Measuring Output and Productivity in Electricity Networks

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1 INTRODUCTION

The main challenge in calculating TFP for an electricity network is the specification of exactly what a distributor's outputs are and how to measure the quantity and value of each of them. Distribution output can be measured from either a 'demand side' or a 'supply side' perspective. At the simplest level, the output would be the amount of energy 'throughput' and its value would be the distributor's total revenue. However, distributors have drawn the analogy between an electricity distribution system and a road network. The distributor has the responsibility of providing the 'road' and keeping it in good condition but it has little, if any, control over the amount of 'traffic' that goes down the road. Consequently, it may be inappropriate to measure the output of the distributor by a volume of sales or 'traffic' type measure. Rather, the distributor's output should be measured by the availability of the infrastructure it has provided and the condition in which it has maintained it – essentially a supply side measure.

In this paper we report the results of a major productivity study of New Zealand's electricity networks undertaken for the electricity regulator, the Commerce Commission, using multilateral TFP and cost function methods. The study covers 29 distributors over an 8 year period and reports TFP levels and growth rates. Sensitivity analyses are reported using different output quantities to reflect demand side and supply side measures. The ranking of distributors on these measures is influenced by their customer and energy densities. We derive an output specification that attempts to adjust for differing densities. The next challenge is to attribute weights to the outputs given that revenue for each is unobservable. We examine engineering considerations that inform expectations on what the weights should be before estimating a cost function to derive empirical estimates. Finally, we review the way these estimates have been used in setting the regulatory parameters for New Zealand's electricity networks.

Under Part 4A of the New Zealand Commerce Act, the Commerce Commission is required to set thresholds for the declaration of control in relation to New Zealand electricity distribution businesses. The thresholds are, in effect, a screening mechanism to identify lines businesses whose performance may warrant further examination through a post–breach inquiry and, if required, control by the Commission.

The Commerce Act defines the Commission's Purpose Statement as:

> "To promote the efficient operation of electricity transmission and distribution markets through targeted control for the long term benefit of consumers by ensuring that suppliers:
>
> - are limited in their ability to extract excessive profits;

- face strong incentives to improve efficiency and provide services at a quality that reflects consumer demands; and,
- share the benefits of efficiency gains with consumers, including through lower prices."

The Commerce Commission has decided to set a price threshold for distributors of the CPI–X form based on a comparison of performance levels. The comparative option involves decomposing the X factor into two components:

- a 'B' factor reflecting the overall or average productivity trend for lines businesses; and,
- a 'C' factor broadly reflecting the circumstances of each lines business or a small number of groups of lines businesses, including:
  - relative productivity performance;
  - the price charged by the business;
  - the level of service quality provided by the business; and
  - operating environment factors beyond management control.

In this paper we discuss the quantitative work undertaken to implement the comparative approach to setting the price thresholds and some of the major measurement problems that had to be addressed. The following section of the paper reviews the rationale for using productivity results in forming the parameters of CPI–X regulation. Section 3 discusses the major measurement problems encountered in electricity network productivity studies, particularly the specification of outputs and capital inputs. Section 4 reviews the data used in the current study and discusses the somewhat unusual characteristics of the New Zealand distribution system. In section 5 we present estimates of overall distribution industry TFP and also review input price changes for the electricity industry and the economy as a whole. Based on this information we then derive the implied B factors for distribution lines businesses. In section 6 we investigate the performance of the 28 distribution lines businesses existing in 2003 using multilateral TFP indexes. This permits the businesses to be allocated to three broad C factor groups based on relative productivity performance. We then examine post–tax residual rates of return as a means of allocating the businesses to three profitability groupings before forming overall C factor estimates for each business taking account of both relative productivity and relative profitability. Finally, conclusions are drawn in section 7.

2 THE USE OF PRODUCTIVITY IN THRESHOLD SETTING

The principal objective of CPI–X regulation is to mimic the outcomes that would be achieved in a competitive market. Competitive markets normally have a number of desirable properties. The process of competition leads to industry output prices reflecting industry unit costs, including a normal rate of return on the market value of assets after allowing for the risk. Because no individual firm can influence industry unit costs, each firm has a strong incentive to maximise its productivity performance to achieve lower unit costs than the rest of the industry. This will allow it to keep the benefit of new, more efficient processes that it may develop until such times as they are generally adopted by the industry. This process leads to the industry operating as efficiently as possible at any point in time and the benefits of productivity improvements being passed on to consumers relatively quickly.

Because infrastructure industries such as the provision of electricity transmission and distribution networks are often subject to decreasing costs, competition is normally limited and incentives to minimise costs and provide the cheapest and best possible quality service to users are not strong. The use of CPI–X regulation in such industries attempts to strengthen the incentive to operate efficiently by imposing similar pressures on the network operator to the process of competition. It does this by constraining the operator's output price to track the level of estimated efficient unit costs for that industry. The change in output prices is 'capped' as follows:

(1) $$\Delta P = \Delta W - X \pm Z$$

where Δ represents the proportional change in a variable, P is the maximum allowed output price, W is a price index taken to approximate changes in the industry's input prices, X is the estimated productivity change for the industry and Z represents relevant changes in external circumstances beyond managers' control which the regulator may wish to allow for. There are several alternative ways of choosing the index W to reflect industry input prices. Perhaps the best way of doing this is to use a specially constructed index which weights together the prices of inputs by their shares in industry costs. However, this price information is often not readily or objectively available, particularly in regulatory regimes that have yet to fully mature. A commonly used alternative is to choose a generally available price index such as the consumer price index or GDP deflator.

In choosing a productivity growth rate to base X on, it is desirable that the productivity growth rate be external to the individual firm being regulated and instead reflect industry trends at a national or even international level. This way the regulated firm is given an incentive to match (or better) this productivity growth rate while having minimal opportunity to 'game' the regulator by acting strategically. The latter can be a problem with the 'building blocks' method for setting X which relies more heavily on information on the firm's own costs and likely best practice for that firm. External factors beyond management control that the regulator may wish to allow for in the Z factor include changes in government policy such as community service obligations and tax treatment.

While the CPI–X framework can provide incentives to reduce costs, it may need to be accompanied by measures to stop firms from achieving those cost reductions by reducing quality. This may take the form of an 'S' factor introduced to provide incentives to maintain or improve quality (so that the formula becomes CPI–X+S) or the setting of minimum service standards.

The framework that underlies the CPI–X approach can be illustrated as follows. We start with the index number definition of TFP growth:

$$(2) \qquad \Delta TFP \equiv [Y^1/Y^0]/[X^1/X^0]$$
$$= \{[R^1/R^0]/[P^1/P^0]\}/\{[C^1/C^0]/[W^1/W^0]\}$$
$$= \{[M^1/M^0][W^1/W^0]\}/[P^1/P^0]$$

where the superscripts represent different time periods, R^t (C^t) is revenue (cost) in period t, M^t is the period t markup and $R^t = M^t C^t$. As a normal return on assets (after allowing for risk) is included in the definition of costs, a firm earning normal returns will have a markup factor of one while a firm earning excess returns will have a markup of greater than one. Rearranging the above equation gives:

$$(3) \qquad P^1/P^0 = \{[M^1/M^0][W^1/W^0]\}/ \Delta TFP$$

where W^1/W^0 is the firm's input price index (which includes intermediate inputs). Equation (3) is approximately equal to:

$$(4) \qquad \Delta P = \Delta M + \Delta W - \Delta TFP.$$

Thus, the admissible rate of output price increase ΔP is equal to the rate of increase of input prices ΔW less the rate of TFP growth ΔTFP provided the regulator wants to keep the monopolistic markup constant (so that ΔM = 0). Equation (3) or its approximation (4) is the key equation for setting up an incentive regulation framework: the term W^1/W^0 would be an input price index of the target firm's peers and the term ΔTFP would be the average TFP growth rate for the target firm's peers. The markup growth term could be set equal to zero under normal circumstances but if the target firm was making an inadequate return on capital due to factors beyond its control, this term could be set equal to a positive number. On the other hand, if the target firm was making monopoly profits or excessive returns, then this term could be set negative. This effectively sets a 'glide path' to bring firms closer to earning a normal or average rate of return.

The next issue to be considered in operationalising (4) is the choice of the price index to reflect changes in the industry's input prices, W. The most common choice for this index is the consumer price index (CPI). But this is actually an index of output prices for the economy rather than input prices. Normally we can expect the economy's input price growth to exceed its output price growth by the extent of economy–wide TFP growth (since labour and capital ultimately get the benefits from productivity growth). We assume that the markup factors for the economy as a whole are one so that the counterpart to equation (2) applied to the entire economy becomes:

(5) $P_E^1/P_E^0 = [W_E^1/W_E^0]/\ \Delta TFP_E.$

Substituting the rate of change of the CPI for the economy–wide output price index on the left hand side of (5) and rearranging terms leads to the following identity:

(6) $1 = [CPI^1/CPI^0]\ \Delta TFP_E/[W_E^1/W_E^0].$

Substituting the right hand side of (6) into (2) produces the following equation:

(7) $P^1/P^0 = \{[CPI^1/CPI^0]\Delta TFP_E\ /[W_E^1/W_E^0]\}\{[M^1/M^0][W^1/W^0]\}/\ \Delta TFP$

$= [CPI^1/CPI^0][\Delta TFP_E\ /\Delta TFP]\{[W^1/W^0]/[\ W_E^1/W_E^0]\}[M^1/M^0].$

Approximating the terms in (7) by finite percentage changes leads to the following:

(8) $\Delta P = \Delta CPI + \Delta M + [\Delta W - \Delta W_E] - [\Delta TFP - \Delta TFP_E]$

so that the X factor is defined as:

(9) $X \equiv [\Delta TFP - \Delta TFP_E] - [\Delta W - \Delta W_E] - \Delta M.$

What equation (9) tells us is that the X factor can effectively be decomposed into three terms. The first differential term takes the difference between the industry's TFP growth and that for the economy as a whole while the second differential term takes the difference between the firm's input prices and those for the economy as whole. Thus, taking just the first two terms, if the regulated industry has the same TFP growth as the economy as a whole and the same rate of input price increase as the economy as a whole then the X factor in this case is zero. If the regulated industry has a higher TFP growth than the economy then X is positive, all else equal, and the rate of allowed price increase for the industry will be less than the CPI. Conversely, if the regulated industry has a higher rate of input price increase than the economy as a whole then X will be negative, all else equal, and the rate of allowed price increase will be higher than the CPI. As noted above, the markup growth term could be set equal to zero under normal circumstances but if the target firm was making excessive returns, then this term could be set negative (leading to a higher X factor).

In the New Zealand thresholds setting context, setting the B factor involves a similar process to that for setting the general X described above. It requires information on the differences between the industry and economy TFP trends and input price trends. However, given the differing operating environments of the New Zealand lines businesses and the fact that the industry is still evolving and likely to have a wide range of productivity performance levels, there is a strong case for supplementing the underlying B factor by a C factor which takes account of the circumstances of each business or groups of similar businesses.

The differential productivity or 'C' factor approach has usually been adopted where industry wide data are used to determine the productivity growth rate and input price growth rate in determining the X factor for a number of firms in the industry. The differential productivity factor is then used to tailor the regulatory regime to the circumstances of each particular firm. It distinguishes between productivity levels and productivity growth rates. Normally, firms which are at the forefront of industry performance have high productivity levels but low productivity growth rates. This is because they have removed almost all unnecessary slack and are only able to increase productivity at the rate of technological change for the industry.

Conversely, laggard firms normally have low productivity levels but are potentially capable of high productivity growth rates. This is because they can make some easy gains by removing the slack from their operations to mimic the operations of the industry's best performers. Consequently, they can achieve productivity growth far in excess of the rate of technological change for the industry for an interim period while they catch up to the productivity levels of the best performing firms. As a result of this catch up process, the best performing firms in the industry will, ironically, not be able to match the average productivity level growth rates for the industry (although they have superior productivity levels) while laggard firms will be able to outperform the industry average productivity growth rate.

In a regulatory context, if a firm is a long way from best practice (after allowing for operating environment and service quality differences) then a positive differential factor may be applied to allow for the fact that the firm should be able to make some easy 'catch up' gains and exceed the average industry productivity growth rate. This ensures the firm's consumers receive some of those initial catch up benefits. In subsequent regulatory periods we would expect the firm to move closer to the average industry productivity performance and so the size of the differential productivity factor would diminish. Conversely, for a firm that is already close to best practice, a negative differential factor may be set to allow for the fact that this firm is unlikely to be able to match industry average productivity growth performance as it cannot make easy catch up gains and is instead only able to grow its productivity at the rate of technological change.

3 MEASUREMENT ISSUES

Measuring the productivity of electricity lines businesses to facilitate setting appropriate X factors presents a number of challenges, not the least of which is defining exactly what a lines business's output is. This is a non–trivial exercise for lines businesses given the network nature of the industry and the peculiar characteristics of electricity as a product including its non–storability. In this section we examine a number of difficult measurement issues including how to define lines business output and how to measure capital inputs.

3.1 Measuring lines business outputs

The main challenge in calculating TFP for a lines business is the specification of exactly what a lines business's outputs are and how to measure the quantity and value of each of them. Distribution output can be measured from either a 'supply side' or a 'demand side' perspective. At the simplest level, the output would be the amount of energy 'throughput' and its value would be the distributor's total revenue. This approach essentially treats the distribution system in an analogous fashion to a pipeline and was a common approach of early studies of electricity distribution using TFP or other comprehensive indicators. It simply concentrates on the demand for the final product delivered by the distribution network. However, there are other important dimensions to a distributor's output that need to be taken into account. These include the reliability and quality as well as the quantity of the electricity supply and the coverage and capacity of the system (ie the fact that the system is there to meet the highest potential peak as well as actual day to day demand).

A number of distributor representatives in Australia have drawn the analogy between an electricity distribution system and a road network. The distributor has the responsibility of providing the 'road' and keeping it in good condition but it has little, if any, control over the amount of 'traffic' that goes down the road. Consequently, they argue it is inappropriate to measure the output of the distributor by a volume of sales or 'traffic' type measure. Rather, the distributor's output should be measured by the availability of the infrastructure it has provided and the condition in which it has maintained it – essentially a supply side measure.

This way of viewing the output of a network industry can be extended to a number of public utilities. For instance, a number of analysts have measured the output of public transport providers using both a 'supply side' and a 'demand side' measure of output. The supply side measure of a passenger train system, for instance, would be measured by the number of seat kilometres the system provides while the demand side output would be measured by the number of passenger kilometres. In the case of public transport this distinction is often drawn because suppliers are required to provide transport for community service obligation and other non–commercial reasons. Using the supply side measure looks at how efficient the supplier has been in providing the service required of it without disadvantaging the supplier as happens with the demand side measure because of low levels of patronage beyond its control.

In previous work on distribution efficiency we have estimated both supply side and demand side output models. In the Australian context, the demand side models tend to favour urban distributors with dense networks while the supply side models tend to favour rural distributors with sparse networks (but long line lengths). In Tasman Asia Pacific (2000a,b) and other recent work in Australia we have further advanced the output specification by combining the key elements of the demand and supply models to form a comprehensive output measure which contains three components – throughput, network line capacity and the number of connections. The connection component recognises that some distribution outputs are related to the very existence of customers rather than either throughput or system line capacity. This will include customer service functions such as call centres and, more importantly, connection related capacity (eg having more residential customers requires more small transformers and poles). This three output specification has the advantage of incorporating key features of the main density variables (customers per kilometre and sales per customer).

There is also a fourth dimension to a lines business's output. This is the quality of supply which encompasses reliability (the number and duration of interruptions), technical aspects such as voltage dips and surges and customer service (eg the time to answer calls and to connect or reconnect supply). Reliability is likely to be the most important of these service quality attributes and the one for which the most data is available. However, previous attempts to include reliability measures as a fourth output have proven unsuccessful due to the way output is measured. As both the frequency and duration of interruptions are measured by indexes where a decrease in the value of the index represents an improvement in service quality, it would be necessary to either include the indexes as 'negative' outputs (ie a decrease in the measure represents an increase in output) or else to convert them to measures where an increase in the converted measure represents an increase in output. Most indexing methods cannot readily incorporate negative outputs and inverting the measures to produce an increase in the measure equating to an increase in output leads to non–linear results. Measuring reliability by the time on supply each year rather than the time off supply effectively produces a constant as the time off supply is such a small proportion of the total time each year. Given these difficulties we again omit service quality as an explicit output.

Of the three outputs that can readily be included, energy throughput can be measured by the number of kWh of energy delivered. The line capacity of the system can be measured by the number of MVA–kilometres formed by summing the product of line length for each voltage capacity and a conversion factor based on the voltage of the line. This measures not only the length of line but also its overall capacity. Finally, the connections variable can be measured by the number of connections or customers.

To aggregate the three outputs into a total output index using indexing procedures, we have to allocate a weight to each output. For most industries which produce multiple outputs these output weights are taken to be the revenue shares. However, in this case we cannot observe separate amounts being paid for the different output components. In this case we can either make some arbitrary judgements about the relative importance of the output components or we can draw on econometric evidence. One way of doing this using econometrics is to use the relative shares of cost elasticities derived from an econometric cost function. The latter approach is often used in industries not subject to high levels of competition because the cost elasticity shares reflect the marginal cost of providing an output. For instance, using Pacific Economics Group's (2000a,b) cost elasticity shares derived from their large sample of over 100 US distributors over several years implies cost shares for throughput of 47 per cent, for network length of 20 per cent and for customers of 33 per cent. Using the cost function we estimate for the 29 New Zealand distributors in section 6, we find output cost shares for throughput of 22 per cent, for network line capacity of 32 per cent and for connections of 46 per cent.

From an engineering perspective we would expect there to be a lower cost share for the throughput output than found in either of these cost function studies. To consider this, extend the network analogy for the three outputs as follows:

- the main 'road' system; ie the wires and poles/underground cable system that will enable delivery of electricity from supply points to major demand points;
- the system of transformers and 'pumping' equipment that will deliver the electricity from supply points to demand points; and,
- the local access road system that gives access to individual properties and also proxies the customer service system to respond to customer connection needs, enquiries, complaints, etc.

There are costs associated with each of the above three components of the distribution system. Hence, continuing the analogy with the road network, the distribution system also incorporates aspects of the 'trucking' industry, which has output in tonne kilometres. In terms of the trucking industry, the output of the first part would be measured in kilometres of road of standard width, segmented by type of construction (asphalt versus concrete) and possibly segmented by type of terrain.

In terms of the relative importance of the three components of output and cost listed above, the first component is likely to be a large part of cost as the capital costs associated with constructing the network are large. Each customer will specify a peak load that they want delivered and the distributor has to supply the wire that can carry the peak load to major demand points. Hence, the distributor's costs of serving a particular demand point will be equal to the cost of the wire that can carry the peak load times the length of wire from that location to the distributor's network lines plus a share of the network overhead to be attributed to the customer (these are the network main 'road' costs). Note that these costs will be independent of demand. If all customers had identical connection characteristics, these costs would be proportional to some measure of line capacity times length of the network.

The costs of the second output do depend on demand, being roughly proportional to the demand of the consumer. From the viewpoint of the final demander, it is this volume of energy delivered that is the most important measure of final demand but from the network's perspective the marginal costs associated with supplying another unit of power (ie the 'pumping' costs) are very low once the network is in place. However, one could argue that even if consumption of electricity was zero in any given time period (such as might occur for a seasonal business or a weekender), the final demander would still place an option value on having the right to have electricity supplied even though momentary demand was zero. Hence, both the throughput and line capacity outputs are valuable to the final demander even though the costs to the distributor are much higher for line capacity.

The connection output costs (ie the costs of accessing each property by local road) are also largely independent of the amount of throughput. Quite apart from the spatial impact on operating and capital costs from a larger number of connections, dedicated asset costs of connection are a significant network cost and are driven by customer numbers more than line capacity. The other aspect of connection related outputs – customer service functions – are also real although one could argue that the corresponding 'output' is less important to the final demander although they will again place an option value on being able to receive good customer service when they need it.

This discussion gives us some insights into how to build up the various parts of the three types of costs. The line capacity costs include most of the line and transformer costs plus the associated maintenance costs. Throughput costs are likely to be relatively small and may be limited to extra maintenance costs for transformers. Connection costs can be attributed to local transformers and poles plus the workers in the customer service departments plus the associated vehicles and office buildings.

Based on this analysis it would be reasonable to expect the network line capacity output and the connections output to each have relatively high cost shares and the throughput output to have a relatively low cost share. The fact that the two econometric studies, particularly the US based study, allocate higher than expected cost shares to throughput may reflect multicollinearity problems in the respective data sets. However, wherever possible our strategy is to rely on New Zealand empirical evidence in the first instance. In section 6 we report a number of sensitivity analyses on the specification of outputs.

3.2 Normalisation for operating environment conditions

Operating environment conditions can have a significant impact on lines business costs and productivity and in many cases are beyond the control of managers. Consequently, to ensure we have reasonably like–with–like comparisons it is desirable to 'normalise' for at least the most important operating environment differences. Likely candidates for normalisation include energy density (energy delivered per customer), customer density (customers per kilometre of line), customer mix, the degree of undergrounding, the availability of alternative energy sources, and climatic and geographic conditions.

Energy density and customer density are generally found to be the two most important operating environment variables in normalisation studies. Being able to deliver more energy to each customer means that a distributor will usually require less inputs to deliver a given volume of electricity as it will require less poles and wires than a less energy dense distributor would require to reach more customers to deliver the same total volume. Offsetting this to some degree may be the requirement for the higher density distributor to have larger transformers to service its higher consumption customers but again it will require a smaller number of transformers than its less dense counterpart.

A distributor with lower customer density will require more poles and wires to reach its customers than will a distributor with higher customer density but the same consumption per customer making the lower density distributor appear less efficient unless the differing densities are allowed for. Most studies incorporate density variables by ensuring that the three main output components – throughput, system capacity and customers (or connections) – are all explicitly included. This means that distributors who have low customer density, for instance, receive credit for their longer line lengths whereas this would not be the case if output was measured by only one output such as throughput.

There has been some debate over whether reliability should be included as a form of operating environment condition. By rights, reliability should be included as a fourth type of output as noted in the previous section as it is something that is ultimately under the distributor's control. Attempts to include reliability as an operating environment variable often result in the reliability indicator acting as a proxy for unmeasured geographic and climatic conditions. Distributors operating in mountainous terrain, areas where there is rapid vegetation growth and more storm–prone areas will have to expend higher amounts of operating expenditure and possibly capital expenditure to achieve a given reliability level than their peers operating in flat, drier areas.

There is also some uncertainty about the direction of causation and associated lags between input use and changes in reliability. On the one hand, it may take some time for reliability problems to be recognised and solutions to be approved and implemented. This would point to a relationship between current productivity performance and the reliability performance of, say, two years previously. On the other hand, distributors in remote locations with large service areas have argued that it takes around three years for them to complete a suite of projects addressing the performance of their worst performing feeders. This would point to a relationship between current input use and reliability performance three years into the future. The complexities of the relationship between reliability and efficiency performance point to the need for this issue to be addressed in a separate study.

In this study we have information on the three output components and the degree of undergrounding. Information on the split of customers between residential and industrial/commercial was available for one year only making it difficult to use this information in estimation. This information gave only an indication of the number of residential customers, without associated energy consumption data, and without data on other customer types. Data on geographic and climatic conditions and competition from alternative energy sources is not available. Consequently, our main focus in normalisation will be the key density variables and the degree of undergrounding.

3.3 Capital inputs and depreciation

There are a number of different approaches to measuring both the quantity and cost of capital inputs. The quantity of capital inputs can be measured either directly in quantity terms (eg using a measure of line length) or indirectly using a constant dollar measure of the value of assets. Similarly, the annual cost of using capital inputs can be measured either directly by applying the sum of an estimated depreciation rate and a rate reflecting the opportunity cost of capital to the optimised deprival value (ODV) of assets or indirectly as the residual of revenue less operating costs.

Some analysts have argued that measuring the quantity of capital by the deflated asset value method provides a better estimate of total input as it better reflects the quality of capital and can include all capital items, not just lines and transformers. There are two potential problems with this approach. Firstly, it is better suited to more mature systems where the asset valuations are very consistent over time and across organisations. If the asset valuation process is still being bedded down, as it is in New Zealand, then the estimated quantity of capital inputs in likely to be artificially variable using this approach. Secondly, approaches using the capital stock to reflect the quantity of inputs usually incorporate some variant of the declining balance approach to measuring depreciation. Electricity lines business assets tend to be long lived and to produce a relatively constant flow of services over their lifetime. Consequently, their true depreciation profile is more likely to reflect the 'one hoss shay' or 'light bulb' assumption than that of a declining balance. That is, they produce the same service each year of their life until the end of their specified life rather than producing a given percentage less service every year. In these circumstances it is better to measure the quantity of capital input by the physical quantity of the principal assets. This approach is also invariant to different depreciation profiles that may have been used by different lines businesses. In this study we use direct physical asset measures to proxy the quantity of capital inputs wherever possible, ie we adopt the 'one hoss shay' assumption.

The direct approach to measuring capital costs involves applying a constant percentage reflecting depreciation and the opportunity cost of capital to the value of assets. Normally this asset value would be built up using investment data over a number of decades using the perpetual inventory approach (see Lawrence 2002). In the case of the New Zealand lines businesses, however, capital information is only available for a short number of years and even this has been subject to some major revaluations. Consequently, the way of implementing the direct approach that is most consistent with the perpetual inventory approach used in earlier studies is to multiply the ODV by a percentage reflecting depreciation and opportunity costs.

Following NZIER (2001) we assume a common depreciation rate of 4.5 per cent of ODV and an opportunity cost rate of 8 per cent of ODV in calculating the cost of capital inputs. This approach is consistent with a declining balance depreciation profile where 10 per cent of asset value is left after 50 years. It produces an estimate of depreciation costs which is somewhat higher than the current regulatory accounts figure based on optimised replacement cost for all but three of the distributors. Again, this approach abstracts from the different depreciation profiles that may have been used by individual distributors. The use of an 8 per cent opportunity cost rate is consistent with previous infrastructure TFP studies in Australia.

The indirect approach of allocating a residual or ex post cost to capital of the difference between revenue and operating costs has been favoured by some regulatory agencies such as the US Federal Communications Commission (1997). However, estimating productivity using a direct estimate of the cost of capital is more consistent with the underlying producer theory where an ex ante measure is required. The indirect approach may also be problematic where firms are earning a wide range of rates of return or where, as is the case with New Zealand lines businesses, some firms provide low prices to customer–owners as a form of dividend.

3.4 Trusts and rebates

The variety of ownership arrangements applying to the distribution businesses presents some problems for assessing performance. This is because there is a mixture of commercial firms and locally owned trusts that return their dividends to the local community either explicitly through rebates and line charge holidays or implicitly through lower prices. Consequently, two lines businesses may have the same underlying efficiency but one may have higher prices because it is privately owned and provides a dividend to its shareholders through normal channels while the other is a locally owned trust that aims to both minimise its tax liability and provide an implicit rebate to its owner–customers by charging lower prices.

Provided rebates explicitly paid to customers (and other community groups) are excluded from operating costs, the form of ownership should not present problems for cost based comparisons. Similarly, by making price comparisons before explicit rebates are paid we will have reasonable comparability between commercial lines businesses and those trusts making explicit rebates but not between these two types of businesses and those trusts providing implicit rebates through lower prices. Given that it is not possible to make completely like–with–like comparisons across the three types of businesses with the data currently available, this approach appears to offer the least distortionary basis for making comparisons.

3.5 Average versus frontier estimation

There are arguments for and against using both the average and frontier approaches. The average approach does appear to replicate the market outcome more closely but runs the risk of too low a target being set. On the other hand, frontier approaches (including stochastic frontier analysis) are more sensitive to data errors and can lead to unrealistically high and, indeed unachievable, targets being set. Given the scarcity of relevant data for the New Zealand lines businesses, using an average estimation approach is likely to be more appropriate and minimise the impact of data errors and omissions. Frontier approaches may be contemplated in the future once data quality and availability improves.

4 DATA

The data source for this study is the official electricity lines business Disclosure Data required under the *Electricity (Information Disclosure) Regulations 1994 and 1999*. These data were first required for the 1995 March year and included physical, service quality and financial information. Legal (as opposed to reporting) separation of distribution and retail activities occurred during the 1999 financial year, and the disclosure data requirements were revised at this time.

Despite the wide range of items now reported in the Disclosure Data, the consistency and quality of the data is variable, particularly in the earlier years. A number of the key variables that would normally be required for productivity analyses are missing. For instance, there is effectively no useful labour data. There are some coverage gaps in years where distributors have amalgamated due to a requirement that data only has to be provided for entities existing at the end of the financial year. Some corrections were made to improve the consistency and coverage of the database.

To provide an adequate basis for establishing trends we use the eight data years 1996–2003 to calculate trend rates of aggregate industry level productivity growth used to derive B factor estimates. The 1995 data year was discarded due to the apparent teething problems with providing Disclosure Data in the first year and the absence of ODV estimates. A number of assumptions are made to address data problems surrounding the 1999 financial year. The changes introduced in 1999 have generally improved the quality of the data available. We use the five data years 1999–2003 to derive multilateral TFP estimates used to derive C factor productivity groupings as this data has better consistency.

4.1 Output and input definitions

The distribution productivity analyses reported generally contain three outputs and five inputs.

Output quantities

Throughput: The quantity of the distributor's throughput is measured by the number of kilowatt hours of electricity supplied. This is similar to the output measures used in most early TFP studies of distribution.

System line capacity: The quantity of the distributor's system capacity is measured by its total megavolt–ampere (MVA) kilometres. The MVA kilometres measure seeks to provide a more representative measure of system capacity than either line length alone or the simpler kilovolt kilometres measure. Low voltage distribution lines were converted to system capacity in MVA kilometres using a factor of 0.4, 6.6kV high voltage distribution lines using a factor of 2.4, 11kV high voltage distribution lines using a factor of 4, 22kV high voltage distribution lines using a factor of 8, 33kV high voltage distribution lines using a factor of 15, 66 kV lines using a factor of 35, and 110 kV lines using a factor of 80. These factors are based on a review of the factors used in our initial report by Parsons Brinckerhoff Associates (2003). They have been tailored specifically to reflect New Zealand operating conditions and the fact that the effective capacity of an individual line depends not only on the voltage of the line but also on a range of other factors, including the number, material and size of conductors used, the allowable temperature rise as well as limits through stability or voltage drop.

Connections: Connection dependent and customer service activities are proxied by the distributor's number of connections.

Output weights

To aggregate a diverse range of outputs into an aggregate output index using indexing procedures, we have to allocate a weight to each output. For most industries which produce multiple outputs these output weights are taken to be the revenue shares. However, in this case we cannot observe separate amounts being paid for the different output components. As discussed in section 3.1, in this case we can either make some arbitrary judgements about the relative importance of the output components in costs or we can use the estimated output cost shares derived from an econometric cost function. We have chosen to rely on New Zealand based empirical evidence wherever possible in this study and use the output cost shares derived from the econometric cost function reported in section 6.2. A weighted average of the output cost shares is formed using the share of each observation's estimated costs in the total estimated costs for all distributors and all time periods. This produces an output cost share for throughput of 22 per cent, for system line capacity of 32 per cent and for connections of 46 per cent.

Input quantities

Operating expenditure: The quantity of the distributor's operating expenses is derived by deflating the sum of the grossed up values of direct costs per kilometre and indirect costs per customer by the index of labour costs for the electricity, gas and water sector. The grossed up values of direct costs per kilometre and indirect costs per customer are used as the value of operating costs because these measures best reflect the purchases of actual labour, materials and services used in operating the lines business and exclude rebates. The index of labour costs for the electricity, gas and water sector is used as the price of operating expenditure as it directly measures the price of a major component of operating expenditure.

Overhead network: The quantity of poles and wires input in the overhead network is proxied by the distributor's overhead MVA kilometres calculated using the same factors as listed above. At this point in time there is inadequate information available to use the alternative indirect measure of a constant price ODV for poles and wires.

Underground network: The quantity of underground cables input is proxied by the distributor's underground MVA kilometres calculated using the same factors as listed above. Again, at this point in time there is inadequate information available to use the alternative indirect measure of a constant price ODV for underground cables.

Transformers: The quantity of transformer inputs is proxied by the kilovolt–amperes (KVA) of the distributor's installed transformers.

Other assets: The quantity of other capital inputs such as computers and control systems, etc is proxied by their ODV where the share of total ODV attributable to these assets is estimated for the average of distributors having disaggregated ODV information in each of four groups (rural high density, rural low density, urban high density and urban low density). The shares of other assets in total ODV range from 2 to 4 per cent. The price of other assets is assumed to remain unchanged over the period.

Input weights

The value of total costs is formed by summing the estimated value of operating expenditure and 12.5 per cent of total ODV. As discussed in the preceding section, we follow NZIER (2001) in assuming a common depreciation rate of 4.5 per cent and an opportunity cost rate of 8 per cent for capital assets. Disaggregated ODV data has been formed for all but three of the distributors although a number of allocation assumptions have had to be made and the quality of the data is very variable. To allocate ODV to the four asset classes used here we take the weighted average shares for the distributors that have this data in each of four groups (rural high density, rural low density, urban high density and urban low density) and apply these shares to all distributors in the respective group. This strategy was adopted to minimise risks as little confidence can be placed in the disaggregated asset data for several of the distributors. Input weights were then formed from the share of the cost of each of the five inputs in total cost.

4.2 Key characteristics of the distributors

The key characteristics of the 29 distributors in 2002 are presented in table 1. Two of the distributors, UnitedNetworks and Vector, account for over 40 per cent of throughput. UnitedNetworks has subsequently been split between Vector, Powerco and Unison. The five largest businesses in terms of throughput in 2002 account for around 65 per cent of energy delivered. The smallest business in terms of throughput, Scanpower, accounts for only 0.3 per cent of energy delivered.

Table 1: **Distributors' key characteristics, 2002**

ELB	Deemed revenue	Energy	Customer numbers	Line length	Trans-formers	Energy density	Cust. density
	$m	*GWh*	*'000*	*kms*	*MVA*	*kWh/cust*	*cust/km*
Alpine Energy	16.92	565.29	28.38	3,687	274.51	19,921	7.70
Buller Elec	2.66	44.53	4.11	595	27.82	10,840	6.90
Centralines	5.28	111.12	7.43	1,615	71.49	14,954	4.60
Counties Power	19.89	418.09	30.82	3,385	237.73	13,567	9.10
Dunedin Elec	36.18	1,240.26	71.43	4,743	725.94	17,363	15.06
Eastland N/W	15.30	290.31	25.55	3,679	224.97	11,362	6.95
Electra	15.71	383.91	38.29	2,127	273.58	10,026	18.00
Elec Ashburton	11.20	342.70	14.56	2,579	262.74	23,540	5.64
Elec Invercargill	8.85	264.56	16.85	688	140.77	15,704	24.49
Horizon Energy	17.51	594.50	23.09	2,383	185.65	25,745	9.69
MainPower	15.76	382.19	25.05	4,327	257.48	15,259	5.79
Marlborough	12.14	303.56	21.04	3,050	222.36	14,429	6.90
Nelson Elec	5.51	146.92	8.58	241	78.19	17,134	35.58
N/W Tasman	17.49	684.84	31.29	3,122	276.45	21,885	10.02
N/W Waitaki	5.77	175.81	11.34	1,911	125.11	15,502	5.93
Northpower	17.95	852.23	46.71	5,337	397.45	18,244	8.75
Orion	92.97	2,901.02	168.46	11,506	1,495.44	17,221	14.64
Otago Power	8.44	348.37	14.43	4,191	130.63	24,135	3.44
Powerco	101.02	2,077.34	157.45	15,960	1,312.24	13,194	9.87
Scanpower	3.46	88.47	6.62	872	55.63	13,374	7.59
The Lines Co	14.39	286.25	25.71	4,602	188.80	11,133	5.59
The Power Co	15.52	608.06	31.80	7,540	298.00	19,121	4.22
Top Energy	13.63	316.15	27.04	4,834	180.90	11,690	5.59
Unison	20.05	867.33	58.07	3,903	557.00	14,936	14.88
UnitedNetworks	299.43	6,873.04	505.06	30,022	3,887.57	13,608	16.82
Vector	170.02	5,115.12	274.00	8,579	2,349.45	18,668	31.94
Waipa N/W	5.30	316.48	20.29	1,764	160.30	15,596	11.50
WEL Networks	41.97	962.39	72.94	4,692	495.12	13,194	15.55
Westpower	9.56	197.99	12.07	1,972	104.36	16,401	6.12
Total	1,019.84	27,758.83	1,778.46	143,905	14,997.67	15,608	12.36

Source: Meyrick and Associates database formed from MED consolidation of Disclosure Data

There is a high degree of correlation between energy supplied and the number of customers with a correlation coefficient of 98.5 per cent in 2002. There is less correlation between energy delivered and line length with a correlation coefficient of 87 per cent reflecting differences in customer density between distributors. This correlation falls to 58 per cent when the alternative line capacity measure of MVA kilometres (not shown in table 1) is compared to energy supplied. There is, however, a very close relationship between transformer capacity and energy delivered with a correlation of over 99 per cent.

The highest average consumption per customer or energy density is found in Horizon Energy, Otago Power, Electricity Ashburton, Buller Electricity and Network Tasman with average consumption of between 20,000 and 25,000 kWh. While these distributors are all predominantly rural, they each have significant industrial facilities located in their territory. The three rural distributors Electra, Eastland Networks and The Lines Company have the lowest energy densities with around 11,000 kWh average consumption.

The distributors exhibit a wide range of customer densities with the Auckland based Vector and the smaller urban based Nelson Electricity and Electricity Invercargill each having over 24 customers per kilometre of line. The rural distributors Centralines, Electricity Ashburton, MainPower, Network Waitaki, The Lines Company, The Power Company and Top Energy have the lowest customer densities at less than 6 customers per kilometre.

5 INDUSTRY PRODUCTIVITY AND THE B FACTOR

In this section we use the Fisher TFP index method to calculate the productivity performance of distribution as a whole for the eight years 1996 to 2003. We then examine evidence on input price changes before deriving implied B factors for distribution.

5.1 The Fisher TFP index

TFP is defined as the change in total output quantity divided by the change in total input quantity between two periods. Mathematically, this is given by:

(10) $TFP = \Delta Q / \Delta I$

where ΔQ is the proportional change in the quantity of total output between the current period and the base period and ΔI is the corresponding proportional change in the quantity of total inputs.

To operationalise this concept we need a way to combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs. To aggregate these changes in diverse components into a total change, index number methodology essentially takes a weighted average of the changes in the components. Different index number methods take this weighted average change in different ways. Alternative index number methods can be evaluated by examining their economic properties or by assessing their performance relative to a number of axiomatic tests. The index number which performs best against these tests and which is being increasingly favoured by statistical agencies is the Fisher ideal index.

Mathematically, the Fisher ideal output index is given by:

(11) $Q_F^t = [(\sum_{i=1}^m P_i^B Y_i^t / \sum_{j=1}^m P_j^B Y_j^B)(\sum_{i=1}^m P_i^t Y_i^t / \sum_{j=1}^m P_j^t Y_j^B)]^{0.5}$

where: Q_F^t is the Fisher ideal output index for observation t;

P_i^B is the price of the ith output for the base observation;

Y_i^t is the quantity of the ith output for observation t;

P_i^t is the price of the ith output for observation t; and

Y_j^B is the quantity of the jth output for the base observation.

In this case we have three outputs (so $m = 3$) and seven years (so $t = 1, \ldots, 7$).

Similarly, the Fisher ideal input index is given by:

(12) $I_F^t = [(\sum_{i=1}^n W_i^B X_i^t / \sum_{j=1}^n W_j^B X_j^B)(\sum_{i=1}^n W_i^t X_i^t / \sum_{j=1}^n W_j^t X_j^B)]^{0.5}$

where: I_F^t is the Fisher ideal input index for observation *t*;

W_i^B is the price of the *i*th input for the base observation;

X_i^t is the quantity of the *i*th input for observation *t*;

W_i^t is the price of the *i*th input for observation *t*; and

X_j^B is the quantity of the *j*th input for the base observation.

In this case we have five inputs (so $n = 5$) and seven years (so $t = 1, \ldots, 7$).

The Fisher ideal TFP index is then given by:

(13) $$TFP_F^t = Q_F^t / I_F^t \,.$$

The Fisher index can be used in either the unchained form denoted above or in the chained form used in this study where weights are more closely matched to pair–wise comparisons of observations. Denoting the Fisher output index between observations *i* and *j* by $Q_F^{i,j}$, the chained Fisher index between observations 1 and *t* is given by:

(14) $$Q_F^{1,t} = 1 \times Q_F^{1,2} \times Q_F^{2,3} \times \ldots. \times Q_F^{t-1,t} \,.$$

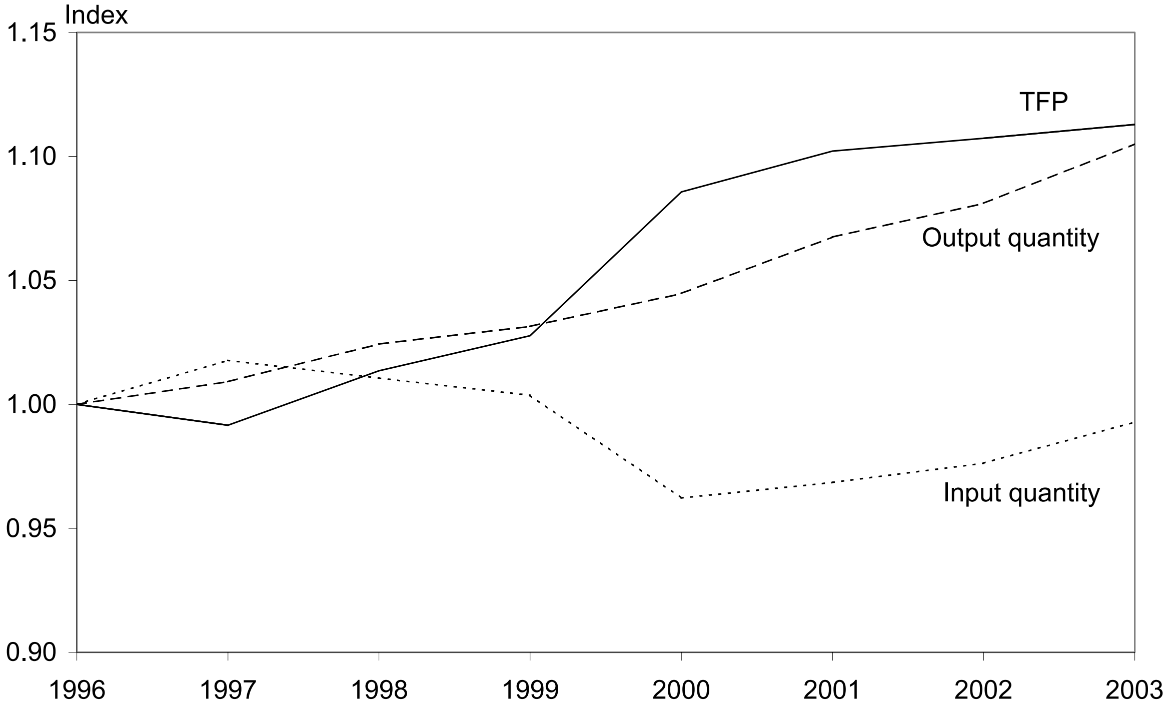
5.2 Aggregate distribution productivity

Our model of aggregate distribution TFP involves the three outputs and five inputs defined in section 4.1. The outputs are energy delivered in kilowatt hours, system line capacity in MVA kilometres and connection numbers. The five inputs are operating costs, overhead lines capital, underground lines capital, transformer capital and other capital items.

TFP results for the aggregate distribution industry are presented in figure 1 and table 2 using the chained Fisher indexing method and the eight years of available data from 1996 to 2003. As described in the preceding section, a number of revisions have been made to the database. The two most important of these are adjustment of operating expenditure for the 1999 accounting changes by applying the average change in the quantity of operating expenditure for the years 1997, 1998, 2000 and 2001 to 1999 and adjusting for the 1999 Auckland CBD outage by applying Vector's 1998 indirect cost per connection to 1999 and 2000.

Output quantity increases steadily over the period although somewhat more rapidly after 2000. Input quantities were initially relatively flat through to 1999 before falling somewhat in 2000 and again remaining relatively flat for the last three years. The TFP index increased by 3 per cent between 1996 and 1999. The TFP index then increased by 5.6 per cent in 2000 and by another 2.5 per cent through to 2003, the latter driven mainly by increased output quantities. For the 8 year period aggregate distribution TFP increased at a trend annual rate of 2 per cent.

Figure 1: **Aggregate distribution output, input and TFP indexes, 1996–2003**



Source: Meyrick and Associates estimates

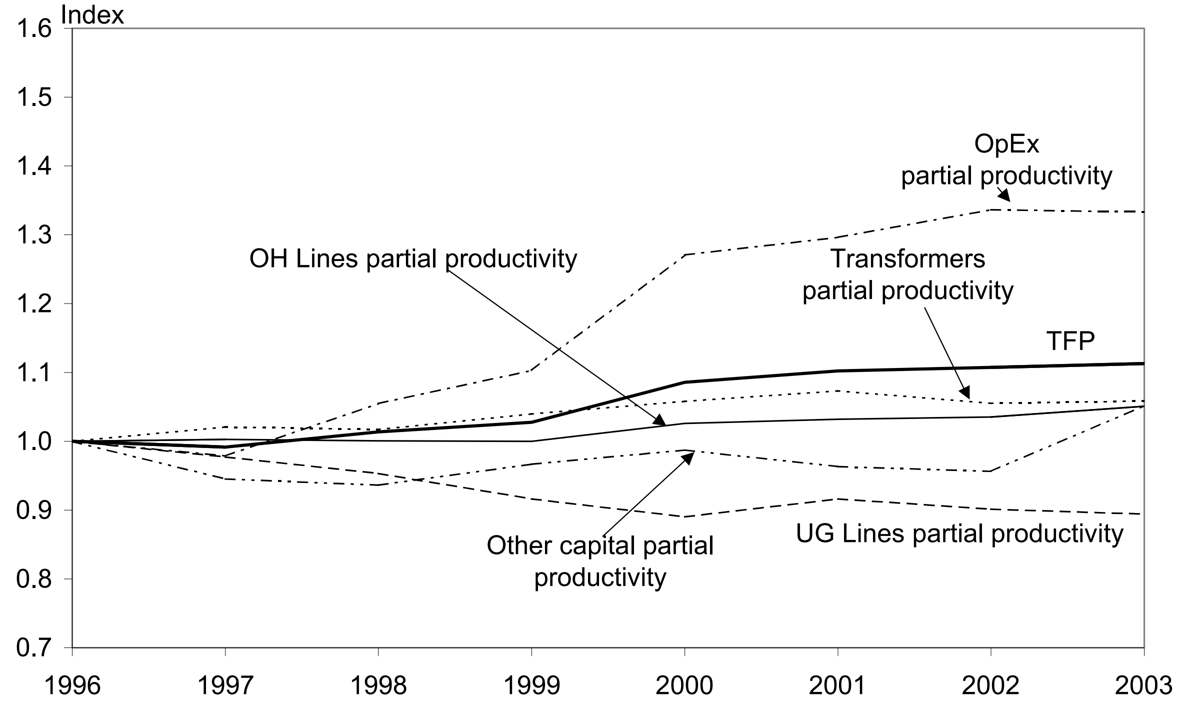
Table 2: **Aggregate distribution TFP and partial productivity indexes, 1996–2003**

	Quantity indexes			Partial productivities				
	Outputs	Inputs	TFP	OpEx	O/H lines	U/G lines	T'formers	Other
1996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1997	1.009	1.018	0.992	0.979	1.003	0.977	1.021	0.945
1998	1.024	1.011	1.014	1.055	1.001	0.953	1.017	0.936
1999	1.031	1.004	1.028	1.103	1.000	0.916	1.040	0.967
2000	1.045	0.962	1.086	1.271	1.026	0.890	1.058	0.987
2001	1.067	0.969	1.102	1.296	1.032	0.916	1.073	0.963
2002	1.081	0.976	1.107	1.336	1.036	0.901	1.055	0.956
2003	1.105	0.993	1.113	1.333	1.051	0.894	1.059	1.052

Source: Meyrick and Associates estimates

The TFP index increased by only 0.5 per cent in 2003 despite an increase in output of over 2 per cent. This was due to an increase in estimated operating expenditure for the aggregate of the full year equivalents of Vector, Powerco and Unison of 7 per cent (despite the removal of one–off, non–recurring costs associated with the merger) due to assumptions made in scaling the data to full year equivalents. This led to operating expenditure for the industry as a whole increasing by 5.6 per cent in 2003. It is unlikely that this high estimated cost level is likely to be representative of the post–acquisition operating costs of the three distribution businesses involved in the UnitedNetworks acquisition and an analysis of distribution TFP which includes the 2003 data is likely to understate the long term TFP trend growth rate. Excluding the 2003 data leads to a trend growth rate in TFP of 2.1 per cent for the seven years 1996 to 2002. As less confidence can be placed in the estimated 2003 operating expenditure data constructed for the full year equivalents of the three businesses that acquired UnitedNetworks, we take the trend TFP growth rate up to 2002 as the most robust estimate.

Figure 2: **Aggregate distribution partial productivity indexes, 1996–2003**



Source: Meyrick and Associates estimates

In figure 2 and table 2 we present the five aggregate distribution partial productivities – the output quantity index divided by the relevant input quantity index. The partial productivity of operating costs has increased by around one third between 1996 and 2003 while the partial productivities of transformers, overhead lines and other capital have all increased by over 5 per cent.

The partial productivity of underground lines has decreased by 10 per cent reflecting the increasing use of undergrounding. TFP is essentially a weighted average of these five partial productivities and lies above the four capital partial productivities but below operating expenditure partial productivity. TFP lies closer to the capital partial productivities reflecting the relative weights used in constructing the TFP index.

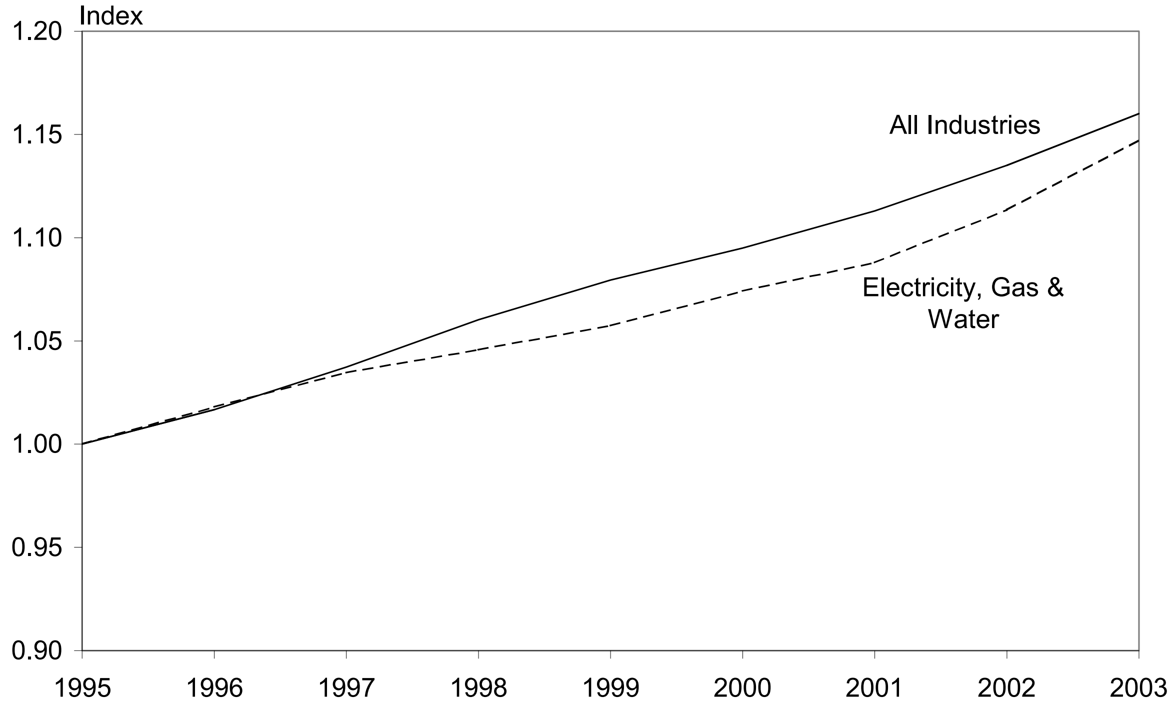
Given the assumptions that have had to be made to assemble 2003 data in the wake of the UnitedNetworks split, we take the trend annual TFP growth rate for all distributors of 2.1 per cent for the period 1996 to 2002 as our preferred estimate of distribution TFP performance.

5.3 Input price changes

As well as information on the difference between the productivity performances of the electricity industry and the economy as a whole, we also require information on the difference between the electricity industry's and the economy's input price growth rates to derive the B factor. There was considerable debate regarding what was a suitable index of changes in distribution input prices.

A number of distributors advocated the use of a capital price index instead of the labour cost index given the capital intensity of lines businesses. Many lines businesses also noted they are experiencing a significant increase in the wages paid to linesmen in response to recruitment of local linesmen by overseas lines businesses, particularly from Ireland and Australia. In response to these submissions we examined a broad range of input price indexes.

Figure 3: **All salaries and wages price indexes, 1995–2003**

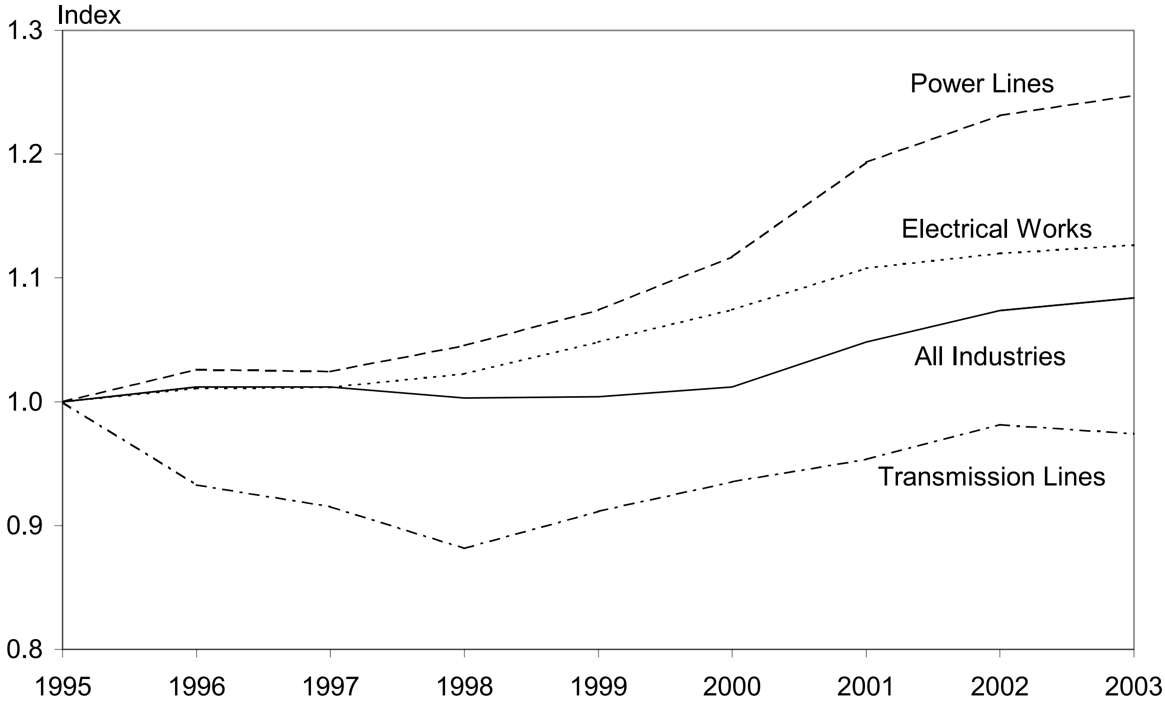


Source: Statistics New Zealand

Using the 'all industries' price index for all wages and salaries and the corresponding index for the electricity, gas and water sector failed to reveal a marked reversal in the pattern of electricity, gas and water sector labour costs relative to the economy up to the end of March 2003. These indexes are plotted in figure 3. There is some narrowing in the gap between the two indexes in 2002 and 2003, with the all industries index increasing at a trend growth rate of 1.83 per cent for the nine year period 1995 to 2003 and the electricity, gas and water sector index increasing at a trend rate of 1.58 per cent. This leaves a price differential of 0.25 per cent. While the main impact of the reported shortage of linesmen may not have impacted until after March 2003, there is also increasing evidence of a general shortage of skilled labour in the economy (Watson 2003). This means that any upturn in the price of electricity, gas and water labour costs may be matched by increased wage rates in other parts of the economy.

Charles Rivers Associates (2003) advocated the use of Statistics New Zealand's distribution power line capital price index to represent lines businesses' input prices. This price index shows rapid increase between 1999 and 2001 with more modest increases on either side of this period. This period of rapid price increase produces a relatively high trend growth rate for this price index of 3 per cent between 1995 and 2003. This compares to a 1 per cent trend increase for the capital price index for all sectors over the same period. Examination of related capital price indexes does, however, produce a different picture. From figure 4 we see that the SNZ transmission power line price index for the same period behaves very differently and only increases by a trend rate of 0.3 per cent. Information supplied by SNZ shows that the two indexes have very similar regimen (31 per cent cable and wire, 20 per cent wages and salary, 12 per cent excavation, 9 per cent concrete and poles, 7 per cent nuts and bolts, 5 per cent machinery hire and 3 per cent transport and storage). This makes explanation of the differences in these indexes difficult.

Figure 4: **Capital price indexes, 1995–2003**



Source: Statistics New Zealand

A third capital price index in figure 4 shows the price of 'electrical works' increasing somewhat faster than the capital price index for all sectors at a trend rate of 1.7 per cent per annum. However, this price index covers a wide range of activities outside of lines businesses such as installing traffic lights and telecommunications facilities as well as power line construction.

Overall, little conclusive evidence can be drawn from the capital price indexes due to the conflicting nature of the information from different relevant indexes. Producer price indexes also failed to provide a consistent picture of relative input price movements.

One response to this would be to say that four of the five most relevant SNZ price indexes increase less rapidly for lines business than for the economy as a whole and hence there should be a positive price differential term in calculating the B factor as we had in the initial report. Similarly, the implicit total inputs price index derived from the distribution TFP database increases by substantially less than two of the three broad input price indexes for all industries.

An alternative argument advanced by Pacific Economics Group (2003) is that unless there is clear cut evidence of a statistically significant difference in rates of input price increase then the price differential term should be set at zero. In light of the conflicting information coming through from the official statistics and the fact that the implicit input price index derived from the database is close to the all industries capital price index (and this is a capital intensive industry), we adopt the Pacific Economics Group approach of minimising risks by setting the price differential to zero.

5.4 B factor conclusions

Based on the review of available information for the lines businesses and for the economy, we can now draw conclusions on the appropriate size of the B factor for distribution. In both forming and using these conclusions we need to be cognizant of the less than perfect quality of the data they are based on.

In terms of the two productivity components, we have the preferred annual growth rate for TFP in the New Zealand economy of 1.1 per cent per annum using the trend rate derived from the indexes reported in the Treasury update (Black, Guy and McLellan 2003) of Diewert and Lawrence (1999). For the distribution lines businesses we have derived a trend annual TFP growth rate of 2.1 per cent per annum from the adjusted Disclosure Data. The estimate of a 2.1 per cent per annum TFP growth rate for the industry for the seven year period 1996 to 2002 is likely to be lower than that which could be expected over the next several years as economies from the recent split up of UnitedNetworks are realised. The 2003 year exhibited what are likely to be unusually large increases in aggregate operating expenditure as a result of this split up, as well as assumptions used in scaling operating expenditure data for the acquiring businesses to full year equivalents.

The annual input price trends observed in the preceding section produce no consistent pattern for an input price differential. Labour cost increases still appear higher for the economy as a whole than for lines businesses although some anecdotal evidence indicates that wage rates for linesmen are likely to increase further due to recruitment activities by overseas utilities. Capital price indexes produce mixed information with relevant power line construction price indexes increasing both faster and slower than capital price indexes for the economy as a whole. Producer price input indexes for power lines, power projects and substations have increased less rapidly than the producer price input index for all industries. Despite the fact that four of the most relevant five SNZ input price indexes increase less rapidly for lines businesses than for the economy as a whole, it is appropriate to adopt a zero price differential in constructing the B factor given the uncertainty involved.

Substituting these figures in equation (9), and ignoring the markup component for now, we obtain the following for distribution:

(15) $$B = [(\Delta TFP - \Delta TFP_E) - (\Delta W - \Delta W_E)]$$

$$= [(2.1\% - 1.1\%) - (0\%)]$$

$$= [(1.0\%) - (0\%)]$$

$$= 1.0\%$$

A B factor of 1.0 per cent would be appropriate for the distribution lines businesses.

6 DISTRIBUTOR PRODUCTIVITY AND C FACTORS

As well as the industry productivity growth related B factor, we use a number of additional considerations in arriving at distributors' X factors. These distributor–specific considerations are represented by a C factor for each distributor reflecting the distributor's comparative productivity performance (taking account of differences in distributors' operating environments to the maximum extent possible) and relative profitability. Those distributors performing better than the industry average on productivity levels and those earning low rates of return would be set less onerous overall X factors compared to those performing near the industry average. Those performing worse than the industry average on productivity levels and those earning high rates of return would be set more onerous overall X factors compared to those performing near the industry average.

The overall X factor for a given distributor is made up of an amalgam of its B and C factors. The B factor is common to all distributors and the C factors are to be determined for broad groups of distributors.

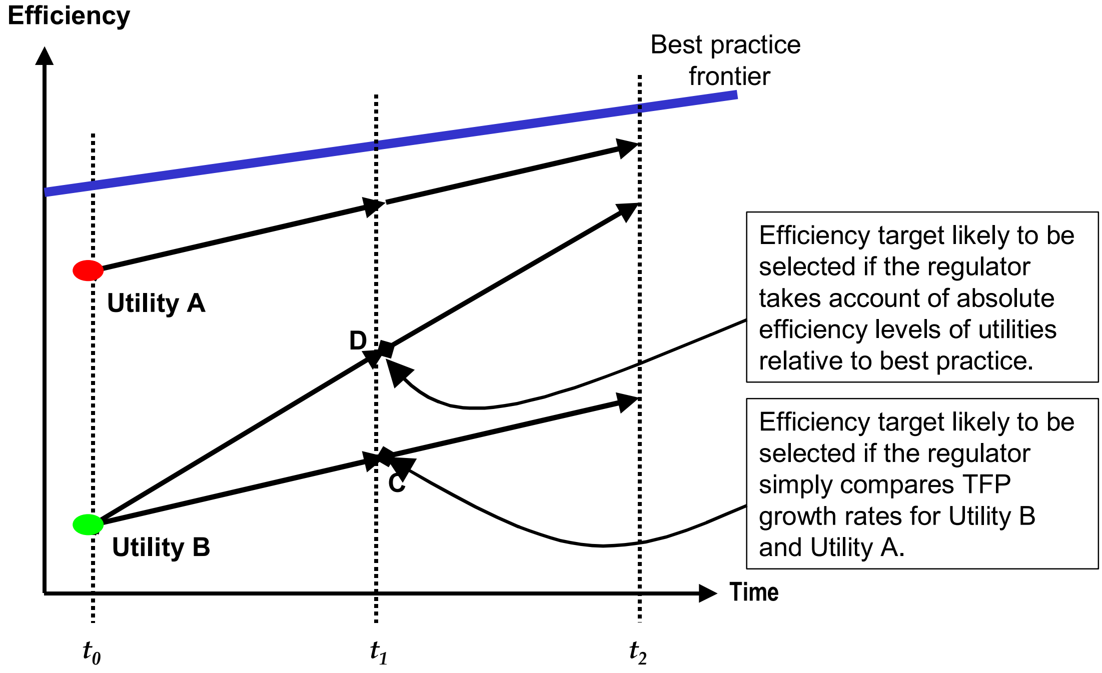
We again proceed with a two stage analysis. The first stage allocates distributors to three groupings based on relative productivity performance while the second stage allocates distributors to three groupings based on profitability considerations. We then form overall C factor groupings by summing the relative productivity and profitability components.

In this section we initially concentrate on the comparative productivity performance of the 28 distributors existing in 2003 (29 in earlier years) using an extension of the TFP index concept used in section 5 to enable 'multilateral' comparisons using combined time series, cross section or 'panel' data. We then examine profitability levels using the after–tax residual rate of return derived from the TFP database before using all this information to allocate distributors to four broad C factor groups.

6.1 Multilateral TFP

For benchmarking purposes we need to extend the time series indexing methods discussed in the earlier sections to include analysis of productivity levels as well as growth rates. The reasons for this can be illustrated using figure 15 where the efficiency performance of two similar utilities is plotted relative to a best practice frontier. Utility A is initially performing at close to best practice efficiency as reflected by its closeness to the best practice frontier while Utility B is initially well below best practice efficiency. Say we are reviewing the utilities at time t_1 and setting price caps for the period through to t_2. Because Utility A is close to best practice initially it will have limited options for efficiency improvement and so its productivity growth rate will consist of small movements towards the frontier plus movement of the frontier due to technical change which will be relatively slow in industries like electricity distribution. Utility B, on the other hand, has the potential to make large catch–up changes to its operations and so could achieve a much higher productivity growth rate than Utility A although it is starting from a much lower productivity level.

Figure 15: Efficiency levels and growth rates



If Utility B had a low productivity growth rate in the period up to t_1 getting only to point C then in the absence of yardstick competition we would have no way of distinguishing Utilities A and B. Extrapolating the low productivity growth rate would be appropriate for Utility A but inappropriate for Utility B. Rather, Utility B should be set a higher X factor to provide it with an incentive to move closer to the frontier. If, on the other hand, Utility B had had a higher growth rate in the period up to t_1 getting to point D then extrapolating this growth rate in setting the X factor would be appropriate. However, setting an X factor of that magnitude would be inappropriate and indeed unachievable for Utility A. Only by examining the utilities' productivity levels as well as their growth rates can we set appropriate X factors for them.

Traditional measures of TFP such as those discussed earlier in the paper have enabled comparisons to be made of rates of change of productivity between organisations but have not enabled comparisons to be made of differences in the absolute levels of productivity in combined time series, cross section data. This is due to the failure of conventional TFP measures to satisfy the important technical property of transitivity. This property states that direct comparisons between observations *m* and *n* should be the same as indirect comparisons of *m* and *n* via any intermediate observation *k*.

Caves, Christensen and Diewert (1982) developed the multilateral translog TFP (MTFP) index measure to allow comparisons of the absolute levels as well as growth rates of productivity. It satisfies the technical properties of transitivity and characteristicity which are required to accurately compare TFP levels within panel data. Lawrence, Swan and Zeitsch (1991) and the Bureau of Industry Economics (BIE 1996) have used this index to compare the productivity levels and growth rates of the five major Australian state electricity systems and the United States investor–owned system. Zeitsch and Lawrence (1996) use the method to compare the efficiency of coal–fired electricity generation plants in the United States, Canada and Australia.

The Caves, Christensen and Diewert (CCD) multilateral translog index is given by:

$$(16) \qquad \log (TFP_m/TFP_n) = \sum_i (R_{im}+R_i^*) (\log Y_{im} - \log Y_i^*)/2 - \sum_i (R_{in}+R_i^*) (\log Y_{in} - \log Y_i^*)/2 - \sum_j (S_{jm}+S_j^*) (\log X_{jm} - \log X_j^*)/2 + \sum_j (S_{jn}+S_j^*) (\log X_{jn} - \log X_j^*)/2$$

where R_i^* (S_j^*) is the revenue (cost) share averaged over all utilities and time periods and $\log Y_i^*$ ($\log X_j^*$) is the average of the log of output *i* (input *j*). In the main application reported in the following section we have three outputs (throughput, system line capacity and connections) and, hence, *i* runs from 1 to 3. We have five inputs (operating expenses, overhead lines, underground cables, transformers and other capital) and, hence, *j* runs from 1 to 5. The Y_i and X_j terms are the output and input quantities, respectively, described in section 6.1. The R_i and S_j terms are the output and input weights, respectively, from section 4.1.

The formula in (16) gives the proportional change in MTFP between two adjacent observations (denoted *m* and *n*). An index is formed by setting some observation (usually the first in the database) equal to one and then multiplying through by the proportional changes between all subsequent observations in the database to form a full set of indexes. The index for any observation then expresses its productivity level relative to the observation that was set equal to one. However, this is merely an expositional convenience as, given the invariant nature of the comparisons, the result of a comparison between any two observations will be independent of which observation in the database was set equal to one.

This means that using equation (16) comparisons between any two observations *m* and *n* will be both base–distributor and base–year independent. Transitivity is satisfied since comparisons between the two distributors for 1999 will be the same regardless of whether they are compared directly or via, say, one of the distributors in 2002. An alternative interpretation of this index is that it compares each observation to a hypothetical average distributor with output vector $log\ Y_i{}^*$, input vector $log\ X_j{}^*$, revenue shares $R_i{}^*$ and cost shares $S_j{}^*$.

With the index number MTFP approach there is scope to capture density related operating environment conditions by the specification of multiple outputs. For example, in previous studies, output specifications that focus on energy delivered have tended to favour dense urban distributors while output specifications that have focused on the network's capacity as measured by MVA–kilometres have tended to favour low density rural distributors (Tasman Asia Pacific 2000a,b). Incorporating both the energy delivered and network capacity measures of distribution output leads to a more even–handed treatment of urban and rural distributors. By choosing multiple outputs such as energy delivered, MVA–kilometres and connection numbers, it is possible to incorporate aspects of density such as customers per kilometre and energy delivered per customer into the MTFP measure directly in an analogous fashion to how this is captured in multiple output econometric cost functions (see Tasman Asia Pacific 2000a,b and Pacific Economics Group 2000a,b).

The multilateral TFP index has some important advantages. It is a robust technique which is relatively insensitive to data errors, does not require a large number of observations, provides information on productivity levels as well as growth rates and can be readily communicated to non–technical audiences. In the following section we present the results of the MTFP analysis.

6.2 MTFP results

The database we used in section 5 to calculate the overall distribution industry productivity performance was formed by aggregating the individual data for the 29 distributors for the years 1996 to 2002 and for the 28 full–year equivalent distributors in 2003. In this section we use the same data from the distributors but for the five years 1999 to 2003 and look at individual distributor results. We use the shorter time period in this analysis because it avoids problematic individual distributor data issues associated with the 1999 accounting changes and only recent information is used to determine distributor productivity rankings.

We again use three outputs (throughput in kilowatt hours, system line capacity in MVA kilometres and connection numbers) and five inputs (operating costs, overhead line capacity, underground line capacity, transformer capacity in KVAs and other capital). The main decision we have to make again relates to how to weight the three outputs together. Our preferred weighting method relies on New Zealand empirical evidence. As described in section 4.1, we use the weighted average estimated output cost shares derived from running econometric Leontief cost functions using the eight year database. For the purposes of the cost function estimation the same adjustment for the 1999 accounting changes as used at the aggregate level in section 5 is applied to each distributor except Orion New Zealand where revised audited data is used. The weighted average output cost shares derived from the Leontief cost function are 22 per cent for throughput, 32 per cent for system line capacity and 46 per cent for connections.

We present the MTFP results using the three outputs and weighted average cost function shares in table 3. Index values and ranks are shown for each of the five years 1999 to 2003 and for the average of the five years. The index values indicate the productivity level relative to the performance of Alpine Energy in 1999. The results are invariant to this choice of the 'base' observation. The distributors are listed by decreasing MTFP level for the average of the five years.

A mixture of urban and rural based distributors with both high and low (energy) density are found to have the highest MTFP levels for the average of the five years. We define rural distributors as those having less than 13 connection points per kilometre while low density distributors have an average consumption of less than 16,000 kilowatt hours per customer. The urban low density distributor Electricity Invercargill has the highest productivity level in each of the five years. This is followed by the urban high density distributor Nelson Electricity, the rural low density Waipa Networks and the rural high density Horizon Energy. The two large urban distributors, Vector and UnitedNetworks, also have MTFP levels in the top third of the sample.

The distributors with the lowest average MTFP levels over the five years also reflect a mixture of distributor types. The rural high density distributors, Electricity Ashburton and Buller Electricity, have the lowest MTFP levels followed by four rural low density distributors (Eastland Network, Westpower, Marlborough Lines and MainPower) and the urban high density Aurora Energy (formerly Dunedin Electricity).

Load growth does not appear to be a good indicator of a distributor's average MTFP level ranking with Electricity Invercargill, the distributor with the highest MTFP level, having one of the lowest increases in energy throughput between 1996 and 2003. Conversely, Electricity Ashburton, the distributor with the second lowest average MTFP level, had the highest increase in electricity throughput over the same period. The two large urban distributors, Vector and UnitedNetworks, have only had mid–range increases in throughput over the period up to 2002 although they had among the highest increases in customer numbers. Generally, rural high density networks have achieved the highest increases in throughput. With the exception of Westpower, the rural low density distributors that have lower average MTFP levels do not appear to have had unusually low load growth over the period.

Table 3: **MTFP indexes using 3 outputs, average cost function weights, 1999–2003**

	1999	*Rk*	*2000*	*Rk*	*2001*	*Rk*	*2002*	*Rk*	*2003*	*Rk*[1]	*Mean*	*Rk*
Elec Invercargill	1.401	1	1.441	1	1.508	1	1.603	1	1.781	1	1.547	1
Nelson Electricity	1.262	2	1.363	2	1.318	2	1.404	2	1.201	4	1.309	2
Waipa Networks	1.227	3	1.221	3	1.296	3	1.296	3	1.239	3	1.256	3
Horizon Energy	0.987	16	1.143	6	1.257	4	1.201	6	1.254	2	1.168	4
Vector	1.093	5	1.168	4	1.165	6	1.251	4	1.104	9	1.156	5
Network Tasman	0.989	14	1.154	5	1.145	7	1.227	5	1.161	6	1.135	6
Northpower	1.105	4	1.111	8	1.171	5	1.126	7	1.159	7	1.134	7
Scanpower	1.038	9	1.136	7	1.106	9	1.123	8	1.100	10	1.100	8
UnitedNetworks	0.981	17	1.089	9	1.111	8	1.115	9			1.074[2]	9
OtagoNet	1.005	12	1.023	15	1.071	10	1.078	10	1.175	5	1.070	10
Orion NZ	1.065	7	1.032	13	1.059	11	1.047	11	1.050	14	1.051	11
Alpine Energy	1.000	13	1.033	12	1.037	13	1.040	12	1.067	13	1.035	12
Network Waitaki	1.077	6	1.040	11	1.041	12	1.013	16	1.001	17	1.034	13
Powerco	1.053	8	1.026	14	0.986	19	1.007	19	1.097	11	1.034	14
Electra	0.987	15	1.046	10	1.031	15	1.012	17	1.012	16	1.018	15
Unison	0.957	18	1.008	16	0.986	18	1.028	13	1.067	12	1.009	16
Counties Power	1.023	10	0.971	21	0.999	17	1.010	18	0.973	20	0.995	17
WEL Networks	0.926	20	0.987	19	1.008	16	1.016	15	1.000	18	0.987	18
Top Energy	1.011	11	0.991	18	0.970	21	0.987	20	0.977	19	0.987	19
The Power Co'y	0.937	19	0.954	22	0.983	20	0.966	21	0.946	24	0.957	20
The Lines Co'y	0.762	28	1.005	17	1.034	14	1.018	14	0.962	21	0.956	21
Centralines	0.827	24	0.974	20	0.950	23	0.950	22	1.047	15	0.950	22
Aurora Energy	0.912	21	0.954	23	0.959	22	0.946	23	0.952	23	0.944	23
MainPower	0.889	22	0.927	24	0.946	24	0.923	24	0.942	25	0.925	24
Marlborough	0.878	23	0.853	25	0.873	26	0.847	26	0.868	26	0.864	25
Westpower	0.791	26	0.784	28	0.875	25	0.824	27	0.842	27	0.823	26
Eastland Network	0.702	29	0.817	26	0.766	29	0.859	25	0.959	22	0.821	27
Elec Ashburton	0.778	27	0.789	27	0.812	28	0.797	28	0.765	28	0.788	28
Buller Electricity	0.817	25	0.734	29	0.834	27	0.712	29	0.674	29	0.754	29

[1] For 2003 rankings UnitedNetworks was assumed to have same MTFP as in 2002 to facilitate greater comparability of rankings of firms ranked below it. Hence, 2003 rankings go to 29, not 28.

[2] Four year average for UnitedNetworks.

Source: Meyrick and Associates estimates

Scale of operations also does not appear to be a major determinant of average MTFP levels with the smallest distributor in terms of throughput (Scanpower) appearing near the top of the list and the second smallest distributor (Buller Electricity) appearing near the bottom. The five largest distributors (UnitedNetworks, Vector, Orion, Powerco and Aurora Energy) are spread across the top, middle and bottom thirds of the sample.

In Meyrick and Associates (2003a) we examined the sensitivity of the results to output specification by looking at the corresponding MTFP indexes if each of the three outputs was used in isolation. Using throughput as the sole output leads to a predominance of high density and urban distributors in the top half of the ranking and mainly rural low density distributors in the bottom half of the ranking. Electricity Invercargill retains its highest ranking on this measure and the large urban distributors move closer to the top. Waipa Networks is the only rural low density distributor in the top half of the table. There is now a much wider spread in MTFP levels than was the case using the three output based measure. The finding that the throughput based output measure favours high density and urban distributors is consistent with the findings of similar studies in Australia. It reflects the fact that these distributors can deliver a given amount of electricity using fewer inputs than distributors who have to serve more customers and/or traverse greater distances to deliver the same total volume of electricity.

Using system capacity as measured by MVA kilometres as the sole output, the results are reversed. The rural distributors now occupy the top two thirds of the table while all the urban distributors are in the bottom third. This is because rural distributors require more line length to reach their customers compared to urban distributors and will, hence, do better when output is only measured by system capacity.

The MTFP results using connection numbers as the sole output again favour the urban distributors who occupy the top third of the rankings with the exception of the rural low density distributor, Waipa Networks, which lies in seventh place. The other rural distributors occupy the bottom two thirds of the ranking with the exception of the urban high density Dunedin Electricity which is in the middle of the ranking.

Based on the discussion in section 3.1 of the appropriate definition of distribution output and the above sensitivity analyses, we conclude that the MTFP results reported in table 3 provide the most appropriate measure of individual distributor productivity performance given information currently available. It may be possible to refine these estimates in future if more direct information on cost allocation between outputs becomes available. The sensitivity analyses reported above also illustrate how using the MTFP specification with three outputs and using weighted average output cost shares derived from New Zealand data goes a large way towards normalising for different density dimensions across the different types of distributors.

6.3 Cost function estimation

The sophistication of the cost function model we are able to estimate is limited by the number of observations we have for each distributor and the range of variables available. In particular, we have no information on the price individual distributors pay for their operating expenses and have assumed they face a common price given by the Electricity, Gas and

Water labour cost index. Further, as noted earlier, we effectively have no labour data at all which precludes including the input common to nearly all cost function studies.

To overcome these problems, we estimate a multi–output Leontief cost function. This functional form essentially assumes that distributors use inputs in fixed proportions for each output. We include the three outputs of throughput, system line capacity and connections. We include four of the five inputs used earlier: operating expenses, overhead lines, underground lines and transformers. We exclude the other capital item which only makes up between two and three per cent of total costs to conserve degrees of freedom. To improve the statistical properties of the model we change to measuring system line capacity by a transformer capacity and line length based measure rather than the line length and voltage based measure used earlier. This change is made to reduce the potential for linear dependence between the system line capacity output quantity and the overhead line and underground cable input quantities. We retain the line length and voltage based measure for the overhead and underground lines capital input quantities.

The Leontief cost function is given by:

(17) $$C(y^t, w^t, t) = \sum_{i=1}^{4} w_i^t \, [\sum_{j=1}^{3} (a_{ij})^2 \, y_j^t \, (1 + b_i t)]$$

where w_i is an input price, y_j is an output and t is a time trend representing technological change. The input/output coefficients a_{ij} are squared to ensure the non–negativity requirement is satisfied, ie increasing the quantity of any output cannot be achieved by reducing an input quantity. This means we have to use non–linear regression methods. To conserve degrees of freedom we impose a common rate of technological change for each input across the three outputs but this can be either positive or negative.

The estimating equations are the four input demand equations:

(18) $$x_i^t = \sum_{j=1}^{3} (a_{ij})^2 \, y_j^t \, (1 + b_i t); \quad i = 1,..,4; \; j = 1,2,3; \; t = 1,..,7.$$

where the i's represent the four inputs, the j's the three outputs and t the seven years, 1996 to 2002.

The input demand equations are estimated separately for each of the 29 distributors using the non–linear regression facility in Shazam (White 1997) and data for the years 1996 to 2002. Given the limited number of observations and the absence of cross equation restrictions, each input demand equation is estimated separately. This leads to a total of 116 separate regressions, the results of which are reported in Meyrick and Associates (2003a).

From the estimated equations we can derive information on each distributor's rate of productivity change and its relative efficiency. The period t productivity change estimate for a distributor is equal to (the negative of) the amount of cost reduction due to the passage of one period:

(19)
$$Tech^t = -[\partial C(y^t, w^t, t)/\partial t]/C(y^t, w^t, t)$$
$$= -[\sum_{i=1}^4 w_i^t [\sum_{j=1}^3 (a_{ij})^2 b_i y_j^t)]/\{\sum_{i=1}^4 w_i^t [\sum_{j=1}^3 (a_{ij})^2 y_j^t (1+b_i t)]\}$$

The efficiency of a particular distributor in a particular year can be derived by comparing its estimated cost for that year with a 'benchmark' cost using a numeraire observation's technology (or estimated parameters) but the distributor's actual output quantities:

(20) $$E_n^t = C(b, y_n^t, w_n^t, t)/C(n, y_n^t, w_n^t, t)$$

where b is the benchmark observation and n is the distributor whose efficiency we are calculating. Thus, if distributor n can produce its output quantities at lower cost using its own technology than it could using the benchmark distributor's technology then E will be greater than one and n will be more efficient than the benchmark. Conversely, if n could produce its output quantities more cheaply using the benchmark distributor's technology than it can using its own then E will be less than one and n will be less efficient than the benchmark.

The problem with equation (20) is that the efficiency scores and rankings are likely to vary depending on which observation we choose as the benchmark or numeraire. To overcome this problem we take the benchmark to be a weighted average of the technologies of all the observations in the sample where the weights are given by the share of the observation's estimated cost in the total cost for all distributors and all time periods:

(21) $$E_n^t = [\sum_{b,t} s_b^t C(b, y_n^t, w_n^t, t)]/C(n, y_n^t, w_n^t, t)$$

where:

(22) $$s_b^t = C(b, y_b^t, w_b^t, t)/\sum_{b,t} C(b, y_b^t, w_b^t, t).$$

Equations (21) and (22) use an analogous idea to the multilateral TFP method in that the benchmark is taken to be a weighted average of all observation's technologies. This means the efficiency scores will be invariant provided the sample is not changed.

We can also derive the output cost shares for each output and each observation as follows:

(23) $$h_j^t = \{\sum_{i=1}^4 w_i^t [(a_{ij})^2 y_j^t (1+b_i t)]\}/\{\sum_{i=1}^4 w_i^t [\sum_{j=1}^3 (a_{ij})^2 y_j^t (1+b_i t)]\}.$$

We then form a weighted average of the estimated output cost shares using equation (22) to form an overall estimated output cost share. This process produces output cost share estimates of 22 per cent for throughput, 32 per cent for system line capacity and 46 per cent for connections. This procedure will produce more robust and stable estimates of the cost shares given the limited number of observations available than the alternative of running one set of regressions on the aggregated data. It is also necessary to run the regressions separately for each distributor to derive efficiency scores and thus forming the output cost share estimates in this manner is consistent with the way the efficiency scores are derived.

The cost function efficiency scores presented in Meyrick and Associates (2003a) cover a wider range than the corresponding three output MTFP indexes but the ranking of distributors is broadly similar. Vector is now found to be the most efficient distributor in 2002 followed by Nelson Electricity, UnitedNetworks and Electricity Invercargill. Westpower, Buller Electricity, Eastland Network and Electricity Ashburton now have the lowest efficiency scores.

The econometric cost function efficiency results thus broadly confirm the findings of our preferred MTFP results despite being derived from a different methodology.

6.4 Profitability considerations

Given that this is effectively the first time the New Zealand lines businesses have been regulated and they are starting from a wide range of circumstances, we now proceed to allocate distribution businesses a second C factor component based on their profitability. The rationale for this is that if a business is currently earning 'high' profits, it can sustain a higher level of real price reduction than that indicated solely by its relative productivity performance, all else equal. Conversely, if a business is currently earning a 'low' return then there is an arguable case for easing the tightness of its threshold based purely on productivity considerations to allow it to return to earning normal rates of return. It is envisaged that the profitability component would be purely temporary and only apply for the first one or two regulatory periods until the businesses get to reasonable starting points. From then on incentive regulation would only contain the productivity factor.

While it would be desirable to also include a service quality component in the C factor, more work is required on better understanding the complex relationship between observed service quality levels and current input levels.

Profitability issues are often addressed separately from productivity issues by the setting of a 'P_0' factor separately from the X factor. While the X factor is based on relative productivity considerations as usual, the P_0 adjustment is applied as an additional adjustment in the first year of the regulatory period to bring the business's profitability back to 'normal' levels. P_0 adjustments have been the subject of much controversy in other countries. By sometimes placing a large adjustment burden on the distributor in a short space of time there is a risk that this process can place undue financial distress on the lines business and endanger the ongoing security of supply. They also assume that the regulator has full information which is rarely the case.

A more reasonable approach to addressing the profitability problem is setting a 'glide path' where prices are adjusted over a period of several years to bring the business to a position of earning a normal return. The overall X factor that a business is set will then consist of two components: the usual productivity–based component plus an additional component aimed at gradually eliminating excess profits or restoring normal returns, as the case may be.

The range of ownership types and associated objectives complicates assessing the profitability of New Zealand lines businesses. The businesses can be broadly divided into three groups: commercial businesses that issue dividends to shareholders in the normal way; trusts which offer 'dividends' to their consumers/owners in the form of explicit rebates which may take the form of line charge holidays; and, trusts which provide a 'return' to their consumers/owners implicitly in the form of lower prices. This makes assessing profitability against normal commercial criteria such as the rate of return difficult. However, we do not have enough information to attempt to adjust for ownership influences. Instead we assess businesses on the basis of pre–rebate prices. This is equivalent to treating the explicit trust rebates as a form of dividend to 'shareholders'.

We assess distributor profitability on the basis of a relatively simple post–tax residual rate of return measure. This was derived by subtracting operating expenses, tax–equivalent payments and estimated depreciation from 'deemed' revenue. The tax equivalent payments deducted are actual taxes paid plus 33 per cent of subvention payments plus the interest tax shield. Subvention payments are payments from one business entity to another in the same tax group (eg subsidiary to parent company) while the interest tax shield is an adjustment to correct for the tax implications of debt rather than equity funding.

The tax adjusted residual rates of return derived from our database are presented in table 4 for the years 2000 to 2003 and the average of these four years. With the exception of Powerco, Unison and Vector, for which 2003 deemed revenue data are neither available nor readily able to be estimated, distribution businesses have been ranked on their average tax adjusted residual rates of return for the average of the four year period. The three business involved in the acquisition of UnitedNetworks have been ranked on their average tax adjusted residual rates of return for the three year period from 2000 to 2002 instead.

We divide the businesses into three groups – high, medium and low rates of return – with approximately one third of the businesses in each group. This also corresponds with breakpoints in the list of tax adjusted residual rates of return. This leads to businesses with low rates of return being those with a tax adjusted residual rate of return of less than 6 per cent and those with high rates having tax adjusted residual rates of return in excess of 8.1 per cent.

Table 4: **Tax adjusted residual rate of return estimates, 2000–2003**

	2000	*2001*	*2002*	*2003*	*4 yr average*
High return					
Nelson Electricity	13.90%	15.53%	18.20%	13.23%	15.2%
UnitedNetworks	11.68%	11.84%	12.95%		12.2% [a]
Counties Power	6.41%	10.61%	13.45%	9.92%	10.1%
The Lines Company	9.01%	9.31%	11.72%	9.81%	10.0%
Powerco	8.00%	10.79%	10.19%		9.7% [a]
WEL Networks	9.19%	8.86%	9.22%	11.30%	9.6%
Network Tasman	6.01%	10.02%	10.96%	9.87%	9.2%
Centralines	2.17%	14.38%	10.13%	9.86%	9.1%
Horizon Energy	7.66%	9.39%	10.40%	8.36%	9.0%
Electra	9.58%	8.49%	9.05%	7.70%	8.7%
Medium return					
Alpine Energy	5.57%	7.31%	9.30%	10.23%	8.1%
Scanpower	7.84%	7.25%	7.54%	8.98%	7.9%
Marlborough Lines	9.01%	10.44%	5.63%	5.95%	7.8%
Electricity Invercargill	5.93%	7.05%	8.33%	9.30%	7.7%
MainPower	6.25%	7.32%	7.18%	8.97%	7.4%
Orion New Zealand	8.45%	7.24%	6.40%	6.33%	7.1%
Eastland Network	6.80%	5.30%	6.60%	6.49%	6.3%
Vector	8.79%	4.61%	5.21%		6.2% [a]
Low return					
Unison	5.56%	4.02%	6.31%		5.3% [a]
Aurora Energy	4.80%	4.97%	4.95%	5.13%	5.0%
Top Energy	3.90%	4.16%	5.35%	5.23%	4.7%
Network Waitaki	3.46%	5.75%	4.29%	2.34%	4.0%
Westpower	1.77%	4.29%	4.96%	4.57%	3.9%
Electricity Ashburton	3.55%	4.48%	4.34%	3.04%	3.9%
Northpower	4.31%	1.89%	2.54%	3.03%	2.9%
OtagoNet	1.55%	3.22%	1.88%	3.25%	2.5%
Buller Electricity	2.31%	4.47%	0.90%	1.56%	2.3%
Waipa Networks	3.27%	3.74%	0.30%	-0.14%	1.8%
The Power Company	0.29%	1.35%	1.12%	2.33%	1.3%

[a] Three year average

Source: Meyrick and Associates estimates

The distributors earning the highest residual rates of return include a mixture of listed businesses, trusts, consumer trusts and council owned entities. Nelson Electricity has the highest residual rate of return. UnitedNetworks, Counties Power, The Lines Company and Powerco have the next highest tax adjusted residual rates of return. The businesses in the low rate of return group are all trusts plus the former consumer cooperative OtagoNet. The Power Company, Waipa Networks (which ranked highly in the MTFP rankings), Buller Electricity and OtagoNet have the lowest residual rates of return followed by Northpower. Moving to the tax adjusted basis for comparison changes the ranking of some businesses substantially, as the relative level of subvention payments and interest tax shields varies considerably between businesses.

6.5 C and X factor recommendations

We are now in a position to assemble the information presented in the preceding sections on productivity levels and profitability to form recommendations for C factors. In doing this, we have adopted targets that minimise likely risks in light of the relatively small amount of information we have to work with.

Given the capital intensive nature of electricity lines businesses and the long lived nature of the assets involved, it is unrealistic to expect lines businesses to be able to remove large productivity gaps in a short space of time. Rather, a timeframe of a decade, or two five–year regulatory periods, is likely to be necessary for businesses performing near the bottom of the range to lift themselves into the middle of the pack. This timeframe would allow sufficient time for asset bases to be adjusted significantly, new work practices to be adopted and bedded down and for amalgamations and rationalisations to be implemented and consolidated. It is, however, reasonable to expect profitability levels to be adjusted over a shorter period, say one regulatory period of five years. This should allow sufficient time for adjustment in a sustainable fashion without incurring the risk of financial stress or failure resulting from large P_0 adjustments.

For productivity adjustments we form the distributors into three groups with high, medium and low productivity levels. In 2003 the high productivity group (excluding Electricity Invercargill) was 15 per cent more productive on average than the middle productivity group which was in turn around 15 per cent more productive than the low productivity group. Using the distribution B factor of 1 per cent derived in section 5 for the middle group and a 10 year timeframe, the average productivity of the bottom group would have to increase by 2.5 per cent annually to reach the same average productivity level as the middle group after 10 years. Conversely, the high productivity group would have to change its average TFP by –0.5 per cent annually to reach the same average productivity level as the middle group after 10 years. This implies overall X factors of –0.5, 1 and 2.5 per cent per annum for the three groups or C factors of –1.5, 0 and 1.5 per cent per annum, respectively. Given the need to minimise risks given the variable quality of the available data and residual uncertainties, we reduce the range of C factors to –1, 0 and 1 per cent. This range also allows the high productivity group to maintain its absolute productivity levels while the other groups catch up.

For a similar spread of tax adjusted residual rates of return, the same range of C factors (–1, 0 and 1 per cent) would imply adjustment of average residual returns for the low and high return groups, respectively, to the average of the medium return group over less than 10 years. This is because the rate of return component will usually make up less than half of total annual costs. Therefore, a 1 per cent change in total revenue has a magnified effect on the residual rate of return.

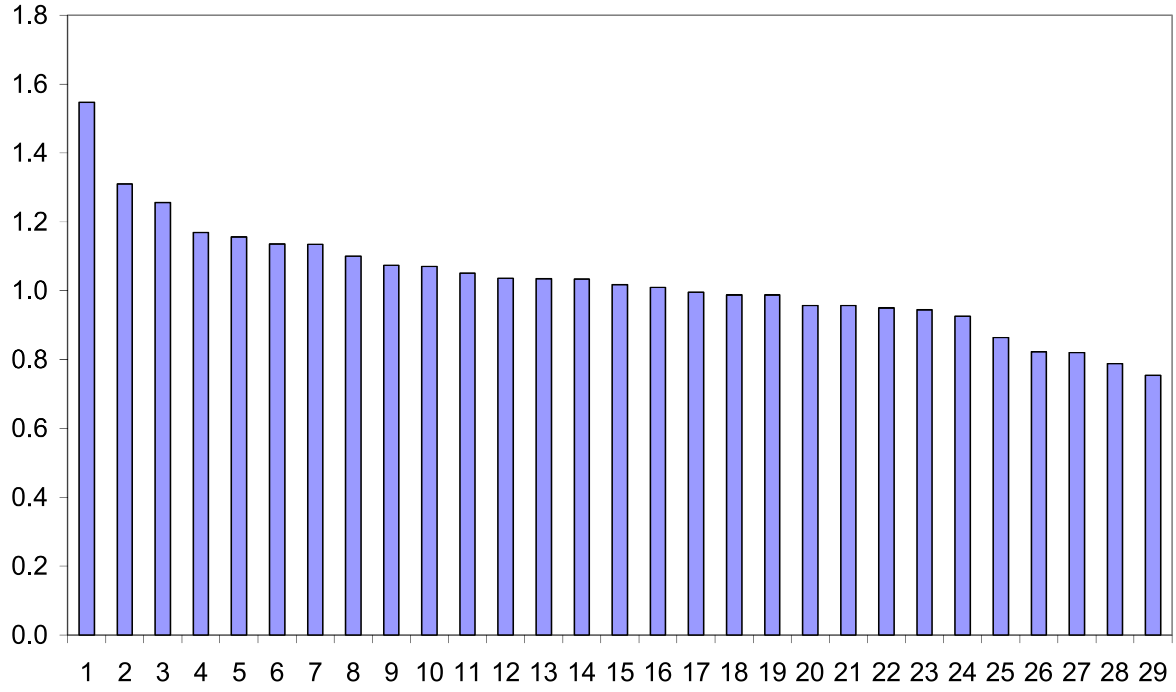
To recap, distributors performing near the industry average on all counts would receive a C factor of zero while those achieving high productivity levels (taking their density characteristics into account) and low rates of return would be set the less onerous C factor components of –1 per cent. Distributors achieving low productivity levels taking their density characteristics into account and high rates of return would be set the higher C factor components of 1 per cent. Those achieving, say, high productivity and high profitability would receive offsetting C factor components of –1 and 1 per cent, respectively, leading to an overall C factor of zero.

We use the information from the multilateral TFP indexes using three outputs and the cost function based output cost shares to allocate initial C factors based on the average productivity levels estimated for the five years 1999 to 2003. For clarity, we will refer to these as C_1 components. We then proceed to derive C_2 components based on relative profitability by using the tax adjusted residual rate of return information

We proceed by generally dividing the distributors into groups of around one third each. These groupings generally coincide with step points in the MTFP and tax adjusted residual rate of return results. In any exercise of this nature there will be boundary issues where discrete changes are made in the factors between the three groups. Making the change in the C_1 or C_2 components more graduated can reduce these boundary issues. For instance, the top and bottom groups could be each divided into another three groups each receiving a change of one third of one per cent instead of the group as a whole receiving a change of 1 per cent. However, this comes at the expense of simplicity and requires further allocation decisions to be made within these two larger groups.

Turning to the C_1 components, we present the MTFP efficiency scores for the average of the five years to 2003 in figure 6 in decreasing order. The indexes decrease steadily down to distributor 10 and then flatten out somewhat. The break point is less distinct between the medium and low productivity groups but we make the break after distributor 22. We use these groupings of 10, 12 and 7 distributors to define high, average and low levels of productivity, respectively, and allocate them C_1 components of –1, 0 and 1 per cent, respectively.

Figure 6: **MTFP indexes using 3 outputs, average cost function weights**, average of 1999–2003



Source: Meyrick and Associates estimates

As noted above, to determine the C_2 component groupings we divide the tax adjusted residual rate of return rankings using breakpoints of 8.1 per cent and 6 per cent. This leads to groups of 10, 8 and 11 distributors being classed as earning high, average and low rates of return, respectively. These groups are allocated C_2 components of 1, 0 and –1 per cent, respectively. These components are designed to 'glide path' distributors earning high and low rates of return towards the average return deadband. Again, these components have been set cautiously as the spread of tax adjusted residual rates of return is wider than is the case for productivity levels but they are considered appropriate given the quality of relevant information available.

The X factors resulting from using aggregate distribution industry TFP and input price estimates relative to those for the economy as a whole to derive the B factor and the MTFP scores in conjunction with the tax adjusted residual rate of return estimates to derive C factors are presented in table 5. For three distributors the C factor components sum to –2. When combined with the B factor of 1, this means these three distributors would be allowed to increase their real prices by 1 per cent per annum to restore their profitability levels. No distributors have both low productivity and high profitability groupings leading to two being the largest X factor recommended.

Table 5: **X factor recommendations**

ELB	*B*	C_1	C_2	$C=C_1+C_2$	$X=B+C$	*ELB*	*B*	C_1	C_2	$C=C_1+C_2$	$X=B+C$
Centralines	1	0	1	1	2	Network Tasman	1	–1	1	0	1
Counties Power	1	0	1	1	2	Orion New Zealand	1	0	0	0	1
Eastland Network	1	1	0	1	2	UnitedNetworks[a]	1	–1	1	0	1
Electra	1	0	1	1	2	Westpower	1	1	–1	0	1
MainPower	1	1	0	1	2	Elec Invercargill	1	–1	0	–1	0
Marlborough Lines	1	1	0	1	2	Network Waitaki	1	0	–1	–1	0
Powerco	1	0	1	1	2	Scanpower	1	–1	0	–1	0
The Lines Company	1	0	1	1	2	The Power Company	1	0	–1	–1	0
WEL Networks	1	0	1	1	2	Top Energy	1	0	–1	–1	0
Alpine Energy	1	0	0	0	1	Unison	1	0	–1	–1	0
Aurora Energy	1	1	–1	0	1	Vector	1	–1	0	–1	0
Buller Electricity	1	1	–1	0	1	Northpower	1	–1	–1	–2	–1
Elec Ashburton	1	1	–1	0	1	OtagoNet	1	–1	–1	–2	–1
Horizon Energy	1	–1	1	0	1	Waipa Networks	1	–1	–1	–2	–1
Nelson Electricity	1	–1	1	0	1						

[a] UnitedNetworks included for information only.
Source: Meyrick and Associates estimates

There is a mixture of business types in each of the three broad X factor groups with urban and rural businesses appearing in each of the low, middle and high X factor groups.

The Commerce Commission accepted the above recommendations which are set out in more detail in Meyrick and Associates (2003b) with the new price thresholds regime coming into effect from the start of April 2004.

7 CONCLUSIONS

In this paper we have illustrated some of the practical measurement issues encountered in assessing electricity network productivity performance. While we believe the solution presented represents the best use of the limited data we had to work with in this instance, electricity networks remain one of the many 'hard to measure' industries where further research will lead to ongoing refinements in productivity measurement. Given the trend toward greater use of incentive regulation in network industries, improving productivity measurement in these industries should have a high priority.

We report the use of Disclosure Data for New Zealand's electricity distribution lines businesses to form estimates of threshold B and C factors. These factors relate to industry productivity trends, and individual business productivity performance and profitability considerations, respectively. The data and our understanding of the complex relationship between quality and costs are insufficient to support inclusion of a C factor component based on price/quality trade–offs at this point in time. Further research on the relationship between service quality, costs and prices is a priority for work during the regulatory period relating to the next reset.

We find that applying the standard productivity and input price differential formula leads to a distribution B factor of 1 per cent and overall X factors that range from –1 per cent to 2 per cent.

With respect to future regulatory resets, the priority for work in this area in New Zealand is improving the quality and quantity of relevant data available. This involves requiring the disclosure of data on the price and quantity of all major outputs and inputs, including labour and broad asset categories. It also includes gaining more accurate information on the allocation of costs between the major output types. Greater effort will be required to ensure businesses report data in a consistent manner both across businesses and over time. Much of the Disclosure Data currently required from businesses is not used for developing comparative performance measures that would be relevant for forming B and C factors. The usefulness of this data should be reviewed with a view to reducing the amount of data required but making its composition more relevant. The addition of more years and better price and quantity data will allow the estimation of more sophisticated econometric cost functions in future.

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