the absence of explicit control of quality of service in incentive regulation, due to the trade-offs between costs and quality, the latter is generally expected to decline. Tangerås (2003) argues that, when quantity is regulated, yardstick competition results in lower quality than under individual regulation although, under individual regulation, the quality would be too high. In principle, the argument can also apply to revenue and price cap regulation. However, evidence shows that utilities respond to incentives and regulation can prevent deterioration of quality.

Evidence from the UK and Norway shows that, although their approaches to regulation differ, utilities have responded to quality of service incentives. At the same time, the non-incentivised aspects of reliability have not necessarily improved (CPB, 2004). A survey of the literature in Sappington (2005) concludes that there are no simple policy solutions for effective regulation of quality of service but they depend on the information available to the regulator, institutional settings, and consumer preferences. The paper also argues in favour of providing the regulated firm with proper reward and penalty incentives for service quality when the regulator has sufficient information on consumer preferences and production technologies.

The NPAM incorporates quality service quality into the design of reference networks. A monetary value of non-delivered energy is used based on service quality level in actual firms and estimates of consumer willingness-to-pay (WTP) for quality. The value of service quality is then deducted from the allowed revenue of the efficient firm. Conceptually, inclusion of service quality in an overall efficiency benchmarking of utilities has clear incentive advantages and this has been advocated in some studies (e.g. Giannakis, Jamasb, and Pollitt, 2005). In Norway, such approach has been used in the 2002-2007 distribution price control and is also expected to be used for the next price control.

Inclusion of the cost of non-delivered energy based on WTP can affect different utilities to rather different degrees. Figure 1 shows the cost of energy non-supplied as percentage of revenue caps for 130 Norwegian distribution utilities in increasing order. As shown in the figure, at the extreme ends of the spectrum, some firms may be unfairly rewarded or penalised by inclusion of the cost of non-delivered energy. In the initial price control periods, the regulator must be confident about the quality of data and particular circumstances of 'outlier' firms and special cases that may give rise to large deviations from the main body of observations.

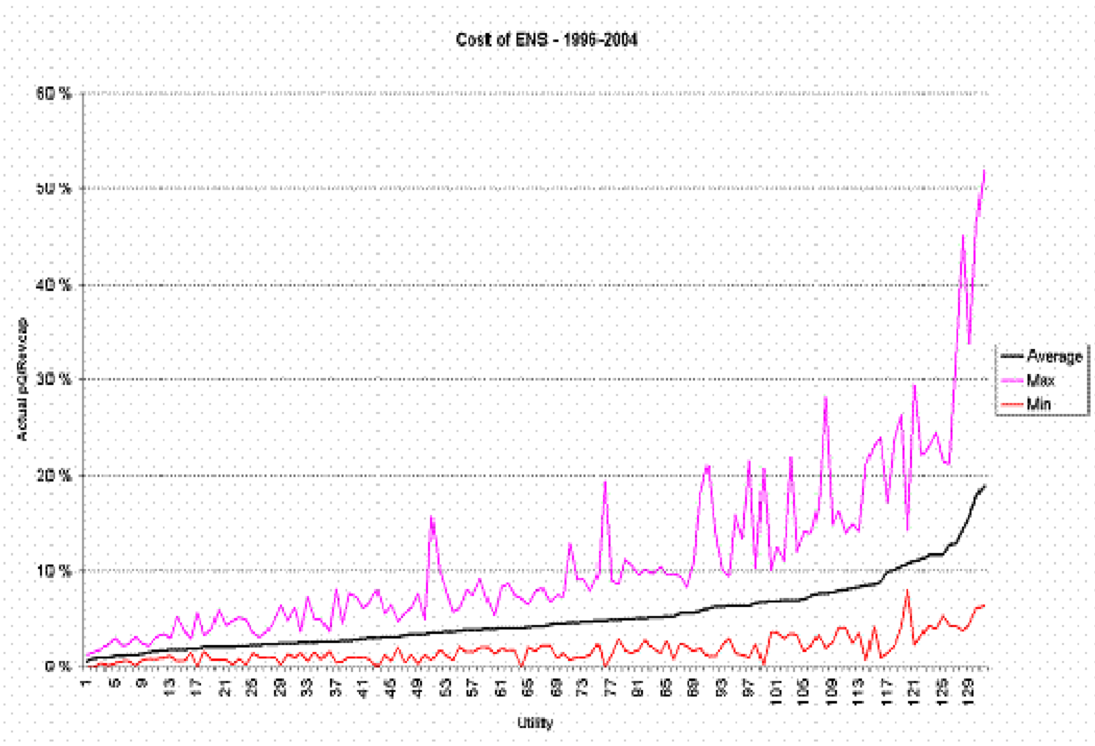

Figure 1: The cost of energy not-supplied (ENS) as percentage of revenue cap for 130 Norwegian distribution utilities
Source: Dalen (2006)

However, there remain two issues. Firstly, using high service quality standards of optimised reference networks as the basis for benchmarking of real firms, some of which can have a different design and cost structure, can prove to be too stringent. In particular, this is likely to be the case at the early years of implementation of the scheme while the firms have had limited opportunity to adopt an updated design and cost structure. In the Norwegian model, the value of service quality is based on those of real firms which are likely to have comparable long-term historical developments.

Secondly, the WTP values used are uniform across the country and for all companies. There is reason to believe that this value can differ across the country and among distribution service areas. To the extent that regional differences in WTP values are not reflected in the incentive scheme, the adaptation of utilities to socially efficient service quality levels can be distorted. A survey of WTP commissioned by the UK regulator Ofgem indicates that such valuation differences among different regions and consumer groups indeed exist (Ofgem, 2004c). The overall WTP of networks for a unit of quality also depends on the composition of customers. For example, industrial customers generally assign a higher value service quality than residential and commercial customers.

Nevertheless, political sensitivities of explicit use of differentiated values of service quality are clear. It is conceivable that the marginal cost curve of improving service quality varies across companies. An implication of subjecting real firms to their marginal cost of quality improvements is that, in the long-run, this could result in differentiated service quality levels across the country. While implicit variable 'sub-optimal' service quality targets are allowed, a unit of quality is assumed to have the same value across the firms.

Lindgren and Mortensen (2005) state that by average European standards, distribution access charges in Sweden are relatively low but quality of service is also low. They also argue that simulations indicate that performance ratios are not sufficiently responsive to quality of service improvements but to reductions in access charges. If this is the case for many utilities, the share of quality incentives as total allowed revenues should be substantial. The effect of including the WTP for quality on total allowed revenues for some Swedish utilities may be stronger than those of the Norwegian utilities in Figure 1.

For some firms with low quality performance, the transition to a high quality network may require large capital investments and time. At the same time, short-term performance considerations of such a transition, when firms are subject to annual ex-post assessments by NPAM, can provide disincentives to embark on large investments. Investment in service quality improvement is not inherently different from other investments. Indeed, the annual assessments by the NPAM are likely to be more influential than the technical details of service quality in the NPAM. Both the UK and Norwegian benchmarking models, despite their differences in approach, have succeeded in improving the quality of service.

3.6 Promote long-term innovation and technical progress

Innovation and technological progress are crucial for long-term efficiency of the individual firms as well as the sector as a whole. Achieving technical progress is closely associated with new investments. Future electricity distribution systems can be described as "active networks" that interact with both demand and supply sides. Industrial combined heat and power (CHP), distributed renewable generation, and micro-generation units installed by households equipped with smart meters will pose new challenges on networks to innovate and adopt new technologies. Most areas of the electricity industry anticipated to achieve technological progress in the coming decades have direct and indirect implications for the networks (see e.g. Jamasb et al., 2006).

Technical change in the networks is dependent on the regulatory framework and incentives. Regulators should take into account the power of influence and long-term implications of incentive schemes in influencing the features and behaviour of regulated firm. In responding to benchmarking models and variables, firms may be led to follow some certain path. An important question is whether reference models and the NPAM can provide incentives for innovation towards achieving the dynamic networks of future?

The NPAM is not built with a view to provide a framework and incentives for technological progress. An important question is the extent to which the regulator is able to continuously identify the latest technology frontiers and reflect these in the model. The likelihood that the regulators is able to constantly identify or predict a frontier and reflect this in the reference model is rather low. The NPAM only allows the regulator to look back at the recent past to identify and reflect the state of the art in the model with some (potentially significant) delay.

Innovation has been described as a discovery process (Weisman and Pfeifenberger, 2003). It then follows that real firms and in particular frontier firms, can better represent best-practice performance than reference networks. However, innovation takes place in the electricity sector as well as in other sectors of the economy. The complex nature of innovation process and its outcomes usually cannot be known in advance and thus internalised by the regulator. The inability of the NPAM to continuously reflect or promote technological change is a significant shortcoming of the model. Actual best-practice firms, under the right incentives, are the likely actors to represent the evolving nature of innovation in the sector.

As discussed, in terms of promoting innovation, the NPAM is deterministic and backward looking. The evolution of best practice and innovation at the frontier are exogenous to the model. In frontier-based benchmarking a general technical change element may be incorporated ex-ante in the X-factor rather than being realised *ex post*. The NPAM's design and parameters are at best based on technologies of the recent past. As a result, the NPAM many penalise a firm that is in transition from an older specification to a more modern and advanced design that the NPAM implies. The design and cost components and design of the model can, therefore, differ from those of efficient real companies.

3.7 Regulatory uncertainty

A key factor in effectiveness of incentive regulation regimes is their ability to create a stable regulatory framework. Regulatory uncertainty has negative implications for the behaviour, cost of capital, long-term investments, and innovation in the regulated firm. The regulatory framework should provide the companies with incentives to achieve their full potential in reducing inefficiency. This overriding priority holds even where the regulatory model may not immediately transfer the efficiency gains to customers. Failure to transfer the efficiency gains to consumers in the medium and long term is, however, a major shortcoming for any incentive regulation regime. Initially, it is preferable if the utilities gain some one-time benefits from efficiency improvements rather than not realising them altogether.

Incentive regulation based on ex-post reviews inherently involves some uncertainty for the regulated firm. In addition, the presence of uncertainty combined with annual reviews can reduce the firms' incentive to engage in long-term efficiency enhancing measures in, particular, if the gains from these do not have a lasting benefit - i.e. they can be subject to regulatory appropriation quickly. As stated in Dalen (1998, p.108): "When the regulator is able to reduce firms' private information ex post, we should expect to find reduced investment incentives ex ante".

Regulatory uncertainty can also be found in ex-ante regulation with, for example five-year, price control reviews. However, with annual ex-post price control reviews, the uncertainty of the regulatory contract, which may take one or two years (and in complex cases even longer) before being finalised, is likely to be higher and has significant negative effects on the firms' cost of capital and incentives for investments in efficiency and innovation.

3.8 Ensuring transparency

Incentive regulation and benchmarking are conceptually based around the power of profit motive and market-oriented mechanisms which are inherently based on transparency. Therefore, transparency of the regulatory framework increases the effectiveness of an incentive models. In benchmarking, transparency should be applied to publication of data, decision rules and process, and results. There is often little known about the progress and achievements of incentive regulation and benchmarking regimes that lack transparency in these respects. Also, the lack of transparency is more likely to lead to regulatory capture by resourceful firms.

Transparency has a disciplinary effect on the regulator and the firms but also facilitates participation and insight for other stakeholders and interest groups. Also, transparency leads to clarity of rules and procedures as it benefits from third-party participation in the process. Transparency should also be extended to open hearings, publication of consultation and opinion documents, and the final decisions. The well-performing incentive regulation regimes such as in Norway and the UK have operated with a high degree of transparency.

The transparency principle also requires the use of a reasonable amount of useful information. A regulatory process that produces a large amount of information that is costly and lengthy to use does not reduce information asymmetry and leads to exclusion of third-party interests. In a study of regulation of Chilean distribution companies, Di Tella and Dyck (2002) point out that collecting and processing excessive amount of information can be overwhelming and counterproductive for the regulator. Simple but well-designed regulatory models and processes can provide much useful information at low cost to all the parties involved.

The use of complex benchmarking models such as the NPAM inevitably tends to reduce the transparency of the regulatory model. In practice, given the highly technical nature of the NPAM, only the regulator and the individual firms will have the insight into and knowledge of the model details for each company. This effect can be strengthened when combined with frequent price control reviews of firms. The complexity and the sheer number of the NPAM models (one model for each firm) reduce the transparency of regulation and limits insight and participation of interest parties interests in the regulatory process.

3.9 Summary of differences between NPAM and frontier-based benchmarking

We defined a set of evaluation criteria drawn from best-practice incentive regulation and frontier-based benchmarking for assessing the use of norm models and reference firms in network regulation in the case of Sweden. The comparison and assessment of the NPAM using based on our evaluation criteria are summarised in Table 3.

The use of the NPAM differs somewhat from those of frontier-based benchmarking methods. The model develops efficient standard reference networks to identify non-performing real firms ex post which then may be subjected to detailed regulatory scrutiny and performance improvement requirement. In contrast, frontier-based benchmarking methods identify an efficient or best practice frontier of actual firms. Less efficient firms are then compared against this frontier and incentivised to move towards this frontier.

	Criteria	NPAM	Frontier Benchmarking
1	Model variables and environmental variables	Essential variables for modelling the network are used in the models. One caveat is the dependence of several important parameters on customer density. Environmental variables are not included in the model.	Usually a limited number of parameters are included in the models as there is degree of correlation between many of the important variables.
2	Quality of service	Cost of quality included in model. The effect of differences in quality performance may be large for some firms.	In the UK, the service quality has been regulated outside of the benchmarking model through performance standards and penalty /reward attached to allowed revenues. In Norway, cost of quality has been included in the DEA models.
3	Efficient comparators	For identification of asset requirements the reference model is an efficient comparator. For identifying capital base and O&M and their trade-offs and organisational feature the reference model is not a likely efficient comparator.	The frontier is made-up of real firms representing best practice. Quality and comparability of data is important.
4	Sufficient investments	Long term nature of investments and design improvement in conflict with frequent reviews. Possibility for case by case model driven effects.	In the UK, capital investments have been regulated outside of the benchmarking model and investment plans have been reviewed for approval and incentivised. In Norway, where Totex is benchmarked, there are not apparent under-investments.
5	Long-term innovation	Updates of the model are not substitute for evolutionary nature of innovation in real firms.	Total factor productivity (TFP) and frontier shift analysis can serve as indicators of innovation and technical progress in the sector.
6	Consistency of results	Unclear whether model results are consistent across the sector as well as with those of other methods.	The consistency results of models and techniques can be examined to increase confidence.
7	Uncertainty	Uncertainty associated with frequent reviews within an ex-post approach likely to have negative effect on investments and innovation.	Stability of the regulatory framework and consultations reduces uncertainty. Uncertainty may also be reduced through selecting appropriate length of price control reviews.
8	Transparency	The resource requirements of large number of models is non trivial. Information requirements, number of models and their technical nature are likely to reduce insight and third-party participation.	Clarity of rules and openness of regulatory process and decisions provides equal information to all firms and facilitates third-party participation in the regulatory process.

Table 3: Performance criteria and comparison of the NPAM and frontier-based benchmarking

Finally, perhaps the most fundamental difference between reference firms and other incentive regulation models is also the most subtle one. Essentially, incentive regulation is based on the application of economic methods and models to a regulated activity and provision of a public service - i.e. transportation of electricity over the networks. The concept of incentive regulation is therefore rooted in basic economic principles of profit maximisation and that, given the right framework and incentives, these will result in an efficient outcome. The structure of the firm, organisation of activities, and the processes by which the form achieves this outcome is generally regarded as a "black box" or matters that are internal to the firm and not for intervention by the regulator.

The use of reference models in incentive regulation, however, implicitly assumes that much of the structure, organisation, and processes of the regulated firm can be represented by an engineering model of the firm. The efficient operation and outcome from model firm is then derived as a deterministic result. It then follows that the engineering models of firms cannot reflect the flexibility, dynamism, synergies, and innovation drive of real firms and comparators.

We have discussed some shortcomings with regards to structure and implementation of the NPAM. However the model can play a role as a regulatory benchmarking tool. This role should not be as the primary benchmarking tool but rather as a tool to be used in conjunction with frontier benchmarking methods.

- Reference firms can be used to assess large new investments for asset renewal, network expansion, and distributed generation by the utilities and regulators. They can also facilitate interaction and settling of related disputes between them.
- Reference firms can be a useful tool in assessing and overseeing the design of access charging methodologies and oversight of them (see Jamasb et al., 2005).
- Reference firms would be more useful in regulation of transmission systems where the number of comparators is generally limited and the use of frontier techniques is difficult.
- Reference firms are useful for countries with few companies which make the application of the commonly used benchmarking techniques difficult without resorting to international benchmarking.
- Reference firms maybe useful for developing countries where severe lack of reliable data does not allow for the use of frontier-based benchmarking in a transition period. However, the application of reference firms in countries with fast growing demand and rapidly expanding networks may be more difficult than in a mature system and slow growing demand as in Sweden.

4. Conclusions

The use of reference networks using norm models as an alternative to frontier-based approaches to benchmarking and regulation is appealing to some regulators. This paper defines a set of evaluation criteria concerning incentive properties and key regulatory issues to assess the model and compare it with frontier-based approach to benchmarking and incentive regulation. We examine the use of such models in the context of the Swedish network regulation and find that the differences between these two approaches are non-trivial.

The NPAM can be characterised as a static and stylized representation of an efficient firm that non-performing firms need to achieve in the medium-term. It captures the main parameters necessary to model a distribution network. In this regard the model is more comprehensive and detailed than the production function of the frontier-based methods. Quality of service is incorporated in the model although the effect of including the cost of service quality on allowed revenues may vary considerably across the firms and can be rather high for some of them.

However, several critical parameters of the model are highly dependent on customer density. While there is some empirical evidence for the cost reducing effect of customer density, it makes the model highly deterministic upon a factor over which the firm has no control. The effect of such uncontrollable variables on firm performance is an empirical question that needs careful examination. In frontier-based benchmarking environmental variables may be included in the model if deemed significant or, alternatively, the efficiency scores can be controlled for their effects. The extent to which the reference model can capture the non-network aspects of firms and the synergies between the different functions of the firms is a shortcoming of the model. In practice, it may become necessary for the regulator to modify the model outcomes by applying judgement and discretion.

When subjected to reference models, firms will also attempt to negotiate and perhaps influence the regulatory decisions. The outcome of such a process largely depends on the firms' bargaining power and the regulator's ability to develop proper design and assign correct costs to the reference models. Whether such outcome is superior to those of frontier-based incentive regulation models such as in Norway and the UK is doubtful.

Reference models cannot allow for innovation in actual firms which is the main source of long-term technical change for the sector. The primary aim of regulation should be to develop appropriate incentives and create the conditions for these to work. It is important to allow the real networks to evolve at a natural pace. The NPAM is not likely to identify and reflect the dynamic and complex nature of product or process innovation in real firms.

Despite the above shortcomings of the structure and use of the NPAM, the model can still play a role as a regulatory benchmarking tool. However, this role may not be as the primary or only benchmarking tool and rather as a supplement to, for example, frontier-based methods. We also pointed out several other potential areas where the NPAM is able to play a significant role.

The combined effect of the model's weaknesses is likely to be compounded by a short-term regulatory framework which is based on annual reviews. The model is applied within an *ex-post* regulatory approach. Ex-post regulation becomes more difficult with long time lags something which may initially have led to annual applications of the model. The incentive properties of the regulatory framework of the model are not desirable as they create regulatory uncertainty and will have a negative effect on long-term investments and innovation and ultimately the performance of networks. However, it would be possible to improve this feature of the regulation without resorting to a frontier based model.

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