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DEA/Malmquist Procedures in the 2nd Reference Report of the Bundesnetzagentur

For Energie Baden-Württemberg

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Executive Summary

The Bundesnetzagentur (BNA) has set out a calculation of the parameter known as the X-factor – the expected rate of productivity growth to be included in price cap formulae for electricity and gas networks in Germany. The BNA has adopted the Tornquist(-Theil) index for this purpose – as is conventional in regulatory estimates of productivity growth – but has also indicated a preference for switching to the Malmquist index. Since both indices produce similar estimates of productivity growth, a switch to the Malmquist index would only be useful if the BNA planned to make use of a special feature of it.

The Tornquist index calculates an estimate of productivity growth from two separate components:

1. estimated growth in inputs; and
2. estimated growth in outputs.

In contrast, the Malmquist index breaks down estimated productivity growth into two different components:

1. the estimated rate of change in a "best practice frontier" and
2. the estimated rate of change in a firm's efficiency relative to that frontier ("catch-up").

The only relevant feature is the Data Envelopment Analyis (DEA) procedure derived from the Malmquist index, which achieves the break down between technological change (shifts in the frontier) and changes in efficiency ("catch-up"). Other European regulators have used this approach to estimate the *level* of productivity of specific firms, as an alternative basis for setting a target level of future costs and, indirectly, the X-factor needed to "catch up" with this target level.

Unfortunately, the DEA/Malmquist procedure does not provide any objective basis for estimating either the "efficient" level of costs or the required level of "catch-up" for a single firm. Experience in other European regulatory regimes confirms the subjective or arbitrary nature of such analysis and contradicts the impression given by the BNA Report, that such an approach is conventional, necessary or a proven method of regulation.

Adopting a regulatory policy based on assessing the *level* of productivity would therefore lead to many subjective regulatory decisions, which undermine confidence in future cost recovery and eventually destroy the incentives for efficient behaviour that incentive regulation is intended to create. Hence, we strongly advise the BNA not to proceed down this path, but to continue to improve the Tornquist index methods it has adopted in its 2nd Reference Report.

1. Introduction

Energie Baden-Württemberg (EnBW) has asked NERA Economic Consulting to review the 2nd Reference BNA Report on Incentive Regulation[1] issued on 26 January 2006 by the Federal network regulation agency, the Bundesnetzagentur or BNA. The BNA Report discusses the method of calculating an "X-factor" for future price controls applying to networks in Germany.

The BNA claims that the Malmquist index is theoretically preferable to the Tornquist index as the basis for calculating productivity growth, but it is forced to use the Tornquist index for the moment because it lacks the required data (paragraph (69)). The BNA states its intention to switch to the Malmquist index at some time in the future.

This review comments on both the BNA's preference for the Malmquist index and on the general implications for regulation of using it.

1.1. Definition of an X-Factor

Under the latest German Energy Law (Energiewirtschaftsgestez or EnWG), the BNA is required to impose a system of "incentive regulation" on electricity and gas networks.[2] The agency interprets incentive regulation to include caps on the prices (or total revenues) of each network, where the cap is automatically adjusted from year to year by a formula (instead of being reviewed in detail at the start of each year). The 2nd Reference Report does not lay out the proposed adjustment formula in any detail, but anticipates in paragraph (20) that it would include automatic adjustment for (at least) two factors:

§ the general rise in prices, which increases the costs of a network business; and

§ the expected increase in productivity, which decreases the costs of a network business.

Because the original papers on the design of regulatory price caps[3] recognised these two factors, this type of formula is sometimes called "RPI-X" or "CPI-X", where

§ "RPI" and "CPI" stand for the rate of change in, respectively, the Retail Price Index or the Consumer Price Index (both measures of general inflation); and

§ X stands for the expected rate of growth in productivity.

The choice of the price index is relatively straightforward, compared with the calculation of the X-factor. The BNA's 2nd Reference Report (which we refer to henceforth as "the BNA

1 BNA (2006), *2. Referenzbericht Anreizregulierung: Generelle sektorale Produktivitätsentwicklung im Rahmen der Anreizregulierung („2nd Reference BNA Report on Incentive Regulation: General sectoral productivity movements in the context of incentive regulation"),* Bundesnetzagentur, Bonn, 26 January 2006.

2 NERA Economic Consulting is not a law firm and we do not provide any legal advice on the laws and regulations covering network regulation in Germany. All our statements represent the views of economists familiar with the economic principles of network regulation. Legal interpretations may be different and affected parties are advised to seek legal advice.

3 See for example M.E. Beesley and S.C. Littlechild (1989), *The Regulation of Privatized Monopolies in the UK,* RAND Journal of Economics 20, pp 454–72, 1989.

Report") sets out the BNA's proposed method of calculating an X-factor, i.e. the expected rate of productivity growth to be included in the price cap formula for German gas and electricity networks.

1.2. Outline of This Review

Although the BNA does not set out its intentions in detail, it states a preference for the Malmquist index, which can only mean that it wishes to collect and to use certain information derived from the Malmquist index to set company-specific ("individual") X-factors. Although we can only infer this intention from the BNA Report, we have commented specifically on this type of regulatory method.

To put our comments into context, chapter 2 discusses this aspect of the BNA's proposal, the purpose of X-factors, and the economic principles that apply to every type of network regulation.

Chapter 3 then looks in detail at the economic literature on index numbers and their suitability for use in the way that the BNA seems to intend. Appendix A provides a more detailed history of the development of index numbers. Overall, this literature indicates that the DEA/Malmquist procedure to which the BNA refers is not capable of providing a stable and objective regulatory method.

Chapter 4 summarises our conclusions.

2. Methods of Regulation

2.1. Background

The BNA report uses the Tornquist index to create a time series of productivity measures, in order to estimate the time trend in the growth of Total Factor Productivity (TFP), i.e. the productivity of all input factors including labour, capital, materials, land, etc. The BNA Report summarises the formula for the Tornquist index in "Exkurs 1" on page 15, and Appendix A below contains a more detailed description of this index and its evolution. The BNA Report also describes the calculation of a Malmquist index in "Exkurs 2" on page 17, and Appendix A below also decribes the Malmquist index and its role.

The Tornquist index relies on cost shares or other value-based weights, which implies a need for price indices as well as quantity indices, whereas calculating the Malmquist index only requires quantity indices. However, both indices were developed with the intention of tracking productivity over time, in order to measure *growth* in productivity. Leaving aside these differences, and provided that adequate data is available, the Tornquist and Malmquist indexes should provide similar estimates of TFP and TFP growth.

The BNA's stated preference for the Malmquist index lies in its ability to separate out an estimate of TFP into "technological change" and "catch-up".

§ The Tornquist index calculates a figure for productivity growth from the respective contributions of (1) output growth and (2) input growth. The index uses data for multiple outputs and inputs, if there is more than one output or input.

§ In contrast, the Malmquist index decomposes productivity growth into (1) "technological change" in a "best practice frontier" and (2) efficiency "catch up", i.e. the extent to which a firm is moving towards or away from the industry's best practice".

The Malmquist and Tornquist indices provide different ways to calculate an index of productivity. For regulatory purposes, Tornquist index number methods have become relatively standard for measuring the various components of outputs and inputs among productivity analysts, so the BNA's stated preference for the Malmquist index is a departure from normal practice.

2.2. BNA Rationale for Using the Malmquist Index

The BNA Report refers to the breakdown of the Malmquist index between technological change and "catch-up" (paras 61-63) and also points out that the Tornquist index does not provide equivalent information (paragraph 65). The BNA Report even claims (paragraph 61) that the Malmquist index provides an "exact" ("exakt", "genaue") breakdown. Such a claim is incorrect, as we explain below, but the BNA's stated preference for the Malmquist index is based on its ability to divide productivity growth between a "frontier shift" (movements in the best practice frontier) and "catch-up" (other changes in efficiency relative to the frontier). This characteristic of the Malmquist index would only be relevant to the choice of method if the BNA expected to use the breakdown for regulatory purposes.

In practice utility regulators in Europe have determined the X-factor by a variety of approaches which fall into two main categories: "growth-based" and "level-based". The first calculates an X-factor ***directly*** on the basis of a procedure for comparing the rate of change in various firms' productivity. The second approach computes a value for X as the ***indirect*** residual result of a comparison between two forecasts of required revenues – one at the start of a multi year price cap period and one at the end.

Although the BNA has not said how it would propose to use the different components of the Malmquist index, we note its intention to develop a "general" X-factor for the sector as a whole and also an "individual" X-factor for each company. The BNA seems to imagine therefore that breaking down the Malmquist index would provide a basis for estimating these two X-factors separately. Indeed, we are aware of attempts to carry out precisely this exercise in other countries, as a basis for estimating the required revenue at the end of a price cap period.

However, in practice it is impossible to calculate "general" and "individual" X-factors objectively using the Malmquist index. Attempts to carry out such a calculation require subjective decisions and assumptions and the range of possible outcomes is so wide that the DEA/Malmquist procedure effectively provides no guidance as to the appropriate figures. This approach is therefore inconsistent with the need for transparent and objective regulatory methods to provide incentives for efficient behaviour, as we explain below.

2.3. Objectivity: The Overriding Consideration

Energy networks are characterised by irreversible investment in long-lived assets. To serve the needs of customers, the regulatory regime as a whole must offer investors an incentive to make such investments, knowing that they have a *reasonable prospect of cost recovery* over the long term. Costs, in this context, means that the firm's operating expenses, depreciation and a reasonable return on capital (also defined as the cost of capital). The regulatory regime does not have to *guarantee* cost recovery, but it must offer the prospect that a reasonably efficient company can recover its costs, i.e. that the regulatory regime will not systematically or arbitrarily prevent cost recovery. To meet this standard, the basis for setting future revenues must be reasonable, meaning that it should use objective, replicable methods and verifiable input data, to minimize the scope for disputes and subjective regulatory decisions.[4]

If these conditions for capital attraction are not met, then regulated firms will still have the short- to medium-term incentive to cut costs offered by the price cap formula, but they will have little or no incentive to make new investments. The firms may be obliged by licence conditions or regulations to meet certain minimum capacity and security of supply standards. However, if investors do not have a reasonable prospect of cost recovery, then either the regulated firms will not invest, or they will run into financial difficulties if they do invest. Neither outcome is efficient or in consumers' interests.

Our discussion of regulatory methods therefore places a high value on objectivity. A method of calculation is objective if the results do not depend upon subjective choices about the

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4 These principles are found in a number of eminent sources, including: (1) Bonbright, James C; Danielsen, Albert L; Kamerschen, David R. (1988), *Principles of Public Utility Rates*, 2nd ed. Arlington, Va, Public Utilities Reports; and (2) Phillips, Charles F. (1993), *The Regulation of Public Utilities: Theory and Practice*, 3rd ed. Arlington, Va, Public Utilities Reports

choice of input data, the method of calculation or interpretation of results. We note incidentally that section 21a of the German Energy Sector Law (EnWG)[5] obliges the regulator to estimate efficiency targets using methods that are not affected excessively by a small change in a single parameter.[6] Although we cannot offer a legal interpretation of this standard, it seems to be consistent with an economic interpretation of the need for objective regulatory methods.

2.4. Regulation Based on Estimated Levels of Productivity

For this method, the regulator reviews information from the company to define a yearly revenue requirement (i.e. allowed costs, including a return on capital) for each year of the next price cap period, or just for the end-year of the next price cap period. This forecast may allow for predicted changes in regular expenditures and planned investment, but also incorporates assumed efficiency gains that the company is expected to achieve, based on a comparison of its costs with some “benchmark” level of costs. The yearly *X-factor* then provides the necessary transition between (1) the *level* of prices in the present year and (2) *level* of prices needed to cover the forecast revenue requirements at the end of the price cap period.

As a result, this *X-factor* (which we italicise, to distinguish it from the normal meaning) only indirectly measures the expected rate of productivity growth, being derived from a comparison of two different levels of productivity – the current level and a regulator’s assessment of “efficient” operations – although it may contain a number of other adjustments as well.[7]

Much of the “forecast revenue requirement” method relies upon forecasts of costs — a technique that relies heavily on subjective assessments of future needs. This area has sometimes led to the use of Data Envelopment Analysis (DEA). DEA also provides a way of estimating the Malmquist index, which the BNA has said it would prefer to use. We therefore discuss the use of DEA in regulation as a representation of the BNA’s intention to switch to a Malmquist index in the future.

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5 Energiewirtschaftsgesetz 2005.

6 EnWG 2005, section 21a paragraph (5): „Die Methode zur Ermittlung von Effizienzvorgaben muss so gestaltet sein, dass eine geringfügige Änderung einzelner Parameter der zugrunde gelegten Methode nicht zu einer, insbesonderere im Vergleich zur Bedeutung, überproportionalen Änderung der Vorgaben führt.“

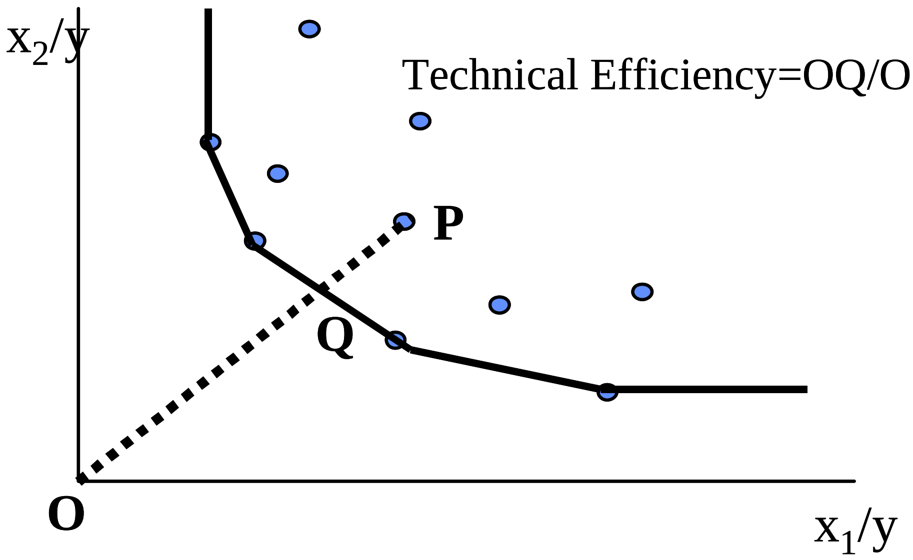
7 This has been a popular method in the UK, the Netherlands and Australia. In Australia, however, a panel of experts is working on a revisions of nationwide regulatory practices, noting the unsatisfactory results associated with using forecasts of costs as the basis for a *derived* X-factor.

3. Index Numbers and Data Envelopment Analysis

Data Envelopment Analysis (DEA) can be combined with the Malmquist index to assume a breakdown between technical change and the efficiency of individual firms. DEA combines multiple input and output measures (both monetary and physical) to generate an overall efficiency measure for a company. Mathematical programming methods allow researchers to use quantitative information about a company and its peer group (i.e. the "comparators") to determine relative performance in terms of efficiency.

Figure 3.1 illustrates the basic DEA approach. This figure displays an input-oriented[8] efficiency measurement for a group of ten companies, which assumes that there is one type of output (e.g. millions of kWh of energy delivered) and two kinds of input (e.g. capital and labour). This type of efficiency measure considers the degree to which input quantities can be proportionally reduced without changing the output quantities.

Figure 3.1
Efficiency Measurement with Data Envelopment Analysis (DEA)



The figure plots the combination of inputs (x_1 and x_2) that each company employs to produce a unit of output, which for simplicity is normalized equal to one. Based on the actual behaviour of the ten companies, an envelope curve or efficiency frontier (shown by the dark broken line) is identified, reflecting the industry best practice. Obviously, the closer a firm is located to this curve the higher is its level of efficiency. Alternatively, firms that are located further out can in principle produce the same amount of output with less inputs, which would bring them closer to the origin and the achievement of higher efficiency. Each firm's efficiency level can be measured empirically. For instance, Firm P's efficiency score is equal

8 DEA also allows the construction of output-oriented efficiency measures, which we describe later on with regard to the issue of total factor productivity. In this case the relevant question is by how much can output quantities be proportionally expanded without altering the input quantities used. Output and input-oriented measures are equivalent only in those cases in which the technology of production exhibits constant returns to scale.

to the ratio OQ/OP. If a firm is located on the efficiency frontier then it obtains the highest possible score, which is equal to one.

Certain analysts (and some regulators) have taken the relative positions on such graphs as Figure 3.1 as indicative of the current *level* of efficiency that each company is achieving, relative to the frontier. Furthermore, they have interpreted the frontier as the efficient level of costs that companies should be *expected* to achieve, albeit within a few years (where the time required to catch up to the frontier varies from case to case). They have therefore used DEA to define an ***X-factor*** for a particular firm, by converting the efficiency score OQ/OP into an annual rate of change. For example, if a company had an efficiency score of 88%, implying a 12% distance from the frontier, some regulators might convert that distance into an annual ***X-factor*** of 3% per annum for 4 years, or 4% per annum for 3 years, or some other combination.

It is possible that the BNA has in mind a similar use of the Malmquist index, decomposed into its two elements. However, such methods are inconsistent with the price cap theory, as we explain below.

3.1. Malmquist and Levels of Efficiency

Users of the Malmquist index number in a regulatory setting frequently refer to the "seminal" 1978 paper by Charnes, Cooper and Rhodes.[9] This paper concerns measure of efficiency "with special reference to possible use in evaluating public programs."[10] In that paper, Charnes, *et al*, make use of Data Envelopment Analysis (DEA) as a method to chart the comparative efficiency of public programs (decision making units or DMUs). That analysis, as shown graphically in Figure 3.1, measures the distance between the presumed efficiency frontier and the position of an individual DMU, implying inefficiency in that unit. They do, however, warn of the method's limitations outside of the public sector, saying

> *One limitation may arise because of lack of data availability at individual [decision making unit] levels. This is likely to be less of a problem in public sector, as contrasted with private sector, applications. … Our measure is intended to evaluate the accomplishments, or resource conservation possibilities, for every DMU with the resources assigned to it.*[11]

That is, by standardizing the "resources assigned to it," as in the case of the school district example discussed by Charnes, *et al*, they recognize the limitation of their suggested DEA method in situations where input choice or environmental factors cannot be standardised and it is not possible to make explicit adjustment in the analysis to "control" for every single variation in resources and environmental conditions.

Despite its limitations for private firms, the Malmquist index (represented in Figure A.2), is a direct analogue to DEA analysis, where the distance of a particular firm's observation (in a

9 Charnes, A., Cooper, W.W., and Rhodes, E. (1978), Measuring the Efficiency of Decision Making Units," *European Journal of Operational Research*, Vol. 2, 1978, pp. 429-444.

10 Charnes et al (1978), p. 429.

11 Charnes et al (1978), p. 443.

particular year or for an average of years) is compared to the "envelope". The most fundamental problem with the use of the Malmquist index in this way for different network utilities is that neither the environmental nor the input factor can be "controlled" (i.e. it is impossible to allow for the effect of all the differences in environmental factors and inputs between the companies being studied).

Federico, has gone right to the heart of the matter of the problem with holding environment issues constant:

> *In spite of its nice theoretical properties, the Malmquist index is subject to all the shortcomings of conventional measures. It does not take into account environmental losses, nor possible distortions from the use of benchmark years and the two measures of technical change differ if technical progress on the "frontier" is not neutral. On top of this, the Malmquist index (as the multi-country production function estimates) assumes that all units can attain the same level of production given their factor endowment –i.e. that they belong to the same production function. This assumption may not hold in agriculture, where feasible techniques heavily depend on environment.*[12] *(Federico, pp.4-5)*

What is true for agriculture in different environments is also true for energy networks in different locations. The question of environmental factors cannot be disentangled from efficiency in either DEA analysis or its Malmquist equivalent. Sena reviews the various methods with a warning about these environmental variables in evaluating the results of either DEA or Malmquist models that purport to identify efficiency for individual firms separate from the frontier:

> *However, the main weakness of the DEA (namely that it is a deterministic method) is still there and so the computed distance functions may include the effect of factors not related to technical efficiency and technical change….The best option left to the researcher is to try to specify the DEA model (underlying the Malmquist index) in the best possible way so to minimize (sic) the impact of external factors on the computed distance functions.*[13]

Sena identifies another problem with the use of DEA analyses underlying the Malmquist index—that of stochastic shocks in the data:

> *DEA does not allow us to model stochastic shocks to production i.e., it is deterministic. Therefore the computed efficiency scores may be biased by factors which are external to the production process. Not surprisingly some attempts have been made to incorporate stochastic components into the linear programming problems. … The data requirements of the chance-constrained*

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[12] Federico, G., "Why are we all alive? The Growth of Agricultural Productivity and its Causes, 1800-2000," European University Institute, paper for the Sixth conference of the European Historical Economics Society, Istanbul, 9-10 September 2005, pp. 4-5, quoted with author's permission.

[13] Sena, V., "The Frontier Approach to the Measurement of Productivity and Technical Efficiency," *Economic Issues*, Vol. 8, Part 2 (2003), p. 90.

> *efficiency measurement, however, are too many. Indeed it is necessary to have information on the expected values of all variables, along with their variance and covariance matrices and the probability levels at which feasibility constraints are to be satisfied. Therefore, this approach is too informationally demanding to be implemented easily.*[14]

The issues associated with bias due to stochastic shocks are genuine and highly problematic for DEA analyses with electric utility data. Appendix B to this paper contains TFP data computed for a 1986 study of electric utilities,[15] using Form 1 data from the Federal Energy Regulatory Commission (the FERC) using the Uniform System of Accounts.[16] The productivity growth figures displayed in the Appendix, generated with a Tornquist aggregation using the most reliable and consistent data for 39 electric utilities across 11 years, still shows considerable levels of stochastic shocks, particular in year-to-year comparisons.

For example, Kentucky Power for the four years 1973 through 1976 shows TFP yearly growth rates of -22.4%, 20.6%, -20.2% and 28.1%. The average TFP growth for Kentucky Power for the 11 years is 3.2 percent, and for those four particular years is 1.6 percent. But a DEA analysis would record great productivity growth for 1974 and 1976, owing only to stochastic shocks. If these shocks happened to push Kentucky Power to the "frontier" – however temporarily – DEA analysis would suggest that the frontier had shifted and that all other companies were less efficient than before. This random event could then define the level of productivity measured in a single year's DEA analysis and used to set a company's ***X-factor*** at a higher level.

However, in fact, the analysis would merely have been identifying a random shock – which was reversed in a later year – as an efficiency gain. Any associated ***X-factor*** would require the affected company to achieve ***deliberately*** something that a random event had imposed on its comparators.

3.2. Malmquist Indices, Levels of Efficiency and Regulation

Given the characteristics of the Malmquist index and of DEA listed above, any plan to base a price cap on the separation of technological change from company efficiency is going to run into problems than cannot be overcome in an objective manner:

§ Index numbers and DEA do not define each company's *level* of efficiency, because they cannot possibly control for all the environmental factors that determine a company's performance;

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[14] Sena (2003), p. 83

[15] The data in Appendix A appears in: Makholm, J.D., "Sources of Total Factor Productivity in the Electric Utility Industry," Doctoral Dissertation, University of Wisconsin/Madison, May 1986 (L.R. Christensen, advisor), Appendix 4A, pp. 88-89.

[16] The Uniform System of Accounts has been used by the FERC and its predecessors since 1938, as mandated by Congress.

- Moreover, random shocks (“noise”) in these unexplained factors can lead to further downwards bias in the “frontier” and hence to a further underestimate of a company’s performance;
- In any case, there is no objective way to convert one observation of the level of productivity into an X-factor; when choosing the period allowed for the required catch-up, it is necessary to have in mind a reasonable target for productivity growth;

Over a long-period, if the effects of biases due to omitted environmental factors remain constant, the effects of “noise” will average out, so it is possible to estimate the time trend in the index, i.e. the long-run average rate of growth. In comparison, both the level and the time trend in the frontier (which is defined partly by the extremely values affected by “noise”) will be of relatively little significance.

3.3. Conclusion

The analysis above tells us that attempting to use information on a company’s *level* of productivity to define incentive regulation formulae is ultimately a futile task.

It is impossible to identify objectively what level of efficiency a single company is achieving at any time, because neither the Malmquist index nor its close cousin DEA can allow for all the idiosyncratic features of complex businesses like energy networks. The results will therefore be biased by the impact of various omitted factors, the nature and distribution of these biases depending upon which factors the regulator has chosen to include.

Moreover, even if it were possible to calculate a level of productivity relative to an “efficiency frontier”, there is no objective way to convert it into an annual rate of growth – unless one has some preconception of the appropriate rate of productivity growth to impose on a regulated network.

Naturally, it is possible to use the index in the manner described – provided that the regulator is prepared to make any subjective assumptions required to produce a result. However, such a subjective or arbitrary regulatory method will not – contrary to the expectations of those who try – succeed in providing incentives for efficient behaviour.

4. Conclusion

The method of estimating an X-factor is subject to the same economic principles of regulation as any other regulatory decision. To offer the reasonable prospect of cost recovery that is necessary to attract investment into regulated businesses, regulators must use objective methods. Objectivity requires the use of standard methods whose results do not depend largely on subjective judgements, a criterion which seems to be supported by the German energy law. Economic theory supports the use of the Tornquist index for estimating growth in productivity as the basis for setting the X-factor. Long-term estimates of growth in productivity are relatively stable and are not affected by constant biases in the estimate of productivity levels. In the 2nd Reference Report, the BNA has adopted this standard approach, although the choice of data sources departs from good practice in several areas.

However, the BNA also indicated a preference for switching to the Malmquist index. Since the Tornquist and Malmquist indices produce similar estimates of productivity *growth*, a switch to the Malmquist index would only be useful, if the BNA planned to make use of the DEA/Malmquist procedure for distinguishing between technological change (shifts in the frontier) and changes in efficiency ("catch-up"). European regulators have occasionally used this breakdown to estimate the *level* of productivity of specific companies, but the procedure is by no means standard. Unfortunately, it does not provide any objective basis for estimating either the "efficient" level of costs or the "required" level of catch-up for a single firm. Experience in other European regulatory regimes confirms the subjective or arbitrary nature of such analysis and contradicts the impression given by the BNA Report, that such an approach is conventional, necessary or a proven method of regulation.

Adopting a regulatory policy based on assessing the *level* of productivity would therefore lead to many subjective regulatory decisions, which undermine confidence in future cost recovery and eventually destroy the incentives for efficient behaviour that incentive regulation is intended to create. Hence, we strongly advise the BNA not to proceed down this path, but to continue to improve the Tornquist index methods it has adopted in its 2nd Reference Report.

Appendix A. Index Numbers

Since price cap regulation was introduced in the UK in the 1980s, and subsequently in the US in the early 1990s, considerable discussion has attended the choice of the index number to mimic productivity. Most of the literature on index numbers for productivity measurement pre-dates the use of such information in price control formulas. Indeed, all three of the productivity index numbers in general use for price cap regimes were formulated by their named authors decades ago. They are the Fisher Ideal index, used by the FCC for price caps in the United States, the Tornquist (or Tørnquist or Törnquist) index (also known as the Tornquist-Theil index[17]), which forms the basis for many electric utility TFP studies, and the Malmquist[18] index, which has been accepted by agreement in the Netherlands and proposed by the German regulator.

A.1. Brief History of the Fisher and Tornquist Index Numbers[19]

Index numbers of widely different construction appeared in the mid-eighteenth century in France and Massachusetts as attempts to obtain a systematic description of commodity price changes and monetary values.[20] The first scholarly study of index numbers was conducted by Jevons (1863) who, using a geometric mean formula, worked out index numbers for English prices back to 1782. His strong endorsement of systematic tabular standard of value kindled a general interest in the subject. For this he is considered by some to be the father of index numbers. The first exhaustive and systematic study of index numbers appeared in Professor Irving Fisher's classic 1922 work on index numbers.[21] He evaluated the biases and tested the accuracy of all index number formulae then known, classifying all into six broad types. Fisher's criteria for evaluating index numbers are used today.

Fisher advocated a particular formula, his "Formula 353", as "probably slightly superior in accuracy to any of the others".[22] This index number, known as the "Fisher Ideal," is the geometric mean of the well-known Laspeyres and Paasche indexes described in almost any basic economics text. While Fisher knew his index to be "ideal" in respect to his own

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17 Tornquist (a statistician in Finnish government service writing in the 1930s) and Theil (an American econometrician) both investigated the validity of index number techniques. The index number used most widely for TFP studies, which is the geometric mean of the Laspeyres and Paasche indexes described in basic economics textbooks, is named after both, but the full name is often abbreviated. Many writers also refer to "Torn*qvist*" and associated variants. In this paper, we have adopted the Anglophone version, Tornquist, except when quoting other authors

18 Malmquist, S. (1953), *Index numbers and indifference curves*, Trabajos de Estatistica, vol. 4, pp. 209–242. As with Tornquist, many writers refer to "Malm*qvist*".

19 This section is drawn from: Makholm, J.D., "Sources of Total Factor Productivity in the Electric Utility Industry," Doctoral Dissertation, University of Wisconsin/Madison, May 1986 (L.R. Christensen, advisor) Chapter 2, pp. 31-43.

20 In France, it concerned a 1738 study of the prices in the times of Louis XII, in Massachusetts it was an attempt by that Colony in 1747 to create a tabular standard for the payment of indebtedness as a means of escaping the effects of the depreciation of paper money. See Fisher, I., *The Making of Index Numbers*, Third Edition, Houghton Mifflin Co, Boston Massachusetts (1927), page 458.

21 Fisher, I., *The Making of Index Numbers, A Study of Their Varieties, Tests, and Reliability*, Houghton Mifflin Company, Boston (1922).

22 Fisher, *op cit*, page 360.

criteria, he did not know that it was also ideal in the context of much later development in economic theory.

The modern microeconomic theory of both consumers and the firm rests on the concepts of utility and production functions, along with their respective duals, like indirect utility functions and cost functions. Long after Fisher's work, economists discovered that the properties of some index numbers are directly related to the properties of these underlying aggregator (i.e. utility and production) functions. Such index numbers are called "exact" for that aggregator function. This link prompted the study of the *economic theory* of index numbers.

Another key discovery in index number theory was that specific index numbers could be derived from particular aggregator functions, allowing for basing index numbers on chosen functional forms. Professor Diewert thus made a strong case for limiting consideration of aggregator functions to those which are "flexible."[23] A flexible functional form can provide a second-order approximation to any arbitrary aggregator function.[24] Diewert deemed as "superlative" any index number that is exact to such a flexible aggregator function.

Diewert found that the "Fisher Ideal" index to be superlative for a quadratic mean of order two (QM2) aggregator function. The other superlative index formula is the Tornquist translog index proposed by Tornquist[25] and Theil.[26] It is exact for the homogeneous translog aggregator function derived by Christensen, Jorgenson and Lau.[27] This translog aggregator function formed the basis of a number of industry cost studies in the early 1980s.

A.1.1. Tornquist index

The source of popularity of the Tornquist index follows its association with "translog" production and cost functions that we discussed above. Simply put, translog functions (which are functions squared in logarithms) were the first to allow economists empirically to study "U-shaped" cost curves of real-life firms. With such functions, scale and substitution economies could be investigated empirically rather than assumed theoretically. With such flexible, empirically developed production technology as a foundation, the theoretical base for index numbers that reflect such production technology is very strong.[28]

TFP growth is measured as the difference between the growth rate of a firm's outputs and its inputs. If more output can be produced from the same or a smaller amount of inputs,

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23 Diewert, W.E., "Exact and Superlative Index Numbers," *Journal of Econometrics*, Vol. 4, No. 2 (May 1976), pp. 115-146.

24 A straightforward second-order Taylor approximation to an arbitrary function is an example.

25 Tornquist, L, "The Bank of Finland's Consumption Price Index," *Bank of Finland Monthly Bulletin*, No. 10, pp. 1-8.

26 Theil, H., "The Information Approach to Demand Analysis," *Econometrica*, Vol. 33, No. 1 (January, 1965), pp. 67-87.

27 Christensen, L.R., Jorgenson, D. W., and Lau, L.J., "Conjugate Duality and the Transcendental Logarithmic Production Function," *Econometrica*, Vol. 39, No 3 (July 1971), pp. 255-256, and Christensen, L.R.,

28 In technical terms, the Tornquist index number "exact" for the flexible homogeneous translog aggregator function. The Index is "exact" in the sense that it can be directly related to the properties of the translog. For further reference, see W. E. Diewert (1976), "Exact and Superlative Index Numbers," *Journal of Econometrics*, Volume 4, Number 2, pages 115-146.

productivity has increased. To measure the productivity, we apply ***index number procedures*** to calculate TFP growth rates directly for a population of suitably comparable companies. This procedure requires data on similar firms to create an aggregate firm index from the inputs and outputs of all the firms in the target population. The weighted average index numbers are collected for all the inputs and outputs for each year, with the input and output quantities as weights. Then the "aggregates" for each year are used to create TFP indexes.[29]

For regulatory purposes, Tornquist index number methods have become relatively standard for the various components of outputs and inputs among productivity analysts.

The computation of a Tornquist index number requires data on a set of inputs and outputs that mirrors reality in the ways that companies produce their output:

1. Quantities, for every type of input and output;

2. Shares, in order to sum the various inputs (output) quantities into a combined input (output) index and to weight the total cost share (total revenue share) of the inputs (outputs) by their respective share in total costs (revenues).

The particular Tornquist index number formula is shown in Figure A.1 below. Figure A.1 shows a complicated-looking set of index numbers in which:

§ the inputs are K (capital), L (labor) and M (materials), and the four hypothetical outputs are labelled A, B, C and D;

§ input shares are signified by small roman letters, and output shares by small Greek letters;

§ a bar (straight line) over the letters represents an arithmetic mean, and a tilde (wavy line) represents a geometric mean.

Complex notation aside, the Tornquist index is merely a very carefully specified index number that allows a direct comparison of average output to input levels for a group of firms over a number of years. Generally speaking, a growth in outputs with respect to inputs represents a growth in productivity, which the Tornquist index number will reliably and consistently measure.

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29 One use of this approach can be found in Jeff D. Makholm, "Sources of Total Factor Productivity in the Electric Utility Industry," Ph.D. Dissertation, University of Wisconsin-Madison, 1986.

Figure A.1
Components of the Tornquist TFP Formula

ln (TFP₁/TFP₀) =

$$\left[\frac{(a_1+\bar{a})}{2}\right]\ln(A_1/\tilde{A})-\left[\frac{(a_0+\bar{a})}{2}\right]\ln(A_0/\tilde{A})$$
$$+\left[\frac{(b_1+\bar{b})}{2}\right]\ln(B_1/\tilde{B})-\left[\frac{(b_0+\bar{b})}{2}\right]\ln(B_0/\tilde{B})$$
$$+\left[\frac{(g_1+\bar{g})}{2}\right]\ln(C_1/\tilde{C})-\left[\frac{(g_0+\bar{g})}{2}\right]\ln(C_0/\tilde{C})$$
$$+\left[\frac{(d_1+\bar{d})}{2}\right]\ln(D_1/\tilde{D})-\left[\frac{(d_0+\bar{d})}{2}\right]\ln(D_0/\tilde{D})$$
$$-\left[\frac{(a_1+\bar{a})}{2}\right]\ln(K_1/\tilde{K})+\left[\frac{(a_0+\bar{a})}{2}\right]\ln(K_0/\tilde{K})$$
$$-\left[\frac{(b_1+\bar{b})}{2}\right]\ln(L_1/\tilde{L})+\left[\frac{(b_0+\bar{b})}{2}\right]\ln(L_0/\tilde{L})$$
$$-\left[\frac{(c_1+\bar{c})}{2}\right]\ln(M_1/\tilde{M})+\left[\frac{(c_0+\bar{c})}{2}\right]\ln(M_0/\tilde{M})$$

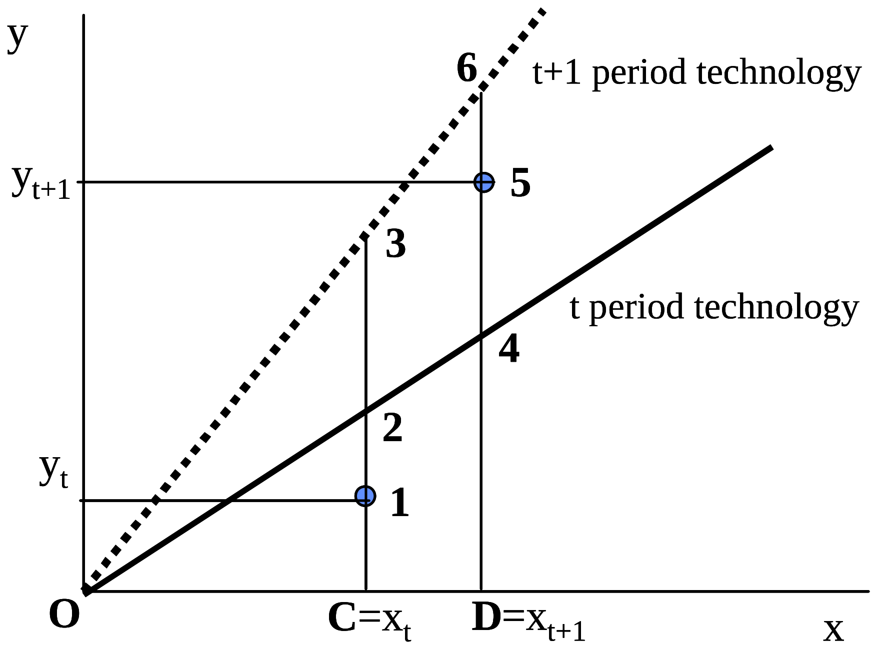
A.2. The Malmquist Index

The Malmquist index in modern regulatory literature is usually mentioned alongside the Tornquist index in the literature on index number theory. The two indexes are indeed close theoretical cousins. For regulatory purposes, however, various analysts have sized upon a particular feature of the Malmquist index that the Tornquist does not share: the purported ability to measure the extent of inefficiency of individual utilities against supposedly more efficient peers. The latter use of the Malmquist index is not based on index number theory, nor is it consistent with the empirical applications for which it appeared in the literature. In this section we will review the use of the Malmquist index by index number theorists and also by academic efficiency analysts. We show that the use of that index to judge the efficiency of particular utilities is a particular misuse of an index number method for which no support appears in the theoretical or empirical academic economic literature.

A.2.1. Definition of the Malmquist index

Figure A.2 illustrates the measurement of the Malmquist index, assuming an output-oriented efficiency measure and a constant return to scale technology. To simplify the exposition, we consider one output and only one type of input category. Figure A.2 shows the efficiency frontier and a firm's output/input combination for two different time periods. Point 1 refers to initial period (time t), and point 5 pertains to the second period (time t+1). Based on the t-period technology the firm's initial efficiency is measured by the distance C1/C2, and using the following period technology as reference it is equivalent to the ratio C1/C3. A similar calculation is made regarding the firm's performance in the following period, so that based on the initial period technology its efficiency is measured as D5/D4 and with the t+1 technology it is equal to the distance D5/D6. The Malmquist index combines productivity information relating to actual efficiency behaviour and best practice frontiers in both periods in order to determine the efficiency change (or productivity growth) between the t and t+1.

Figure A.2: Output-Oriented Malmquist Index



$$\text{Malmquist Index} = \left(\frac{D5/D4}{C1/C2} \, \frac{D5/D6}{C1/C3} \right)^{1/2}$$

In general, the Malmquist Index measures the change in an industry's total factor productivity over time. It accounts for the fact that technology is continually changing and that a firm's efficiency performance is also subject to change. For this reason, calculation of this index requires a panel of data – i.e. data for many companies over an extended period of time – for the identification of both technological change and variations in firm efficiency. The Malmquist index describes productivity growth in terms of two components: a) movements in the best practice frontier (*i.e.* technological change), and b) shifts in firm efficiency that narrow or widen the gap between actual and frontier performance.

A.2.2. The Malmquist index in index number theory

Caves, Christensen and Diewert studied the properties of the Malmquist index number in their 1982 Econometrica as a point of index number theory.[30] Their paper generalized the index numbers that corresponded (i.e. that were "exact") to a particular functional form for production and cost technology:

> *…the geometric mean of the firm k and l Malmquist productivity indexes is a generalization of the Törnquist productivity index originally proposed by Christensen and Jorgenson [note omitted]. This index reduces to the Törnquist index in the case of constant return to scale.*[31]

The index number theory literature has continued to treat the Malmquist index as a close cousin (as is the Fisher Ideal index) in a group of modern index numbers with highly desirable aggregation properties. Professor Diewert uses that index number repeatedly in his trenchant and comprehensive 1993 technical summary of the advances in index number theory. As Diewert duly recognizes, in his overview of that work, index number theory exists to study the aggregation problem in economics. As he says:

> *Economic theory is for the most part concerned with modeling the demand and supply for individual goods and services (commodities) by individual economic agents (producers or consumers). However, due to the truly enormous numbers of both commodities and agents in real life economics, empirical economics uses data that are always aggregated over commodities and often aggregated over agents. How should this aggregation over goods and agents be accomplished? … How exactly to construct these aggregate levels is the index number problem in economics.*[32]

The aggregation problem is key in index number theory, where economists continually search for more general ways to represent production technology with available disaggregated data. Caves, *et al*, in their article referenced in regulatory analyses, make a point of using their theoretical investigations to support the more widespread application of index numbers as opposed to econometric investigations of productivity. For example, in their concluding remarks they state:

> *Comparisons based on econometric estimates of the structure of production have often been viewed as being more desirable than index number comparisons; this view is based on the belief that index numbers are consistent only with restricted structures of production. Our results show that this belief is erroneous; in fact, the structures of production which we have*

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[30] Caves, D.W., Christensen, L.R., and Diewert, W. E., "The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity," *Econometrica*, Vol 50, No. 6 (November 1982), pp. 1393-1414.

[31] Caves, Christensen and Diewert (1982), page 1394.

[32] Diewert, W.E., and Nakamura, A.O.. (Editors), *Essays in Index Number Theory, Volume 1*, North-Holland, Amsterdam (1993), p. 2, emphasis omitted.

> *considered in this paper [with the Malmquist index] are so general that they would be difficult to estimate econometrically.*[33]

Ultimately, where productivity is concerned, index number theorists search for ways to marry discrete data points with a production technology that supposedly moves smoothly over time (i.e. the "time derivative" to productivity theorists or the "trend rate of growth in productivity" to others). That may seem like an esoteric pursuit to non-economists, but it is core to the development of modern index numbers in productivity analyses. As Caves, *et al*, state:

> *Since the pioneering work of Solow [i.e. Robert M. Solow, the 1987 Nobel Prize winner], productivity growth or technical progress has been associated with the time derivative of the production function … but it is not convenient for actual measurement of productivity using index numbers. The reason is that index number procedures entail comparison using discrete data points and, therefore, require a discrete approximation to the time derivative. The purpose of this paper … is to propose a measurement … that does not proceed from a continuous time representation. The key to the proposed approach is the notion of a Malmquist index….*[34]

The Malmquist index arose in productivity theory as a more general, less restrictive, way of representing how a production function moves over time. The particular feature of that index number that interests some analysts who use it in a regulatory setting – that it "has as advantage that it can differentiate between technical change and changes in productivity"[35] – is not a use which index number theorists investigated, nor is it supported in that literature.

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33 Caves, *et al* (1982), p. 1411.

34 Caves, *et al* (1982), p. 1393

35 Dykstra, M., "How Efficient is Dutch Electricity Generation,: Current Research, CPB Report (the Netherlands), 1997/4, pp. 45-47 (http://www.cpb.nl/nl/pub/cpbreeksen/cpbreport/1997_4/s3.pdf)

Appendix B. Examples of Efficiency Indices

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APPENDIX 4A (cont.)

TFP INDEX
FOR 39 ELECTRIC UTILITIES
BINARY INDEX COMPARISON
(DUQUESNE LIGHT 1980 = 1.0)

COMPANY	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
POTOMAC ELECTRIC POWER	0.967	1.103	1.164	1.080	1.021	0.985	1.017	0.930	1.007	0.952	0.946
GULF POWER COMPANY	1.212	1.211	1.109	1.242	1.174	1.119	1.047	1.015	1.051	1.092	0.968
TAMPA ELECTRIC COMPANY	1.161	1.168	1.180	1.221	1.129	1.071	1.107	1.176	1.180	1.182	1.272
SAVANNAH ELEC AND PWR CO	1.103	1.084	1.068	1.087	0.947	0.963	1.009	1.013	0.916	0.929	0.802
HAWAIIAN ELEC PWR CO	0.873	0.908	0.928	0.925	0.942	0.969	0.973	0.990	0.986	1.016	1.015
COMMONWEALTH EDISON	0.902	0.822	0.753	0.739	0.725	0.612	0.574	0.580	0.547	0.523	0.491
INDIANAPOLIS PWR AND LIGHT	1.185	1.121	1.063	1.103	1.091	1.019	1.032	0.927	1.046	1.058	1.090
PUB SERV OF INDIANA	1.042	1.058	1.122	1.126	1.074	1.104	1.153	1.134	1.074	1.110	1.073
KANSAS GAS AND ELECTRIC	1.244	1.165	1.103	1.073	1.131	1.171	1.103	1.214	1.354	1.223	1.279
KENTUCKY POWER COMPANY	1.411	1.506	1.507	1.365	1.447	1.300	1.477	1.386	1.312	1.223	1.385
KENTUCKY UTILITIES COMPANY	0.662	0.865	0.835	0.870	1.001	0.986	1.038	1.060	1.067	0.922	0.998
LOUISIANA PWR AND LIGHT	1.182	1.325	1.408	1.410	1.350	1.383	1.413	1.344	1.301	1.172	1.086
DETROIT EDISON COMPANY	1.021	1.013	0.995	1.006	1.005	0.973	0.928	0.926	0.915	0.891	0.838
MISSISSIPPI POWER CO	1.323	1.232	1.140	1.187	1.224	1.107	1.126	0.963	1.087	0.999	1.020
MISSISSIPPI PWR AND LIGHT	1.138	1.104	1.182	0.878	0.848	0.987	1.140	1.233	1.295	1.170	1.190
KANSAS CITY PWR AND LIGHT	0.946	0.943	0.920	0.884	0.786	0.745	0.721	0.674	0.701	0.491	0.635
UNION ELECTRIC COMPANY	0.825	0.839	0.840	0.936	0.875	0.965	1.001	1.065	1.042	0.997	0.948
NEVADA POWER COMPANY	1.082	1.199	1.151	1.143	1.235	1.204	1.332	1.525	1.333	1.338	1.316
PUB SERV OF NEW HAMPSHIRE	1.042	0.969	1.000	0.899	0.815	0.833	0.814	0.846	0.720	0.825	0.808
PUB SERV OF NEW MEXICO	0.923	0.969	0.970	0.918	0.941	0.935	0.778	0.817	0.538	0.538	0.544
OTTER TAIL POWER CO	0.680	0.622	0.638	0.693	0.650	0.745	0.807	0.800	0.736	0.651	0.701
CLEVELAND ELEC ILLUM CO	1.051	1.135	1.123	1.141	1.076	1.025	1.002	1.016	0.981	0.880	0.818
COLUMBUS AND SOUTHERN OHIO	0.865	0.874	0.944	1.002	0.974	0.899	0.939	0.924	0.861	0.994	0.926
OHIO EDISON COMPANY	1.200	1.123	1.199	1.193	0.916	0.837	0.912	0.772	0.850	0.883	0.882
OKLAHOMA GAS AND ELEC CO	1.133	1.144	1.194	1.264	1.250	1.225	1.171	1.114	1.219	1.200	1.209
PUB SERV CO OF OKLAHOMA	1.260	1.332	1.334	1.260	1.336	1.340	1.384	1.363	1.361	1.246	1.300
DUQUESNE LIGHT COMPANY	0.798	0.805	0.821	0.845	1.022	0.968	1.024	1.011	0.834	0.988	1.000
PENNSYLVANIA PWR AND LIGHT	0.873	0.922	1.048	1.155	1.099	1.169	1.148	1.202	1.136	1.132	1.093
CENTRAL POWER AND LIGHT	1.161	1.269	1.204	1.207	1.154	1.103	1.113	1.140	1.185	1.144	1.104
DALLAS POWER AND LIGHT CO	1.091	1.123	1.161	1.172	1.220	1.297	1.351	1.357	1.373	1.400	1.447
EL PASO ELECTRIC CO	1.121	1.124	1.182	1.211	1.218	1.242	1.180	1.184	1.072	1.145	1.023
HOUSTON LIGHTING AND PWR	1.405	1.422	1.444	1.422	1.363	1.341	1.358	1.323	1.279	1.287	1.238
SOUTHWESTERN ELEC PWR CO	1.194	1.197	1.331	1.202	1.241	1.225	1.176	1.182	1.189	1.203	1.177
SOUTHWESTERN PUB SERV CO	1.092	1.129	1.188	1.178	1.193	1.156	1.188	1.189	1.179	1.162	1.220
TEXAS ELEC SERV CO	1.295	1.279	1.286	1.260	1.324	1.347	1.369	1.352	1.430	1.472	1.486
TEXAS PWR AND LIGHT CO	1.236	1.249	1.221	1.199	1.087	0.999	0.941	0.997	0.990	0.932	0.949
WEST TEXAS UTILITIES CO	1.088	1.121	1.180	1.157	1.194	1.240	1.264	1.286	1.233	1.270	1.301
UTAH PWR AND LIGHT CO	0.673	0.583	0.710	0.859	0.817	0.873	0.665	0.876	1.008	0.988	1.132
APPALACHIAN PWR CO	1.029	1.137	1.436	1.394	1.227	1.115	1.169	1.096	1.082	1.100	1.114
AVERAGE	1.064	1.082	1.105	1.100	1.080	1.066	1.076	1.077	1.063	1.044	1.047
WEIGHTED AVERAGE	1.078	1.095	1.131	1.129	1.094	1.073	1.087	1.082	1.080	1.056	1.052

APPENDIX 4A (cont.)

YEARLY GROWTH RATES FOR
TFP INDEX
FOR 39 ELECTRIC UTILITIES

COMPANY	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	AVG.
POTOMAC ELECTRIC POWER	14.1%	5.5%	-7.2%	-5.4%	-3.6%	3.3%	-8.6%	8.3%	-5.5%	-0.6%	.0%
GULF POWER COMPANY	-0.1%	-8.4%	12.0%	-5.5%	-4.6%	-6.5%	-3.1%	3.5%	3.9%	-11.3%	-2.0%
TAMPA ELECTRIC COMPANY	0.6%	1.1%	3.5%	-7.5%	-5.2%	3.3%	6.2%	0.3%	0.2%	7.6%	1.0%
SAVANNAH ELEC AND PWR CO	-1.7%	-1.5%	1.8%	-12.9%	1.6%	4.8%	0.4%	-9.6%	1.4%	-13.8%	-2.9%
HAWAIIAN ELEC PWR CO	4.0%	2.2%	-0.3%	1.8%	2.9%	0.4%	1.7%	-0.4%	3.0%	-0.1%	1.5%
COMMONWEALTH EDISON	-8.8%	-8.4%	-1.9%	-2.0%	-15.6%	-6.1%	0.9%	-5.7%	-4.4%	-6.2%	-5.8%
INDIANAPOLIS PWR AND LIGHT	-5.5%	-5.1%	3.8%	-1.1%	-6.6%	1.3%	-10.2%	12.8%	1.2%	3.0%	-0.6%
PUB SERV OF INDIANA	1.6%	6.0%	0.4%	-4.7%	2.8%	4.5%	-1.7%	-5.3%	3.3%	-3.3%	0.4%
KANSAS GAS AND ELECTRIC	-6.3%	-5.4%	-2.7%	5.4%	3.6%	-5.8%	10.0%	11.6%	-9.7%	4.6%	0.5%
KENTUCKY POWER COMPANY	6.7%	0.1%	-9.4%	6.0%	-10.2%	13.6%	-6.2%	-5.3%	-6.8%	13.2%	0.2%
KENTUCKY UTILITIES COMPANY	30.5%	-3.4%	4.2%	15.0%	-1.5%	5.3%	2.1%	0.6%	-13.6%	8.3%	4.8%
LOUISIANA PWR AND LIGHT	12.1%	6.3%	0.2%	-4.3%	2.5%	2.1%	-4.9%	-3.2%	-9.9%	-7.4%	-0.6%
DETROIT EDISON COMPANY	-0.7%	-1.8%	1.1%	-0.2%	-3.2%	-4.6%	-0.2%	-1.2%	-2.6%	-6.0%	-1.9%
MISSISSIPPI POWER CO	-6.9%	-7.5%	4.1%	3.1%	-9.6%	1.8%	-14.5%	13.0%	-8.2%	2.1%	-2.3%
MISSISSIPPI PWR AND LIGHT	-3.0%	7.1%	-25.7%	-3.5%	16.4%	15.5%	8.1%	5.0%	-9.7%	1.7%	1.2%
KANSAS CITY PWR AND LIGHT	-0.3%	-2.5%	-3.9%	-11.1%	-5.2%	-3.2%	-6.5%	4.0%	-30.0%	29.4%	-2.9%
UNION ELECTRIC COMPANY	1.8%	.0%	11.5%	-6.5%	10.2%	3.8%	6.4%	-2.2%	-4.3%	-5.0%	1.6%
NEVADA POWER COMPANY	10.8%	-4.1%	-0.7%	8.1%	-2.6%	10.6%	14.5%	-12.6%	0.4%	-1.6%	2.3%
PUB SERV OF NEW HAMPSHIRE	-7.0%	3.2%	-10.1%	-9.4%	2.2%	-2.3%	3.9%	-14.8%	14.6%	-2.1%	-2.2%
PUB SERV OF NEW MEXICO	5.0%	0.1%	-5.4%	2.6%	-0.7%	-16.8%	5.0%	-34.1%	-0.1%	1.1%	-4.3%
OTTER TAIL POWER CO	-8.6%	2.6%	8.6%	-6.3%	14.6%	8.3%	-0.8%	-8.1%	-11.5%	7.8%	0.7%
CLEVELAND ELEC ILLUM CO	8.0%	-1.0%	1.6%	-5.7%	-4.7%	-2.3%	1.4%	-3.5%	-10.2%	-7.1%	-2.4%
COLUMBUS AND SOUTHERN OHIO	1.1%	8.0%	6.2%	-2.8%	-7.8%	4.5%	-1.6%	-6.9%	15.5%	-6.8%	0.9%
OHIO EDISON COMPANY	-6.4%	6.7%	-0.4%	-23.3%	-8.6%	9.0%	-15.4%	10.1%	3.9%	.0%	-2.4%
OKLAHOMA GAS AND ELEC CO	1.0%	4.3%	5.9%	-1.1%	-2.0%	-4.4%	-4.8%	9.4%	-1.6%	0.7%	0.7%
PUB SERV CO OF OKLAHOMA	5.7%	0.2%	-5.6%	6.0%	0.3%	3.3%	-1.5%	-0.2%	-8.4%	4.3%	0.4%
DUQUESNE LIGHT COMPANY	0.9%	2.0%	2.9%	20.9%	-5.2%	5.7%	-1.3%	-17.5%	18.5%	1.2%	2.8%
PENNSYLVANIA PWR AND LIGHT	5.6%	13.7%	10.2%	-4.9%	6.4%	-1.8%	4.7%	-5.5%	-0.4%	-3.4%	2.5%
CENTRAL POWER AND LIGHT	9.2%	-5.1%	0.2%	-4.4%	-4.4%	0.9%	2.5%	4.0%	-3.5%	-3.5%	-0.4%
DALLAS POWER AND LIGHT CO	3.0%	3.4%	0.9%	4.1%	6.3%	4.2%	0.4%	1.2%	2.0%	3.4%	2.9%
EL PASO ELECTRIC CO	0.2%	5.2%	2.5%	0.6%	2.0%	-5.0%	0.3%	-9.5%	6.8%	-10.7%	-0.8%
HOUSTON LIGHTING AND PWR	1.2%	1.5%	-1.5%	-4.1%	-1.6%	1.3%	-2.6%	-3.3%	0.6%	-3.8%	-1.2%
SOUTHWESTERN ELEC PWR CO	0.3%	11.1%	-9.7%	3.3%	-1.3%	-4.0%	0.6%	0.5%	1.2%	-2.2%	.0%
SOUTHWESTERN PUB SERV CO	3.4%	5.2%	-0.9%	1.3%	-3.1%	2.8%	0.1%	-0.9%	-1.4%	5.0%	1.2%
TEXAS ELEC SERV CO	-1.3%	0.6%	-2.1%	5.1%	1.7%	1.6%	-1.3%	5.8%	2.9%	1.0%	1.4%
TEXAS PWR AND LIGHT CO	1.1%	-2.3%	-1.8%	-9.4%	-8.1%	-5.8%	6.0%	-0.8%	-5.8%	1.9%	-2.5%
WEST TEXAS UTILITIES CO	3.0%	5.3%	-2.0%	3.2%	3.9%	1.9%	1.7%	-4.1%	3.0%	2.5%	1.8%
UTAH PWR AND LIGHT CO	-13.4%	21.7%	21.0%	-4.8%	6.9%	-23.8%	31.7%	15.1%	-2.1%	14.6%	6.7%
APPALACHIAN PWR CO	10.5%	26.3%	-3.0%	-11.9%	-9.1%	4.8%	-6.2%	-1.3%	1.7%	1.2%	1.3%
AVERAGE	1.8%	2.4%	0.2%	-1.7%	-1.0%	0.7%	0.4%	-1.3%	-1.7%	0.5%	.0%

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