Electricity Distribution Industry Productivity Analysis: 1996–2013

Report prepared for
Commerce Commission

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EXECUTIVE SUMMARY

The Commerce Commission has engaged Economic Insights to provide information to inform the Commission's decisions regarding the 2014 default price–quality path reset for the 17 non–exempt electricity distribution businesses (EDBs). The reset will involve either resetting EDB starting prices taking account of current and future profitability or, alternatively, rolling over the prices applying in the last year of the preceding regulatory period. If prices are reset, this will be done by the application of the building blocks methodology. The information contained in this report relevant to the application of building blocks is:

- the long–run productivity growth rate for the electricity distribution industry, and
- opex and capital partial productivity growth rates for the electricity distribution industry.

If prices are instead rolled over from the last year of the preceding regulatory period, the Commission has indicated that the rate of change of prices will be determined using information on productivity and input price differentials between the distribution industry and the economy. This is the approach generally used in productivity–based regulation.

In this report we calculate productivity growth rates for New Zealand EDBs using five different output specifications and two different input specifications for the period 1996 to 2013. Growth rates are reported for total factor productivity (TFP) and opex and capital partial productivity for the industry as a whole and for the 17 non–exempt EDBs as a whole. The data used in the study are derived from the Information Disclosure Data. EDB TFP indexes and the economy–wide productivity index are presented in figure A.

Building blocks X factor

In building blocks the starting prices and the rate of change (or X factor) are set to equate the net present values of forecast revenue and forecast costs (or the 'revenue requirement'). Changes in the X factor would be offset by changes in starting prices to maintain this equality. While there is an infinite number of starting price and X factor combinations that will achieve this equality, the Commerce Act states that the X factor should be based on the long run productivity improvement achieved by electricity distribution businesses (EDBs) in New Zealand and/or comparable countries.

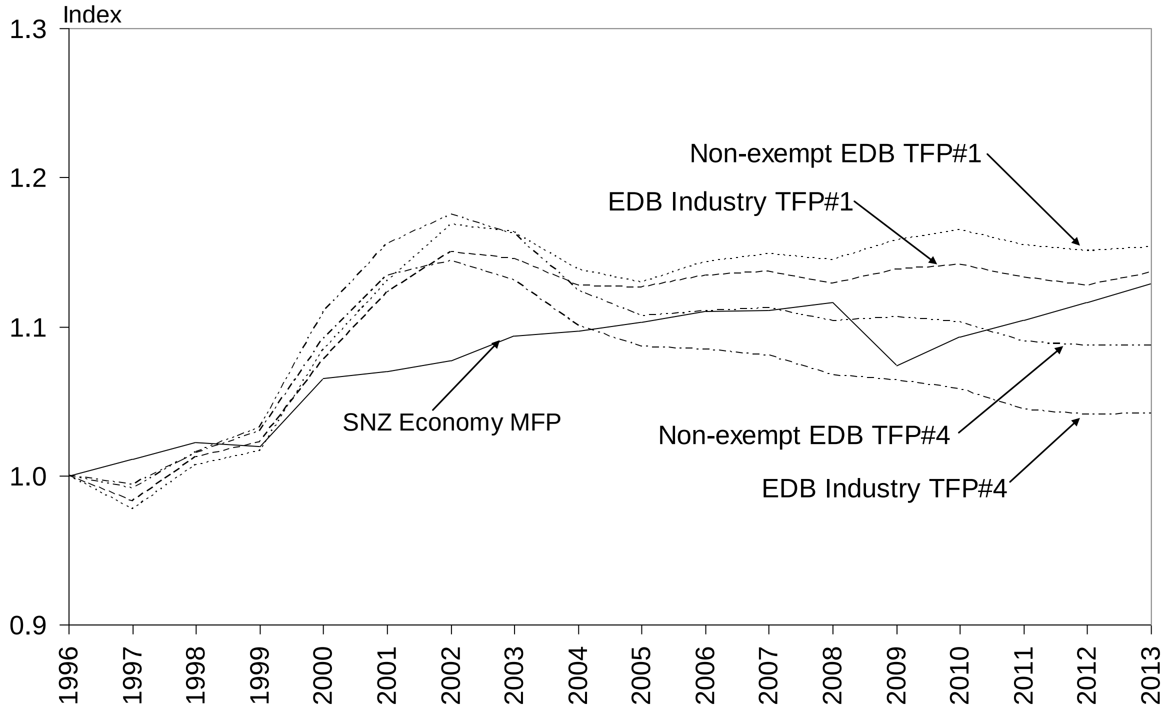
EDB productivity growth rates in New Zealand are found to have been broadly similar to those found in comparable countries such as Canada, those likely to be found in Australia and those reported in larger countries such as the US and the UK.

We have observations for New Zealand spanning the past 18 years. Normally one would seek as long a time period as possible to form an estimate of a long run growth rate. This implicitly assumes that growth occurs in a linear fashion and that there are no fundamental underlying changes occurring.

There is some evidence from a range of comparable countries that a significant change in market conditions facing the energy supply industry has occurred recently. In New Zealand electricity throughput grew at an average annual rate of 2.4 per cent between 1996 and 2007 but since 2007 it has grown at less than 0.5 per cent. While the global financial crisis reduced demand for electricity in 2009, it recovered in 2010 but has remained virtually static since then. In Australia, electricity demand reversed in 2008 and has fallen at an average annual rate of 1.1 per cent since then. A similar pattern has been observed in Ontario (PEGR 2013b). Maximum demand also peaked in Australia in 2009 and has fallen in New Zealand in 2013.

The AER (2013) has attributed this reversal of electricity demand to higher prices, more energy efficient appliances and, importantly, more energy efficient buildings, and the increasing penetration of rooftop solar PV panels. The AER (2013, p.21) does, however, expect that electricity demand will return to positive growth as electricity price rises moderate and population growth continues. It is forecasting a considerably reduced annual growth rate of 1.3 per cent over the next decade.

Figure A: **Non–exempt, industry and economy TFP indexes, 1996–2013**[a]



[a] TFP#1: Outputs of Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%) and Inputs of Opex, Overhead lines, Underground cables, Transformers and other capital

TFP#4: Outputs of Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit length (40%) and Inputs of Opex, Overhead lines, Underground cables, Transformers and other capital

Output cost shares in brackets

Source: Economic Insights estimates and SNZ

Using the three–output specification used in Economic Insights (2009a), electricity distribution industry TFP grew at an average annual rate of 1.5 per cent up to 2004 but at only 0.1 per cent in the decade since. Using the four–output specification used in PEGR (2013a), TFP grew at an average annual rate of 1.2 per cent up to 2004 but at –0.6 per cent in the decade since. The corresponding average annual growth rates for the 18–year period are 0.8 per cent and 0.2 per cent, respectively. The TFP growth rates for the other three output specifications examined in this report lie between those for these two specifications.

We are of the view that a significant change in market conditions facing the energy supply industry occurred around 2007 with a significantly reduced growth rate in demand which has now lasted for 6 years and which seems to be separate from the short term effects of the global financial crisis. This change has also been observed in Australia, Canada and the US. While the TFP specification used in our 2009 report points to marginally positive TFP growth over the past decade, the other five specifications examined point to negative TFP growth rates with the specification used in PEG (2009) pointing to a TFP growth rate of –1 per cent.

Our view is that an estimated TFP growth rate of zero is a reasonable choice for the current long run productivity growth rate and, hence, the X factor for the next regulatory period. While five of the six TFP specifications we have examined have pointed to a negative TFP growth rate for the last decade, there is also some expectation from experts, including the AER and the Australian Energy Market Operator (AEMO 2013, p.ix), that positive electricity demand growth will resume, albeit at a reduced rate compared to the period before 2007. This is likely to contribute to a return to positive TFP growth in the electricity distribution industry in the medium term.

Building blocks opex partial productivity growth

The other important productivity component in the building blocks approach is the rate of opex productivity growth to include in rolling forward the opex component of the revenue requirement. The Commission (2014a) has indicated it intends to roll opex forward by the sum of the forecast growth rate in opex prices plus the forecast growth rate in output (or scale effects) minus the forecast growth rate in opex partial productivity.

A similar situation exists with electricity industry opex partial productivity as with TFP. There was very strong average annual growth in opex partial productivity of around 4 per cent from 1996 to 2004 resulting from both stronger output growth and significant reductions in opex. In the past decade, however, opex partial productivity average annual growth has been in the range of –0.1 to –0.8 per cent as output growth has slowed and opex quantities have grown strongly.

An opex partial productivity growth rate of zero would strike the appropriate balance between recognising the apparent changed circumstances facing electricity distribution over the last decade while anticipating a return to more positive, albeit reduced compared to the period before 2007, output growth while providing an incentive for efficiency improvements.

Productivity–based regulation X factor

If the Commission opts to roll over EDB prices from the last year of the preceding regulatory period, it has indicated it will do so using a productivity regulation based approach to setting the X factor. This involves taking the difference in TFP growth rates between the electricity distribution industry and the economy and subtracting from this the difference in input price growth rates between the electricity distribution industry and the economy.

Using the electricity distribution industry TFP specification used in Economic Insights (2009a), the productivity growth differential relative to the economy–wide MFP growth rate is zero for the 18 year period to 2013 and –0.2 per cent for the last decade. Using the four–output specification used in PEGR (2013a), the productivity growth differential is –0.5 for the 18 year period to 2013 and –0.9 per cent for the last decade. If we use non–exempt EDB results rather than distribution industry results, the productivity differentials lie in the range of 0.1 per cent to –0.7 per cent.

For the period from 1996 to 2004, economy–wide input prices grew somewhat more rapidly than those for the electricity distribution industry. However, this situation has reversed over the last decade with electricity distribution industry input price growth having exceeded that for the economy. Distribution industry opex prices increased by 0.6 per cent more than economy–wide labour prices and distribution capital prices increased by nearly 1.5 per cent more than those for the economy as a whole. EDBs have had to pay more to retain their field staff in recent years and the civil construction–oriented nature of distribution capital means the industry has gained less from computerisation cost savings than have industries which use a higher proportion of machinery and equipment instead of structures. Overall, the input price differential has been around 0.5 per cent on average for the last 18 years and around 1.1 per cent for the past decade.

The apparent significant change in demand conditions which occurred around 2007 points to forming the X factor based on growth over the past decade rather than growth over the whole 18 year period. However, we expect productivity growth to resume, albeit at a reduced rate, in the medium term. Consequently, we believe a productivity growth differential of zero is a conservative choice for the next regulatory period. However, input price pressures the distribution industry has faced recently are likely to continue for some time although at likely reduced rates as competition for labour from other sectors reduces which should dampen both opex and capital construction price increases. Based on this we believe an input price differential – and, therefore, an X factor – of –1 per cent is appropriate.

1 INTRODUCTION

Seventeen New Zealand electricity distribution businesses (EDBs) are currently subject to a default price–quality path under Part 4 of the Commerce Act 1986 (the Act). Four months before the end of the regulatory period the Commerce Commission is required to reset the default price–quality paths applying to each EDB. Amongst other things, the Commission must reset starting prices, rates of change and quality standards. These paths will take effect from 1 April 2015.

Section 53P(3) of the Act states that the starting prices must either be:

- the prices that applied at the end of the preceding regulatory period; or
- prices, determined by the Commission, that are based on the current and projected profitability of each EDB.

The rate of change is the annual rate at which EDBs' maximum allowed prices can increase. This is expressed in the form 'CPI–X', meaning prices are restricted from increasing by more than the rate of inflation, less a certain number of percentage points, termed an 'X–factor'.

Sections 53P(6) and 53P(10) of the Act set out the constraints for the Commission's work, including:

- the rate of change must be based on the long–run average productivity improvement rate achieved by either or both of EDBs in New Zealand, and suppliers in other comparable countries, using appropriate productivity measures, and
- the Commission may not use comparative benchmarking on efficiency to set starting prices, rates of change, quality standards, or incentives to improve quality of supply.

The Commission has engaged Economic Insights to provide an estimate of the productivity improvement rate to inform the 2014 default price–quality path reset. Specifically, the Commission has asked Economic Insights to:

- provide an estimate of the long–run productivity improvement rate in the electricity distribution industry
- provide estimates of the operating expenditure and capital partial productivity improvement rates for the electricity distribution industry
- use publicly available information, adjusted as appropriate, and make available all datasets required for use by stakeholders, and
- advise on the robustness of using a productivity improvement rate based on data for all 29 EDBs or data for only those 17 EDBs that are subject to price–quality regulation.

Previously, productivity analysis has been used for determining the X–factor and allowances for operating expenditure where the building blocks approach is used to determine EDB starting prices based on the current and projected profitability of each EDB.

Economic Insights conducted a half day workshop for stakeholders on 2 May 2014 where the general approach to productivity measurement and its use in EDB regulation was presented. Stakeholder feedback at the workshop has been taken into account in preparing this report.

2 THE USE OF PRODUCTIVITY ANALYSIS IN EDB REGULATION

This chapter provides a brief discussion of the role of productivity measurement in the economic regulation of natural monopolies such as EDBs.

2.1 What is total factor productivity?

Productivity is a measure of the physical output produced from the use of a given quantity of inputs. All enterprises use a range of inputs including labour, capital, land, fuel, materials and services. If the enterprise is not using its inputs as efficiently as possible then there is scope to lower costs through productivity improvements and, hence, lower the prices charged to consumers. This may come about through the use of better quality inputs including a better trained workforce, adoption of technological advances, removal of restrictive work practices and other forms of waste, and better management through a more efficient organisational and institutional structure. When there is scope to improve productivity, this implies there is technical inefficiency. This is not the only source of economic inefficiency. For example, when a different mix of inputs can produce the same output more cheaply, given the prevailing set of inputs prices, there is allocative inefficiency.

Productivity is measured by expressing output as a ratio of inputs used. There are two types of productivity measures: total factor productivity (TFP) and partial factor productivity (PFP). TFP measures total output relative to an index of all inputs used. Output can be increased by using more inputs, making better use of the current level of inputs and by exploiting economies of scale. The TFP index measures the impact of all the factors affecting growth in output other than changes in input levels. PFP measures one or more outputs relative to one particular input (eg labour productivity is the ratio of output quantity to labour input).

Forecast future productivity growth rates can play a key role in setting the annual revenue requirement used in building blocks regulation (as will be discussed in the following section). Productivity studies assist the regulator in determining likely future rates of productivity growth to build into annual revenue requirement forecasts. And, where the building blocks approach is not used (eg where starting prices are taken to be those applying at the end of the previous regulatory period), forecast TFP will have a more direct impact on the EDB's recoverable revenue (as will be discussed in section 2.3).

Productivity indexes are formed by aggregating output quantities into a measure of total output quantity and aggregating input quantities into a measure of total input quantity. The productivity index is then the ratio of the total output quantity to the total input quantity or, if forming a measure of productivity growth, the change in the ratio of total output quantity to total input quantity.

To form the total output and total input measures we need a price and quantity for each output and each input, respectively. The quantities enter the calculation directly as it is changes in output and input quantities that we are aggregating. The relevant output and input prices are used to weight together changes in output quantities and input quantities into measures of total output quantity and total input quantity using revenue and cost measures, respectively.

In forming the output measure for competitive industries, observed revenues shares are typically used to weight together the output quantities sold as price will approximate marginal cost in these industries. For natural monopoly infrastructure industries, however, prices charged will typically not equal marginal costs and pricing patterns may have evolved instead on the basis of convenience or attitudes to risk. Therefore, for industries such as electricity distribution, it is important to ensure that all dimensions of the output supplied are recognised and that prices reflecting marginal costs are used wherever possible to weight these output dimensions into a total output quantity measure. Using marginal cost weights is necessary to determine changes in costs that are due to changes in demands.

On the input side, the most difficult to measure component is the input of capital goods. Like other inputs and outputs, we need a quantity and cost for capital inputs. The appropriate measure to use for the capital input quantity in productivity analysis depends on the change in the physical service potential of the asset over time. For long–lived network assets such as poles, wires, transformers and pipelines, there is likely to be relatively little deterioration in physical service potential over the asset's life. In this case using a measure of physical asset quantity is likely to be a better proxy for capital input quantity than using the constant price depreciated asset value series as a proxy.

The traditional approach to measuring the annual user cost of capital in productivity studies uses the Jorgenson (1963) user cost method. This approach multiplies the value of the capital stock by the sum of the depreciation rate plus the opportunity cost rate minus the rate of capital gains (ie the annual change in the asset price index).

For traditional productivity studies with a limited history of investment data available, the asset value series is typically rolled forwards and backwards from a point estimate using investment and depreciation series. The point estimate would typically reflect the market value of assets at that point in time. It would be standard practice to take the earliest point estimate of the capital stock available, provided there was reasonable confidence in the quality of the valuation process. In the case of energy distribution, sunk assets and new investment have traditionally been treated symmetrically and the concept of financial capital maintenance (FCM) has been an important feature of building blocks regulation in particular. To ensure ex–ante FCM is satisfied, it is important to allocate an annual user cost (AUC) to capital inputs that is broadly analogous to the return of and return on capital components used in calculating the building blocks capital component.

2.2 Building blocks regulation

The Commission currently uses the building blocks approach when it resets EDB starting prices taking account of the current and projected profitability of each EDB. The building blocks approach to price regulation involves calculating an annual 'revenue requirement' for each EDB based on the costs it would incur if it was acting prudently. The costs are made up of opex, capital costs and a benchmark tax liability (which usually takes account of the differences between regulatory and taxation parameters and allowances). Capital costs are, in turn, made up of the return of capital and the return on capital. The return of capital is typically calculated as straight–line depreciation on the DB's opening regulated asset base (RAB) calculated over its estimated remaining life plus straight–line depreciation of assets added during the period calculated over their estimated total lives. The return on capital is the opening RAB multiplied by an opportunity cost rate. The opportunity cost rate is the weighted average cost of capital (WACC) which takes account of the different costs of the nominated debt and equity components of the RAB.

Financial capital maintenance (FCM) is a key principle in the building blocks approach. FCM means that a regulated business is compensated for prudent expenditure and prudent investments such that, on an ex–ante basis, its financial capital is at least maintained in present value terms.

Since the building blocks method involves setting the price cap for each DB at the start of the regulatory period, forecasts have to be made of the annual revenue requirement stream over the coming regulatory period and of the quantities of outputs that will be sold over that period. Since the opening RAB for the regulatory period will be (largely) known, the annual revenue requirements for the upcoming regulatory period can be forecast based on forecasts of opex and capex.

Once the forecasts of annual revenue requirements and output quantities have been made, the P_0 and X factors are set so that the net present value of the forecast operating revenue stream over the upcoming regulatory period is equated with the net present value of the forecast annual revenue requirement stream. There is an infinite number of starting price and X factor combinations which will satisfy this condition. However, in the case of New Zealand, the Act specifies that the X factor is to be set at an exogenous value based on the long–run average productivity improvement rate achieved by EDBs. This means the starting price is then set to equate the net present value streams.

If the starting prices are set based on the current and projected profitability of each supplier, then the rate of change will not affect the amount of revenue the individual EDB can expect to recover over the regulatory period. This is because starting prices for each regulated EDB would simply be adjusted to offset any alteration to the common rate of change to maintain the equality between the present value of expected revenues and the present value of expected costs for that EDB over the regulatory period. This means the regulatory outcome for each EDB is not affected by the measured long–run average productivity improvement rate used to set the rate of change of prices.

However, the forecast partial opex and capital productivities can impact the level of forecast costs and therefore the present value of allowable revenue over the regulatory period for each EDB. In the case of opex, the Commission (2014a) has indicated it expects forecast opex to be set using the following formula:

> operating expenditure$_t$ = operating expenditure$_{t-1}$ × (1 + Δ due to network scale effects – Δ operating expenditure partial productivity + Δ input prices).

This is the 'rate of change' formula commonly used in building blocks whereby the opex forecast is rolled forward by the sum of forecast input price growth plus forecast output growth minus the forecast rate of opex partial productivity growth. A higher forecast opex partial productivity growth rate will thus lead to a lower opex revenue requirement over the next regulatory period for EDBs.

Since productivity analysis provides information on the partial productivity of the overall capital stock, rather than of individual year's capex, it typically plays a limited role in forming annual capex requirements forecasts under the building blocks approach.

2.3 Productivity–based regulation

If the Commission decides to set starting prices to be the same as those applying at the end of the previous regulatory period then the X factor acquires considerably greater importance and will have a direct bearing on EDBs' profitability. In this case the situation would be more akin to traditional productivity–based regulation.

Because infrastructure industries such as the provision of energy distribution networks are often subject to decreasing costs in present value terms, competition is normally limited and incentives to minimise costs and provide the cheapest and best possible quality service to users are typically not strong. The use of CPI–X productivity–based regulation in such industries attempts to strengthen the incentive to operate efficiently by imposing pressures on the network operator similar to the process of competition. It does this by constraining the EDB's output price to track the level of estimated efficient unit costs for the 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 TFP change for the industry and Z represents relevant changes in external circumstances beyond managers' control which the regulator may wish to allow for. Ideally the index W would be 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. A commonly used alternative is to choose a generally available price index such as the consumer price index or GDP deflator.

Productivity–based regulation argues that 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 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.

As outlined in Lawrence (2003), traditional productivity–based regulation has typically been implemented using CPI–X price caps where, as the result of choosing the CPI to index costs, the formula for the X factor takes on the following 'differential of a differential' form:

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

where the E subscript refers to corresponding variables for the economy as a whole and M refers to monopolistic mark–ups or excess profits. What this formula 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.

The change in mark–up term in (2) would be set equal to zero under normal circumstances but if the target firm was making excessive returns, then this term could, in principle, be set negative (leading to a higher X factor).

2.4 Earlier New Zealand electricity distribution productivity studies

The former thresholds regime was based on quantitative work reported in Lawrence (2003). To capture the multiple dimensions of lines business output Lawrence (2003) measured distribution output using three outputs: throughput, system line capacity and connection numbers. Inputs were broken into four categories: operating expenses, overhead lines, underground cables, transformers and other capital.

Lawrence (2003) used the Fisher TFP index method to calculate the productivity performance of the electricity distribution industry as a whole. For the period 1996 to 2002 aggregate distribution TFP was found to have increased at a trend annual rate of 2.1 per cent, 1.0 per cent above that for the economy as a whole.

Lawrence (2003) found there are several conflicting pieces of information on the movement of lines business input prices relative to those for the economy as a whole. Wage rates in the electricity, gas and water sector had increased by less than those for all industries in the nine years to March 2003 although the gap had narrowed somewhat in the last two years and anecdotal evidence at the time pointed to a shortage of linesmen.

Capital price indexes gave conflicting information with one power line price index increasing faster than the capital price index for all sectors and the other major power line price index increasing less rapidly than the all sectors index. Producer price indexes, on the other hand, show that lines business input prices had increased less rapidly than input prices for all industries. The implicit total input price index derived from the Lawrence (2003) distribution database increased at the same trend rate as economy–wide capital prices but substantially less than economy–wide wage rate and producer input price indexes. In light of the conflicting information coming from the official statistics Lawrence (2003) recommended setting the input price growth differential to zero.

Combining the 1.0 per cent productivity growth differential and the zero per cent input price growth differential, Lawrence (2003) recommended an overall X factor of 1.0 per cent for the electricity distribution industry and this was adopted by Commerce Commission (2003).

Lawrence (2007) updated the EDB productivity analysis presented in Lawrence (2003) to cover the years 2004 to 2006. Lawrence (2007) made some minor revisions to the data used in the earlier study for the years 1996 to 2003 as errors contained in the official Disclosure Data had progressively been identified and corrected. To maintain maximum comparability with Lawrence (2003), Lawrence (2007) used an adjusted asset value series that excluded the

2004 optimised deprival value (ODV) asset revaluations.

Extending the period covered forward to 2006 led to the electricity distribution industry output trend growth rate increasing to 1.6 per cent per annum but inputs had also increased by a trend growth rate of 0.7 per cent, instead of decreasing as they had up to 2002. This led to the industry TFP annual trend growth rate for the 11 year period as a whole falling to 0.9 per cent. TFP fell by just under 2 per cent in each of the years 2004 and 2005 before increasing marginally in 2006.

The fall in electricity distribution industry TFP in 2004 and 2005 was found to be mainly in response to a sharp increase in opex and strong growth in the capital stock, particularly increases in underground cables and transformers. The quantity of opex was found to have increased by 14 per cent over this two year period, accounting for nearly 40 per cent of the increase in the total input quantity. Part of the reason for this increase was thought to be large increases in opex for the three businesses that took over the former UnitedNetworks. A series of unusual storms around this time may also have contributed to the observed opex increases.

In 2009 the Commission engaged Economic Insights to examine the electricity distribution industry's productivity performance and make recommendations regarding the X factor that should apply in the next regulatory period. Economic Insights (2009a) noted that the earlier output specification used in Lawrence (2003, 2007) made no allowance for the contribution of distribution transformer capacity to overall system capacity. Distribution transformer capacity had grown rapidly over the preceding several years and failure to recognise the important contribution of increased distribution transformer capacity was likely to have led to the system delivery capacity measure (which reflects the ability to meet capacity demands) being biased downwards.

Using the broader definition of system delivery capacity in the TFP analysis which recognised the contribution of transformer capacity as well as line capacity, led to industry TFP growing strongly to 2003 and then levelling off after that. Over the 13 year period from 1996 to 2008, industry TFP grew at a trend rate of around 1.1 per cent per annum leading to a very small productivity growth differential of effectively zero relative to the economy as a whole.

Economic Insights (2009a) found that the non–exempt part of the industry exhibited somewhat stronger TFP growth than the industry as a whole. TFP trend growth rates for this industry segment were around 1.5 per cent per annum. This segment accounted for 80 per cent of industry throughput and customer numbers. Calculating the productivity growth differential term on the basis of the 'non–exempt' portion of the industry would have led to a productivity growth differential of around 0.4 per cent but a conservative course of action of setting the productivity growth differential term in the X factor to zero based on the overall industry and market sector performance was recommended.

Economic Insights (2009a) also found that, using the rigorous amortisation charge approach to calculating annual capital user costs which takes account of ex ante FCM, the distribution industry as a whole had exhibited slightly slower input price growth than the economy as a whole over the preceding 13 years. This pointed to a small input price growth differential of in the order of –0.3 per cent per annum but a conservative course of action in favour of the EDBs of setting the input price growth differential term in the X factor to zero was recommended. Since the X factor is the difference between the productivity growth differential and the input price growth differential and each of these had been conservatively recommended to be set to zero, it followed that the X factor was also recommended to be zero.

Economic Insights (2009a) used a TFP specification with three outputs:

- throughput in GWh
- customer numbers
- system capacity based on the product of overall system mains length and the last step transformer capacity (kVA*kms)

and four inputs:

- opex
- overhead lines in MVA–kms (being the summation of system overhead mains lengths at various voltages multiplied by an MVA carrying capacity for each voltage level)
- underground lines in MVA–kms
- transformers in kVA and other capital

Output quantities were output cost share weighted and inputs weights were formed using an exogenous capital cost taking account of FCM.

In 2009 the Electricity Networks Association engaged Pacific Economics Group (PEG) to calculate electricity distribution TFP growth rates and these were also considered by the Commission. Despite using a different time period and specification, PEG (2009) found similar electricity distribution industry productivity results to Economic Insights (2009a). PEG found an annual TFP growth rate of 1.2 per cent for the 10 years to 2008 and recommended an X factor range of between 0.19 per cent and –0.63 per cent.

PEG (2009) used a TFP specification with three outputs:

- customer numbers
- throughput in GWh
- peak demand as measured by the non–coincident peak in GW

and two inputs:

- opex
- capital (measured by constant price depreciated asset value).

Outputs were revenue share weighted and inputs weights were formed using an endogenous capital cost (the difference between revenue and opex).

Based on the findings of Economic Insights (2009a) and PEG (2009), the Commission set an X factor of 0 per cent (leading to a rate of change of CPI–0 per cent) and also assumed an opex partial productivity growth 0 per cent in constructing its forecast of opex requirements.

3 DATA USED AND SPECIFICATIONS EXAMINED

3.1 Data sources and adjustments

The starting point for the database used in this study is the database used in Economic Insights (2009a). We extend this to the 18 data years 1996–2013 to calculate trend rates of aggregate industry and aggregate non–exempt EDB productivity growth. The 1995 data year was discarded due to the apparent teething problems with providing Information Disclosure Data (IDD) in the first year and the absence of ODV estimates. A number of assumptions outlined in Lawrence (2003) are also made in this study to address opex data discontinuities in the 1999 financial year and the effects of the extended Auckland CBD outage.

Data for each of the individual EDBs are aggregated up to industry level for each variable. 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[1], and the disclosure data requirements were revised at that time. Some corrections were made to the data in Lawrence (2003) to reflect the businesses' responses to the opportunity to comment on the data set and to ensure maximum consistency of the data through time. Further minor corrections were made in Lawrence (2007) and Economic Insights (2009a) as it became apparent that different EDBs had reported variables on different bases or changed their basis of reporting through time and further corrections have been made in the current study to maintain consistency between the earlier information disclosure formats and the revised format adopted for the 2008 reporting year and later years.

One example of a minor issue with the pre–2008 IDD is that with the release of more detailed data (for some areas) in the new IDD data from 2008 onwards, it has become apparent that EDBs had not reported distribution transformer capacity consistently before 2008. Some had included customer–owned transformers while some had only included transformers they owned themselves. Since it is no longer possible to readily recover consistent data for the earlier period and given that the focus of this study is on productivity growth and not productivity levels, we have continued the series for each EDB on the same basis as it was reported in the pre–2008 IDD.

In a few cases key series contained in the pre–2008 IDD used in the productivity analysis have not been continued in the new IDD. The most important of these relate to opex where the direct cost per line kilometre and indirect cost per customer series were discontinued in the new IDD. Our previous productivity analysis used these ratios scaled up by line length and customer numbers, respectively, as the best source of opex data for productivity analysis purposes. For productivity analysis we require the opex series to reflect the use of physical, non–durable inputs (ie labour, materials and services) each year and to exclude other items which might be included for accounting purposes. For example, a number of EDBs included items such as line charge rebates in the opex series reported in the pre–2008 IDD but these were excluded from the direct cost and indirect cost ratios.

[1] We adopt the convention that financial years are referred to by the year in which they end.

We have compared our 2008 scaled up opex with the 2008 opex reported in the new IDD[2]. For around a third of the EDBs the new 2008 opex value is within 1 per cent of our scaled up 2008 opex value based on the direct and indirect ratios. For another third of the EDBs the new value is within between 1 and 5 per cent of our scaled up 2008 opex value. But there are several EDBs where the difference is more than 5 per cent with some being higher and some being lower than the corresponding scaled up value. Fully resolving the reasons for these variations is beyond the scope of the current project. Since we are confident that the former direct and indirect cost ratios captured the actual physical input use required for productivity analysis, we have opted to roll our former series for each EDB forward beyond 2008 by the change in the overall opex reported in the new IDD for that EDB. Given the spread of the variations in the two series in 2008, the aggregate industry opex series is relatively insensitive to whether no adjustment is made for the 2008 reporting change, whether the post–2008 series is spliced onto the series we have used previously (the approach adopted here) or whether the reverse splicing is done.

Another problematic area is capital data. Optimised deprival valuations (ODV) were only first done on a consistent basis across EDBs in 2004 and consistent roll forward data is only available in the IDD itself from 2008 onwards (although these data were subsequently collected by the Commission for the years 2005–2008 and these were used in Economic Insights (2009a)). Furthermore, the capex data reported in the pre–2008 IDD do not reflect actual expenditure by the EDB but rather valuations based on physical work done and using the specified ODV unit rates. In Economic Insights (2009a) we formed an estimate of a consistent capex series for the years before 2004 using changes in reported asset values and related data. This series was used in constructing the annual user cost of capital amortisation value. It is used for that purpose in this report and also to form a constant price depreciated asset value series (as will be outlined in section 3.4).

A maximum demand variable is used in the current study for the first time. The EDB coincident maximum demand series contains a number of anomalies for the years up to and including 2003. The most notable of these is a step change in the United Networks Ltd (UNL) series in 1999 which leads to a doubling of its reported maximum demand in that and subsequent years despite no unusual change occurring in other output variables such as energy throughput or customer numbers. We adjust for this anomaly by assuming UNL's 1998 maximum demand was the same as that reported for 1999 and splicing the series for the earlier years onto this. Other apparent maximum demand anomalies were observed for Centralines in 2002 and Marlborough Lines in 2003 when the reported values approximately doubled for those years only in both cases. We have assumed the correct value in both cases was equal to the previous year's value for each EDB.

We also include revenue weighting of outputs in one of the specifications used in the current study. We have allocated revenue by type of charge reported in the 2013 IDD into three components for each EDB: fixed charges, energy charges and demand charges. For most EDBs reported charges can readily be allocated to these three components. However, some EDBs have used minimal labelling and charges have had to be allocated on a best endeavours basis in these cases. We adopt a similar approach to PEG (2009) in partly capturing changes

[2] Data for 2008 were available on both bases.

in revenue shares over time by assuming the 2013 price for the three items also applied in other years and creating a corresponding notional revenue item for the earlier years. This allows us to include time–varying weights reflecting changes in relative quantity movements.

For some variables the data files supplied by the Commission contain minor revisions to values back to around 2005 and these are included in the updated database.

Orion is excluded from the database and the analysis given its special circumstances and the difficulty of objectively adjusting its data to exclude the effects of the February 2011 Christchurch earthquake.

The key variables for the 18 year aggregate industry database and the non–exempt EDB database are listed in appendix A.

3.2 Output and input specifications examined

Economic Insights (2009a) used a TFP specification which included three outputs (throughput, overall system capacity and connections) and four inputs (opex, overhead lines, underground cables, and transformers and other assets). Output weights were allocated based on econometrically estimated output cost shares (ie the contribution of each of the three outputs to total costs). Capital input quantities were proxied by physical asset measures while capital input costs were proxied by an amortisation charge.

There has been much debate about whether outputs should be measured on an 'as billed' basis or on a broader 'functional' basis. This distinction arises because EDB charging practices have typically evolved on an ease of implementation basis rather than on a cost reflective basis. Hence, many EDBs levy a high proportion of charges on energy throughput even though changes in throughput usually have little real impact on the costs they face and dimensions that customers may value highly such as reliability, continuity or speedy restoration after any interruption are not explicitly charged for at all. Under productivity–based regulation a case can be made that the 'billed' output specification should be used as output (and, hence, productivity) needs to be measured in the same way that charges are levied to allow the EDB to recover its costs over time. Economic Insights (2009b) showed that this can also be achieved under a functional output specification provided billed outputs are included as a subset of functional outputs and appropriate weights are used. However, under building blocks regulation there is typically not a direct link between the revenue requirement the EDB is allowed and how it structures its prices. Rather, the regulator typically sets the revenue requirement based on the EDB being expected to meet a range of performance standards (including supply availability and reliability performance). In the building blocks context it will be important to measure output in a way that is broadly consistent with the output dimensions implicit in the setting of EDB revenue requirements.

Economic Insights (2009) used a functional outputs specification concentrating on the supply side, ie giving EDBs credit for the network capacity they have provided. In consultation undertaken by the Australian Energy Regulator (AER) in 2013, many user groups – and also some Australian EDBs – argued for the inclusion of demand side functional outputs so that the EDB is only given credit for network capacity actually used and not for capacity that may be installed but excess to users' current or reducing requirements. Including observed maximum demand instead of network capacity was argued to be a way of achieving this. However, this measure would fail to give the EDB credit for capacity it had been required to provide to meet previous maximum demands which may have been higher than those currently observed. Economic Insights (2013a) suggested that inclusion of a 'ratcheted peak demand' variable may be a way of overcoming this problem and Pacific Economics Group Research (PEGR 2013a,b) also used a similar variable in work on Ontario electricity distribution. This variable is simply the highest value of peak demand observed in the time period up to the year in question for each EDB.

PEGR (2013a) included a total of four functional outputs (energy delivered, ratcheted maximum demand, customer numbers and circuit length). We believe this specification has a number of attractions – it captures the key elements of system capacity while also acknowledging a demand side component and overcoming some of the limitations of other functional output specifications. The earlier PEG (2009) New Zealand study used a billed outputs specification with high level proxies for the quantities actually charged for[3].

Given the range of output specifications that have been used in recent EDB regulatory productivity studies, in this study we examine five output specifications as outlined in table 1.

Table 1: **EDB output specifications examined**

No	*Components included and weight applied*	*Weighting basis*
1	Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)	Output cost share
2	Energy (28%), Maximum demand (10%), Customer nos (62%)	Output cost share
3	Energy (24%), Ratcheted maximum demand (23%), Customer nos (53%)	Output cost share
4	Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit length (40%)	Output cost share
5	Energy (68%), Maximum demand (17%), Customer nos (15%)[a]	Revenue share

[a] Shares for the industry, averaged over all years

Output cost shares are derived by estimating Leontief cost functions for each of 24 EDBs and taking a weighted average of estimated output cost shares across the sample of 432 observations (24 EDBs across 18 years each). The weights for each observation are based on its share in the total estimated cost across the entire sample. Given the difficulty of obtaining consistent series for the EDBs involved in the split up of UNL in 2003, we exclude Powerco, Unison, UNL, Vector and Wellington from the sample for econometric analysis. PEGR (2013a) also excluded the largest Ontario EDBs from its econometric estimation of output cost shares given a similar disparity in EDB sizes. Orion is also excluded from the econometric analysis as it is from the sample for all the reported analysis. The resulting output cost share estimates for the four functional output specifications are reported in table 1. The cost function estimation and cost share calculation process used is described in appendix B.

Turning to the specification of inputs, there has also been considerable debate around the best way to proxy the quantity of the annual input of capital in economic benchmarking studies. Some studies have used physical quantity based measures (eg MVA–kms of lines and MVA of transformer capacity) which assume 'one hoss shay' depreciation (of physical capacity) while others have used a deflated depreciated asset value series to proxy annual capital input quantity. The latter approach typically involves a straight–line depreciation assumption.

[3] In a study for the Victorian gas distribution businesses Economic Insights (2012) undertook a detailed comparison of using a billed outputs specification using quantities actually charged for versus a functional outputs specification.

There have also been different approaches adopted to measuring the annual user cost of capital. Economic Insights (2009a) adopted an exogenous amortisation approach which recognised the principle of FCM which is central to building blocks regulation. PEG (2009) adopted a simpler endogenous method whereby the difference between revenue and opex is allocated as the annual user cost of capital.

In this study we include two input specifications – one using the physical quantities proxy to annual capital input quantity and the other using the constant price depreciated asset value proxy. In both cases we use the exogenous amortisation–based annual user cost of capital as we believe this is the best approach to use in building blocks productivity applications (since the annual user cost is calculated in an analogous way to the return of and return on capital and tax components in building blocks). A pre–tax weighted average cost of capital (WACC) of 8.7 per cent is used in the amortisation calculation. This is consistent with the Commission's latest determination (Commerce Commission 2014b). A pre–tax WACC is used as the tax component is not normally separately included in productivity studies in the same way it is in building blocks calculations.

A detailed discussion of a wider range of output and input specification issues in EDB productivity measurement can be found in the recent Economic Insights (2013b) report for the AER.

3.3 Output and input definitions

Output quantities

Throughput: The quantity of electricity distribution throughput is measured by the number of kilowatt hours of electricity supplied.

Overall system capacity: Overall system capacity is measured by the product of the electricity distribution industry's installed distribution transformer kVA capacity of the last level of transformation to the utilisation voltage and its totalled kilometres of mains length (inclusive of all voltages but excluding streetlighting and communications lengths).

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

Maximum demand: The sum of coincident maximum demands for each of the included EDBs. It is thus a non–coincident maximum demand measure for the electricity distribution industry as a whole and for the subset of non–exempt EDBs.

Ratcheted maximum demand: The sum of ratcheted coincident maximum demands for each of the included EDBs where ratcheted maximum demand for a particular year is the highest maximum demand observed in the sample period up to that point. PEGR (2013a,b) refers to an analogous measure as 'system capacity peak demand'.

Circuit length: The sum of overhead and underground circuit kilometres.

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 a functional output specification the weights should reflect the relative costs of producing each output. We use the output cost shares derived from the econometric estimation of Leontief cost functions as output weights for the functional output specifications 1–4 in table 1 above. Table 1 also presents the values of these estimated output shares and the Leontief methodology is presented in appendix B.

Total electricity distribution industry revenue is taken to be ‘deemed’ revenue comprising line charges plus revenue from ‘other’ business plus AC loss rental rebates less payment for transmission charges less avoided transmission charges less AC loss rental expense paid to customers. Line charge revenue is taken to be net of discounts to customers.

As noted in section 3.1, for output specification 5 which uses revenue weighting, we have allocated revenue by type of charge reported in the 2013 IDD into three components for each EDB: fixed charges, energy charges and demand charges. We then assume the 2013 price for the three items also applied in the other years and create a corresponding notional revenue item for the earlier years from which we calculate time–varying weights reflecting changes in relative quantity movements.

Input quantities

Operating expenditure: The quantity of electricity distribution operating and maintenance expenses is derived by deflating the sum of the grossed up values of direct costs per kilometre and indirect costs per customer by a composite index of labour costs for the electricity, gas, water and waste (EGWW) sector and the all industries producer price index for inputs. 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 electricity distribution system and exclude rebates. As discussed in section 3.1, the 2008 grossed up opex values for each EDB are rolled forward using the change in total reported opex in the IDD for years after 2008 as the requisite ratio data were not included in the latest version of the IDD. The all industries producer price index for inputs is used in forming the opex price index in preference to the corresponding EGWW sector index as the latter is relatively volatile, likely reflecting the influence of parts for the sector outside the electricity distribution industry. By contrast, the EGWW sector labour cost index is relatively stable and likely to provide the best reflection of labour costs facing the industry. In our earlier productivity studies for the Commission we have used the sector–specific labour cost index as the sole measure of EDB opex prices.

Overhead network: The quantity of poles and wires input in the overhead network is proxied by the electricity distribution industry’s overhead MVA kilometres. The MVA kilometres measure provides a means of adding up the capacity of lines of differing voltages and capacities in an objective and consistent manner. 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 Parsons Brinckerhoff Associates (2003).

Underground network: The quantity of underground cables input is proxied by the electricity distribution industry’s underground MVA kilometres calculated using the same factors as listed above.

Transformers and other assets: The quantity of transformer and other asset inputs is proxied by the kVA of the electricity distribution industry's installed distribution transformers.

Input weights

For the productivity analysis we take total costs to be the sum of operating expenditure and capital amortisation charges. The method used to calculate amortisation charges is described in section 3.3. The weight given to opex is its share in total cost. The weights given to the three capital input components are the shares of each component in the 2004 ODV multiplied by the overall capital share in total cost.

For the econometric estimation of cost functions at the EDB level, the value of total costs is formed by summing the estimated value of operating expenditure and 12.5 per cent of (estimated) indexed historic cost (IHC). The latter is based on the NZIER (2001) assumption of a common depreciation rate of 4.5 per cent and an opportunity cost rate of 8 per cent for capital assets. This was shown in Economic Insights (2009a) to be a close approximation to the pre–tax amortisation charge.

Non–exempt EDBs

The Commission has requested Economic Insights to prepare TFP estimates for the subset group of non–exempt EDBs as well as for the electricity distribution industry as a whole. The Act specifies that 'consumer–owned' EDBs are exempt from price–quality regulation. Twelve EDBs qualify for 'consumer–owned' status in that they:

- are 100 per cent consumer owned (trust owned) as required by criterion (a)
- have trust deeds meeting the election requirements stipulated by criterion (b)
- have at least 90 per cent of consumers benefiting from income distribution as required by criterion (c), and
- have less than 150,000 ICPs as required by criterion (d).

The 12 EDBs are:

- Buller Electricity
- Counties Power
- Electra
- MainPower New Zealand
- Marlborough Lines
- Network Waitaki
- Northpower
- Scanpower
- The Power Company
- Waipa Networks
- WEL Networks, and

- Westpower

Our non–exempt results thus exclude these 12 EDBs.

3.4 Amortisation charges and constant price asset values

FCM consistent amortisation charges

FCM–consistent amortisation charges can be calculated using a large number of different capital charge profiles. In this study, the profile assumes straight line depreciation of existing assets and capital expenditure based on respective asset lives and estimates the charges in nominal terms for each year using a building blocks approach. This entails adjusting the starting point asset value each year for inflation, the carry forward of depreciation charges adjusted for inflation and the use of a real pre–tax return each year. As a real pre–tax rate of return is used and assets are revalued to take account of inflation there is no need to make an additional adjustment to remove revaluation gains from the estimated nominal capital charges.

Amortisation charges are calculated assuming the 75th percentile post–tax discount rate is 6.8 per cent (Commerce Commission 2014b). The pre–tax discount rate is actually the one that is most relevant for determining prices since taxes have to be paid out of gross revenue received. While the effective tax rate paid by EDBs will likely be less than the statutory corporate tax rate of 28 per cent, for simplicity we assume the corporate tax rate applies. Combining this assumption with one that the expected inflation rate is that observed in 2013 produces a real pre–tax discount rate of 8.5 per cent.

Starting point asset values, new investment and asset lives

The amortisation charges for system fixed assets were calculated for the electricity distribution industry as a whole for the period 1996 to 2013. As in Lawrence (2003, 2007) non–system fixed assets are excluded due to their relatively small size. As noted in Economic Insights (2009a), an 'IHC' asset value series is available from 2004 to 2008 using the 2004 ODV revaluations as the starting point. The components required to roll back before 2004 on an IHC basis are not available and so the earlier ODV series from Lawrence (2003, 2007) was spliced onto the 2004 ODV to proxy the IHC series from 1996 to 2003.

The ODV for year ended 2004 was used as a base to determine the amortisation charge over the remaining life of the assets from 2005 onwards. A charge also had to be calculated for new investment from 2005 to 2013 to recover the cost of new investments over their assumed lives. Asset additions data from the IDD were used as estimates of new investment from 2005 to 2013.

To calculate charges from 1996 to 2004 a similar process was applied to the estimate of capital as at the end of 1995. Since no ODV value was reported in the 1995 IDD, it is estimated by applying the average annual growth rate of the ODV series from 1996 to 2003 to the 1996 reported ODV.

Estimated nominal asset additions for 1996 to 2003 were calculated by use of the perpetual inventory formula $I_t=K_t–(1–d)K_{t–1}(1+\rho)$, where the depreciation rate 'd' was assumed to be the same as the average of reported depreciation for the period 2005 to 2013 (3.79 per cent for the industry and 3.71 per cent for non–exempt EDBs) and the inflation rate 'ρ' was based on the all groups CPI from Statistics New Zealand.

In order to calculate the amortisation charges, asset lives for new investment and remaining asset lives for the asset value bases at the start of 1996 and start of 2005 had to be estimated. Estimates of total asset lives and remaining asset lives as of March 2007 were obtained from Farrier Swier Consulting (2007). Based on this report, the mean standard asset life for the total asset base was 52 years and the ratio of the average age of the network to mean standard lives was 0.49 as of March 2007. Based on these estimates, the remaining mean asset life of the existing asset based was assumed to be 26 years as of March 2007 (37 years in 1996) and the mean standard asset life of new investment was assumed to be 52 years.

The charges prior to 2005 were also adjusted to remove discontinuity in the two series (given that the data prior to 2004 provide only an approximation to relevant IHC series). This was done by obtaining estimates of amortisation charges for 2005 by both approaches and applying the ratio of the 2005 estimate based on the 2004 ODV asset value to the 2005 estimate based on the 1996 spliced ODV and IHC asset value, to the estimated charges based on the latter asset values.

Nominal amortisation charges based on a building blocks approach

The amortisation charges comprise a return on capital and a return of capital in nominal terms for each year.

To determine the nominal return on capital in current year prices it is necessary to calculate an opening value of the asset base each year adjusted for inflation and then multiply it by the real pre-tax rate of return.

The opening asset base for each year is equal to the closing book value of the preceding year calculated as follows:

> Closing book value = Opening book value plus current year capex value less depreciation on the opening value (ie excluding full year depreciation on current capex) less partial year depreciation on current year capex plus revaluation of depreciated opening assets.

The depreciation for the first year is calculated on a straight line basis and residual asset life.

The depreciation of current year capex is calculated at half the normal deprecation rate for new assets (based on assuming installation at mid–year).

The depreciation in each year for existing assets (except the first year) is the depreciation for the preceding year (excluding depreciation of current year capex) adjusted for inflation using the current year inflation rate, plus a full year's depreciation on the previous year's capex (after deducting the previous half year of depreciation).

The revaluation of depreciated opening assets is calculated by applying the inflation rate for the current year to the opening asset value less depreciation (excluding depreciation of current year capex).

The return of capital in each year is the sum of the depreciation of existing assets and the depreciation of current year capex.

The return on capital each year is the sum of the product of the real pre–tax return on capital and the opening asset value and half the product of the real pre–tax return on capital and current year capex. This latter component recognises that current year capex is put in place mid–year.

Constant price depreciated asset value

Our second input specification uses the constant price depreciated asset value as a proxy for the quantity of annual capital input. As noted in section 3.1, forming such a variable for New Zealand EDBs over an extended period is problematic given that consistent asset valuations across EDBs were not first done until 2004 and, prior to that, reported IDD capex was not actual capex spent by each EDB but rather taking physical work done valued at ODV unit rates. To overcome these problems we use the capital data constructed to form consistent amortisation charges over the entire period.

We use the 2004 ODV as the starting point for constructing a constant price depreciated asset value series and apply the following standard perpetual inventory equation to update and backdate it from this point:

(3) $$K_t = (1-d)K_{t-1} + Capex_t / PK_t$$

where *K* is the constant price capital stock, *d* is the depreciation rate, *Capex* is annual capital additions, *PK* is a capital price index and subscripts reflect time periods.

We form a nominal capex series by splicing our estimated capex series for the years 1996 to 2005 from the amortisation calculations onto the actual capex series for 2005 to 2013. The choice of an appropriate capital price index to deflate the nominal capex series by is not straightforward in the case of New Zealand as outlined in Economic Insights (2009a, pp.34–5). The Statistics New Zealand (SNZ) Power lines capital goods price index (CGPI) is, in principle, the most relevant deflator. However, as we have previously outlined, this price index exhibits very high growth after 2004. Despite having a similar regimen, the related Transmission lines CGPI does not exhibit this very high growth. Instead, we use the higher level Electrical works CGPI which both the power lines and transmission lines CGPIs feed into, along with many other electrical construction activities[4]. We do not use the Electricity distribution and control apparatus CGPI as this mainly covers machinery and equipment for switching or protecting electrical circuits rather than civil construction projects such as power line construction which fall within the Electrical works CGPI.

Once capex is converted into constant 2004 prices it is used in equation (3) along with the depreciation rate derived from the expected life of capital assets derived from Farrier Swier (2007) to form a constant price depreciated asset value.

[4] It should be noted that historic productivity analysis generally uses more targeted price indexes than those typically used in higher level building blocks analysis since the latter requires price forecasts to be available and reliable forecasts are generally only available for economy–wide price indexes.

4 ELECTRICITY DISTRIBUTION INDUSTRY PRODUCTIVITY

In this section we use the Fisher TFP index method to calculate the productivity performance of the electricity distribution industry as a whole and for the non–exempt EDBs as a subset group for the 18 years 1996 to 2013. We then examine alternative approaches to forming the input price growth differential term.

4.1 TFP indexing methods

Productivity is a measure of the quantities of outputs produced in proportion to the quantities of inputs used in the production process, and changes in productivity are measured by changes in the ratio of outputs to inputs between two time periods. Since firms usually use several inputs, and may produce several different outputs, the levels of outputs and inputs are measured by indexes. Index numbers are perhaps the most commonly used means of measuring economic variables (Coelli et al. 2005, p. 85). An index number measures a set of related variables relative to a base period. Growth rates for individual outputs and inputs are weighted together using revenue or output cost shares and input cost shares, respectively. In other words, the TFP index is essentially a weighted average of changes in output quantities relative to a weighted average of changes in input quantities.

Total factor productivity is measured by the ratio of an index of all outputs (Q) to an index of all inputs (I):

(4) $$TFP = Q/I$$

Since indexes are defined relative to a base period, the TFP index measures the *proportionate* change in productivity level relative to the base period. The *rate* of change in TFP between two periods is measured by:

(5) $$\dot{TFP} = \dot{Q} - \dot{I}$$

where a dot above a variable represents the rate of change of the variable. TFP indexes have a number of advantages including:

- indexing procedures are simple and robust;
- they can be implemented when there are only a small number of observations;
- the results are readily reproducible;
- they have a rigorous grounding in economic theory;
- the procedure imposes good disciplines regarding data consistency; and
- they maximise transparency in the early stages of analysis by making data errors and inconsistencies easier to spot than using some of the alternative econometric techniques.

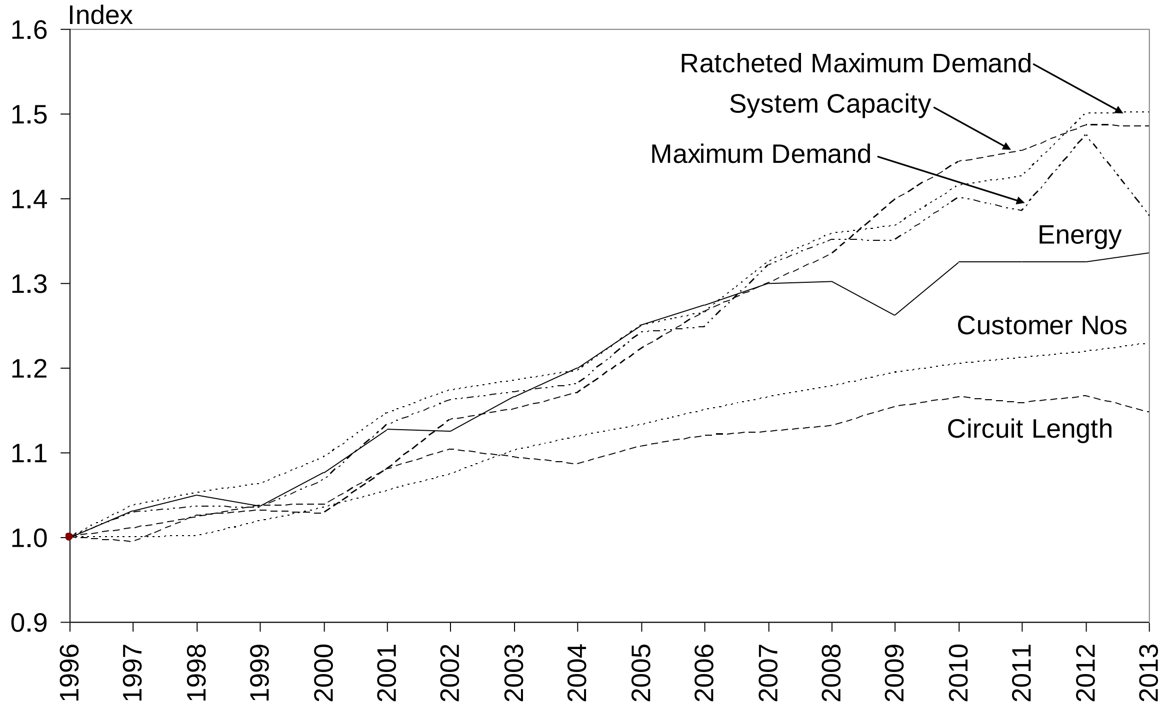
To operationalise TFP measurement we need to combine changes in diverse outputs and inputs into measures of change in total outputs and total inputs. There are alternative index number methods that calculate the weighted average change in outputs or inputs in different ways. Alternative index number 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. The chained version of the Fisher index is used in this study. The formula for the Fisher index is presented in appendix C.

4.2 Distribution industry productivity growth

Output component and total output quantity indexes

As discussed in section 3.2, in this study we examine five different output specifications involving a total of six different output components. The individual output components of energy throughput (in kWh), system capacity (in kWh*kms), customer numbers, maximum demand (in MW), ratcheted maximum demand (in MW) and circuit length (in kilometres) are graphed in figure 1 and listed in table 2. Table 2 also reports average annual growth rates for three different periods – 1996 to 2013, 1996 to 2004 and 2004 to 2013.

Figure 1: **Distribution industry output component quantity indexes, 1996–2013**



Source: Economic Insights EDB Database

For the whole 18 year period, the three capacity–related measures of system capacity, maximum demand and ratcheted maximum demand have all grown steadily with system capacity and ratcheted maximum demand growing at an average annual rate of around 2.3 per cent. A downturn in maximum demand in the last year of the period led to maximum demand growing at a lower average annual rate of 1.9 per cent but it had been similar to the other two capacity measures up to 2012. With the exception of maximum demand, growth rates were somewhat higher in the second half of the period compared to the first half.

Table 2: **Distribution industry output component quantity indexes, 1996–2013**

Year	Energy	Sys Capacity	Customers	Max Demand	Rat.MDemand	Circuit kms
1996	1.000	1.000	1.000	1.000	1.000	1.000
1997	1.031	0.994	1.000	1.029	1.037	1.010
1998	1.051	1.025	1.001	1.036	1.052	1.023
1999	1.037	1.032	1.018	1.035	1.063	1.037
2000	1.077	1.028	1.035	1.067	1.094	1.038
2001	1.127	1.080	1.055	1.132	1.147	1.080
2002	1.125	1.139	1.074	1.161	1.173	1.103
2003	1.166	1.151	1.103	1.171	1.185	1.095
2004	1.200	1.169	1.119	1.180	1.197	1.086
2005	1.251	1.222	1.133	1.242	1.250	1.107
2006	1.275	1.266	1.151	1.247	1.266	1.119
2007	1.300	1.300	1.165	1.321	1.326	1.125
2008	1.303	1.334	1.177	1.351	1.358	1.131
2009	1.263	1.397	1.194	1.350	1.368	1.153
2010	1.325	1.443	1.204	1.401	1.415	1.165
2011	1.325	1.456	1.212	1.385	1.425	1.159
2012	1.326	1.486	1.219	1.475	1.499	1.166
2013	1.336	1.484	1.229	1.379	1.501	1.147
Gr 1996–2013	1.71%	2.32%	1.21%	1.89%	2.39%	0.81%
Gr 1996–2004	2.28%	1.95%	1.40%	2.07%	2.25%	1.03%
Gr 2004–2013	1.20%	2.65%	1.05%	1.73%	2.52%	0.61%

Source: Economic Insights EDB Database

Energy throughput grew at a similar rate to the three capacity–related measures up to 2007 but since then has grown by an average annual rate of only 0.5 per cent. The global financial crisis of led to a fall in energy throughput of 3 per cent in 2009 but this was recovered in 2010. However, since then energy throughput has remained almost stationary. This contrasts with the Australian situation where energy demand has fallen at an average annual rate of 1.1 per cent since 2008 (AER 2013a, p.20). Australia did not experience an immediate downturn due to the global financial crisis. Instead, the AER attributes the ongoing decline in electricity demand to:

- commercial and residential customers responding to higher electricity costs by reducing energy use and adopting energy efficiency measures such as solar water heating – new building regulations on energy efficiency reinforce this trend
- subdued economic growth and weaker energy demand from the manufacturing sector, and
- the continued rise in rooftop solar photovoltaic (PV) generation (which reduces demand for electricity supplied through the grid).

The AER (2013, p.21) stated that it expected growth in electricity demand to resume 'in the longer term' with a rising population and moderation of growth in electricity prices. There is thus some evidence that the change in the growth rate of electricity throughput from 2007 onwards represents a significant change in market conditions facing the energy supply industry that can be expected to continue for some years yet. Australia's maximum demand peaked in 2011 and has since fallen by around 6 per cent. New Zealand's peak demand continued rising until 2012 and has fallen by just over 6 per cent in 2013.

New Zealand EDB customer numbers have grown at an average annual rate of 1.2 per cent over the last 18 years, considerably lower than the growth in the capacity–related outputs and in energy throughput up to 2007. Again, customer numbers growth was somewhat lower in the second half of the period compared to the first.

The output component with the lowest growth rate has been circuit length which has only increased at 0.8 per cent per annum over the last 18 years. Again, this component grew more strongly up to 2002 but at a much more moderate since then.

Table 3: **Distribution industry total output quantity indexes, 1996–2013[a]**

Year	Specification #1	Specification #2	Specification #3	Specification #4	Specification #5
1996	1.000	1.000	1.000	1.000	1.000
1997	1.004	1.012	1.016	1.016	1.025
1998	1.024	1.018	1.024	1.027	1.040
1999	1.029	1.025	1.033	1.036	1.033
2000	1.040	1.050	1.058	1.053	1.068
2001	1.081	1.082	1.093	1.092	1.115
2002	1.117	1.097	1.109	1.111	1.121
2003	1.138	1.127	1.136	1.123	1.156
2004	1.159	1.147	1.155	1.131	1.183
2005	1.201	1.175	1.187	1.160	1.229
2006	1.230	1.194	1.205	1.176	1.248
2007	1.258	1.216	1.232	1.195	1.279
2008	1.277	1.228	1.247	1.207	1.288
2009	1.301	1.228	1.249	1.217	1.265
2010	1.339	1.256	1.279	1.241	1.316
2011	1.347	1.259	1.285	1.242	1.314
2012	1.363	1.272	1.304	1.258	1.330
2013	1.369	1.273	1.313	1.255	1.324
G'th 1996–2013	1.85%	1.42%	1.60%	1.34%	1.65%
G'th 1996–2004	1.84%	1.71%	1.81%	1.54%	2.10%
G'th 2004–2013	1.85%	1.16%	1.42%	1.15%	1.26%

[a] Output specification #1: Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)
Output specification #2: Energy (28%), Maximum demand (10%), Customer nos (62%)
Output specification #3: Energy (24%), Ratcheted maximum demand (23%), Customer nos (53%)
Output specification #4: Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit length (40%)
Output specification #5: Energy, Maximum demand, Customer nos – with revenue–based weights
Output cost shares in brackets
Source: Economic Insights EDB Database

From the examination of the growth rates of the six output components, we can see that output specifications that place more weight on the capacity–related components of system capacity, maximum demand and ratcheted maximum demand will have higher total output growth rates – and therefore higher productivity growth rates – than output specifications that place more weight on slow growing outputs such as customer numbers, circuit length and, since 2007, energy throughput.

The five total output quantity indexes examined are presented in table 3. Output specification #1 is that used in Economic Insights (2009a) but with updated output cost shares that now place more weight on the system capacity component. As well as system capacity, it includes energy throughput and customer numbers as output components. Approximately half the weight is placed on system capacity and a quarter on each of energy throughput and customer numbers. This output index grows at an average annual rate of a little under 1.9 per cent over the period with little variation between subperiods.

The next fastest growing output index is specification #5 which is that used in PEG (2009). It is made up of energy throughput, maximum demand and customer numbers. It places around two thirds of the weight on energy throughput due to energy charges' high share of revenue. This index grew the most rapidly up to 2008 and but has grown less rapidly since with the levelling off in electricity consumption. This index grew at an average annual rate of 1.7 per cent over the 18 year period but at 2.1 per cent up to 2004 and only 1.3 per cent after 2004.

Output index specification #3 grew at an average annual rate of 1.6 per cent over the whole 18 year period and 1.4 per cent over the last 10 years. This index places approximately half the weight on customer numbers and a quarter on each of energy throughput and ratcheted maximum demand.

Output index specification #2 comprises energy throughput, maximum demand and customer numbers with around 60 per cent of the weight on customer numbers and only 10 per cent on the faster growing maximum demand. It grew at an average annual rate of 1.4 per cent over the whole 18 year period and 1.2 per cent over the last 10 years.

The slowest growing output index over the whole period is specification #4 with an average annual growth rate of 1.3 per cent. It grew at an average annual rate of 1.2 per cent over the last decade. This specification combines four outputs (energy throughput, ratcheted maximum demand, customer numbers and circuit length) and is that used by PEGR (2013a). Although this specification contains similar component parts to the system capacity measure used in specification #1, just under 70 per cent of the weight are on the slower growing components of circuit length and customer numbers and only 30 per cent on the faster growing ratcheted maximum demand and (up to 2007) energy throughput components.

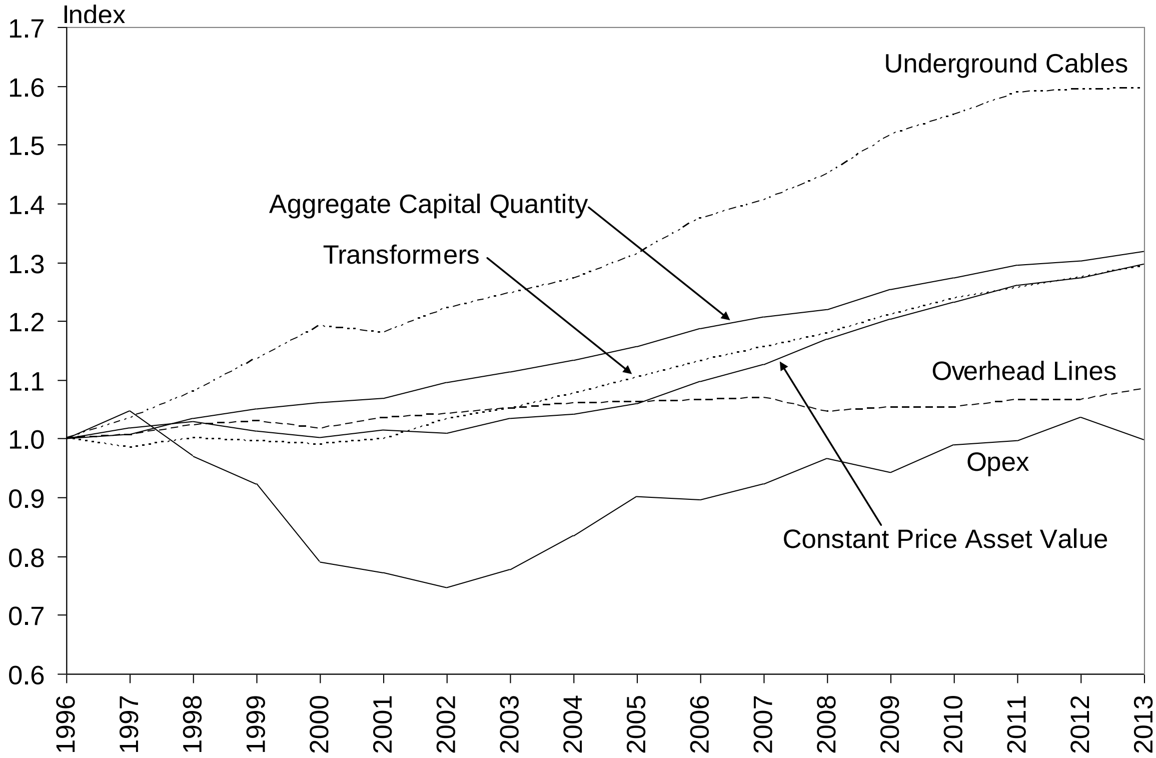
Our preferred output specifications are #1 and #4. These specifications capture the supply–side dimension of system capacity (#1) and demand–side dimension of system capacity (#4) in a functional approach to measuring EDB output. The alternative revenue–based output specification #5 produces relatively similar results to specification #1.

Input component and total input quantity indexes

We next turn to the five input measures used in this study. Economic Insights (2009a) used the quantity of opex and the quantities of three capital input components proxied by physical measures – overhead lines, underground cables and transformers. PEG (2009) used a constant price depreciated asset value measure to proxy the capital input quantity.

The five input component quantities are presented in figure 2 and table 4 in index form. The quantity of opex input declined by 25 per cent between 1996 and 2002 before growing over the rest of the period to exceed its 1996 level in 2012 before declining slightly in 2013. For the 18 year period as a whole the average annual opex growth rate was zero although this was made up of growth rate of –2.2 per cent up to 2004 and 2 per cent in the period since 2004.

Figure 2: **Distribution industry input component quantity indexes, 1996–2013**



Source: Economic Insights EDB Database

Capital input quantities have been more consistent in their growth over the 18 year period. Overhead lines quantity grew the least with an average annual growth rate of 0.5 per cent over the whole period and 0.3 per cent over the past decade. Transformer quantity grew by an average annual rate of 1.5 per cent over the whole period although this rate doubled from 0.9 per cent up to 2004 to 2 per cent since 2004. Underground cables quantity grew by far the strongest (albeit from a relatively low base) with an average annual growth rate of 2.8 per cent over the whole period.

The aggregate of the three capital input quantities (weighted by their respective amortisation annual user costs) grew at an average annual rate of 1.6 per cent with little variation between subperiods. The three components receive between 30 and 36 per cent each in the aggregation process with transformers and other capital receiving the higher weight. The alternative capital input quantity proxy of the constant price depreciated asset value grew by a similar average annual rate for the overall period but this was made up of a much lower average annual growth rate of 0.5 per cent up to 2004 and a much higher average annual growth rate of 2.4 per cent over the last decade. A similar difference in growth rates in the constant price depreciated asset value before and after 2004 was seen in PEG (2009).

Table 4: **Distribution industry input component quantity indexes, 1996–2013**

Year	Opex	Overhead	Underground	Transformers	Capital	Const. price asset value
1996	1.000	1.000	1.000	1.000	1.000	1.000
1997	1.048	1.006	1.036	0.984	1.008	1.020
1998	0.970	1.023	1.081	1.002	1.034	1.029
1999	0.924	1.030	1.136	0.995	1.052	1.014
2000	0.790	1.017	1.191	0.990	1.063	1.002
2001	0.773	1.034	1.181	1.000	1.069	1.016
2002	0.748	1.042	1.221	1.032	1.096	1.009
2003	0.778	1.052	1.246	1.051	1.114	1.036
2004	0.836	1.061	1.272	1.076	1.134	1.043
2005	0.901	1.062	1.313	1.104	1.157	1.061
2006	0.897	1.066	1.375	1.131	1.188	1.097
2007	0.923	1.070	1.405	1.156	1.207	1.127
2008	0.966	1.045	1.450	1.179	1.220	1.170
2009	0.944	1.053	1.516	1.212	1.254	1.204
2010	0.990	1.053	1.550	1.238	1.273	1.232
2011	0.997	1.065	1.589	1.256	1.295	1.261
2012	1.037	1.066	1.595	1.274	1.303	1.274
2013	0.999	1.085	1.596	1.294	1.318	1.297
Gr 1996–2013	–0.01%	0.48%	2.75%	1.52%	1.62%	1.53%
Gr 1996–2004	–2.24%	0.74%	3.00%	0.92%	1.57%	0.52%
Gr 2004–2013	1.97%	0.26%	2.52%	2.04%	1.67%	2.43%

Source: Economic Insights EDB Database

The two total input specifications outlined in section 3.2 are opex combined with each of the two capital input quantity proxies – the physical quantities aggregate in specification #1 and the constant price depreciated asset value in specification #2. The average annual growth rates in these two total input quantities are each just over 1 per cent for the whole 18 year period. However, they have slightly different patterns in the periods up to and after 2004. The physical quantities based specification #1 grew at an average annual rate for the period up to 2004 of 0.3 per cent whereas the growth rate for the constant price asset value based specification #2 was –0.4 per cent. Over the last decade, specification #2 then grew at a higher average annual rate of 2.3 per cent versus the physical quantities based specification #1 growth rate of 1.8 per cent.

Industry TFP growth rates

We now combine the total output and total input quantity indexes discussed above to form EDB industry TFP indexes. Table 5 presents TFP indexes based on the five different output specifications and using the first input specification using physical quantities to proxy the annual capital input quantity. We also present one TFP index using the fifth output specification and the second input specification using constant price depreciated asset value to proxy the annual capital input quantity.

Table 5: **Distribution industry total factor productivity indexes, 1996–2013[a]**

Year	Output#1 and Input#1	Output#2 and Input#1	Output#3 and Input#1	Output#4 and Input#1	Output#5 and Input#1	Output#5 and Input#2
1996	1.000	1.000	1.000	1.000	1.000	1.000
1997	0.983	0.990	0.994	0.994	1.003	0.996
1998	1.012	1.007	1.013	1.015	1.028	1.031
1999	1.022	1.018	1.026	1.030	1.027	1.052
2000	1.077	1.088	1.096	1.091	1.106	1.151
2001	1.123	1.124	1.134	1.134	1.158	1.198
2002	1.150	1.130	1.142	1.144	1.155	1.222
2003	1.145	1.134	1.144	1.131	1.163	1.223
2004	1.127	1.116	1.124	1.100	1.150	1.218
2005	1.126	1.102	1.112	1.087	1.152	1.222
2006	1.134	1.101	1.112	1.084	1.151	1.215
2007	1.137	1.100	1.114	1.081	1.157	1.212
2008	1.129	1.086	1.102	1.067	1.139	1.172
2009	1.138	1.074	1.092	1.064	1.106	1.137
2010	1.142	1.071	1.090	1.058	1.122	1.147
2011	1.133	1.059	1.081	1.044	1.105	1.125
2012	1.127	1.052	1.079	1.041	1.100	1.117
2013	1.136	1.056	1.090	1.041	1.099	1.111
Gr 1996–2013	0.75%	0.32%	0.51%	0.24%	0.55%	0.62%
Gr 1996–2004	1.50%	1.37%	1.46%	1.19%	1.75%	2.47%
Gr 2004–2013	0.09%	–0.61%	–0.34%	–0.61%	–0.51%	–1.03%

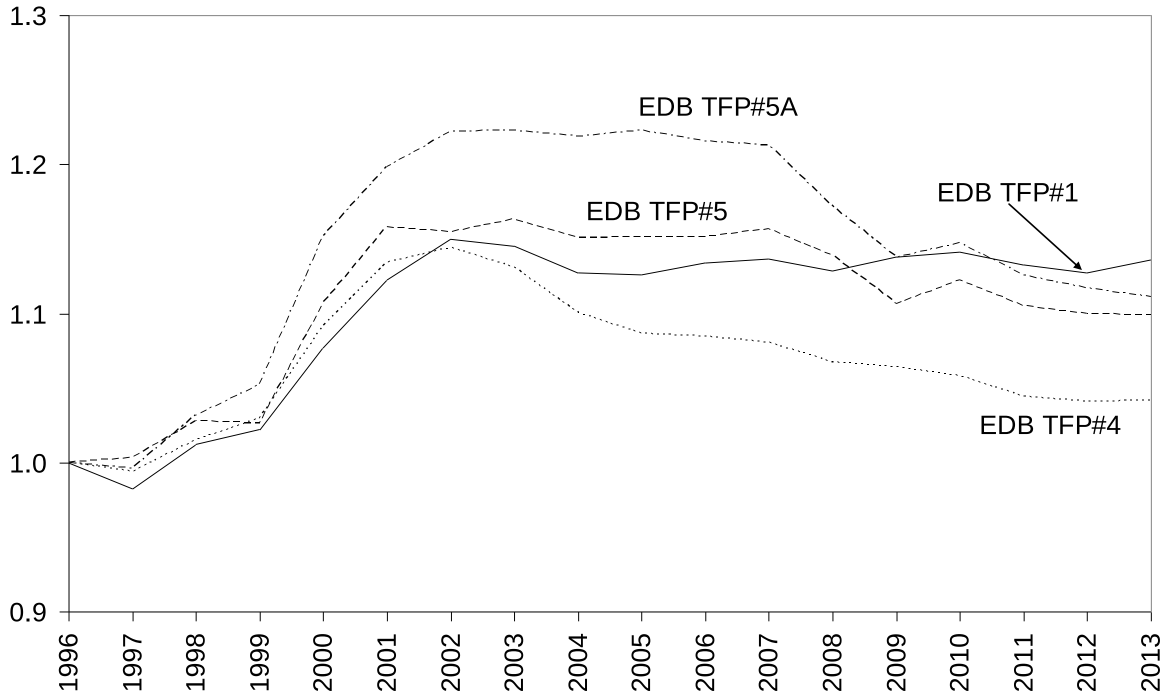
[a] Output specification #1: Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)
Output specification #2: Energy (28%), Maximum demand (10%), Customer nos (62%)
Output specification #3: Energy (24%), Ratcheted maximum demand (23%), Customer nos (53%)
Output specification #4: Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit length (40%)
Output specification #5: Energy, Maximum demand, Customer nos – with revenue–based weights
Output cost shares in brackets
Input specification #1: Opex, Overhead lines, Underground cables, Transformers and other capital
Input specification #2: Opex, Constant price depreciated asset value
Source: Economic Insights estimates

The first column of results uses the output and input specification used in Economic Insights (2009a). EDB industry TFP increased strongly up to 2004 at an average annual growth rate of 1.5 per cent but has levelled off after this to grow at an average annual rate of only 0.1 per cent over the last decade. For the 18 year period as a whole average annual TFP growth was 0.8 per cent.

The fourth column of results present the four output specification used in PEGR (2013a) which incorporates the major components of the first output specification but which also introduces a demand–side element to the system capacity component. Because our cost function estimation led to a high weight of 40 per cent being placed on the slowest growing output component of circuit length, this specification produces the lowest TFP average annual growth rate of 0.2 per cent for the 18 year period as a whole, made up of an average annual growth rate of 1.2 per cent for the period up to 2004 and of –0.6 per cent for the decade since then.

The second and third columns of TFP results lie between the first and fourth columns of results described above.

Figure 3: **Distribution industry total factor productivity indexes, 1996–2013**



[a] TFP#1: Outputs of Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%) and Inputs of Opex, Overhead lines, Underground cables, Transformers and other capital

TFP#4: Outputs of Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit length (40%) and Inputs of Opex, Overhead lines, Underground cables, Transformers and other capital

TFP#5: Outputs of Energy, Maximum demand, Customer nos with revenue–based weights and Inputs of Opex, Overhead lines, Underground cables, Transformers and other capital

TFP#5A: Outputs of Energy, Maximum demand, Customer nos with revenue–based weights and Inputs of Opex and Constant price depreciated asset value

Output cost shares in brackets
Source: Economic Insights estimates

The fifth column of TFP results is the revenue weighted output specification used in PEG (2009) but with the first input specification based on capital physical quantity proxies. This TFP index shows faster average annual growth of 1.8 per cent up to 2004 due to the high weighting given to energy throughput but then has a lower average annual growth rate of –0.5 per cent for the last decade as energy changed form being a fast growing output to one which was relatively stationary. However, overall it is relatively close to the set of results reported in the first column of the table using the Economic Insights (2009a) specification.

The first, fourth and fifth indexes from table 5 are plotted in figure 3 along with that from the last column of table 5 which uses both the output and input specifications used in Pacific Economics Group (2009). The difference between the indexes labelled TFP#5 and TFP#5A is thus the use of the constant price depreciated asset value as the proxy for capital input quantity in TFP#5A versus the use of physical capital proxies in TFP#5.

Including the constant price depreciated asset value as the proxy for capital input quantity leads to a faster growing TFP index up to around 2002, a period during which this proxy exhibits negligible growth. But it then leads to a larger fall in measured TFP from 2007 onwards when the asset value proxy starts to grow relatively rapidly compared to the more steadily growing physical proxy. So, while TFP#5 and TFP#5A finish the 18 year period at relatively similar levels, the asset value based TFP#5A initially grows quicker than but then falls faster than TFP#5. A similar pattern is observed for using the asset value capital quantity proxy instead of the physical capital quantity proxy in conjunction with the other output specifications so these are not reported separately.

Industry opex partial productivity growth rates

EDB opex partial productivity indexes and average annual growth rates are presented in table 6 for the five different output specifications.

Table 6: **Distribution industry opex partial productivity indexes, 1996–2013[a]**

Year	Specification #1	Specification #2	Specification #3	Specification #4	Specification #5
1996	1.000	1.000	1.000	1.000	1.000
1997	0.959	0.966	0.970	0.970	0.979
1998	1.055	1.050	1.056	1.058	1.072
1999	1.113	1.109	1.118	1.121	1.118
2000	1.317	1.329	1.340	1.333	1.352
2001	1.398	1.400	1.413	1.412	1.442
2002	1.493	1.467	1.482	1.485	1.499
2003	1.462	1.448	1.461	1.444	1.486
2004	1.386	1.372	1.382	1.353	1.414
2005	1.333	1.304	1.316	1.286	1.363
2006	1.371	1.330	1.343	1.310	1.391
2007	1.363	1.318	1.335	1.295	1.387
2008	1.321	1.271	1.290	1.249	1.333
2009	1.379	1.301	1.323	1.289	1.340
2010	1.353	1.269	1.292	1.254	1.330
2011	1.351	1.263	1.289	1.246	1.318
2012	1.315	1.227	1.258	1.214	1.283
2013	1.371	1.275	1.315	1.256	1.326
G'th 1996–2013	1.86%	1.43%	1.61%	1.34%	1.66%
G'th 1996–2004	4.08%	3.95%	4.04%	3.77%	4.33%
G'th 2004–2013	-0.12%	-0.82%	-0.55%	-0.82%	-0.72%

[a] Specification #1 has outputs of Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)
Specification #2 has outputs of Energy (28%), Maximum demand (10%), Customer nos (62%)
Specification #3 has outputs of Energy (24%), Ratcheted maximum demand (23%), Customer nos (53%)
Specification #4 has outputs of Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit kms (40%)
Specification #5 has outputs of Energy, Maximum demand, Customer nos – with revenue–based weights
Output cost shares in brackets
Source: Economic Insights estimates

The opex partial productivity indexes exhibit a broadly similar pattern to that of TFP except that there is faster growth in the first half of the period before a levelling off or decline over the last decade, depending on the output specification used. Because opex declined substantially between 1996 and 2002 while total input use only declined by a small amount over the same period, opex partial productivity average annual growth rates are in the range of approximately 4 per cent for the period up to 2004 while TFP growth rates were only around 1.5 per cent for this period. For the period since 2004, opex partial productivity average annual growth using output specification #1 (as used in Economic Insights 2009a) was –0.1 per cent or effectively flat. Average annual opex partial productivity growth rates using the other four output specifications were all in the range –0.6 to –0.8 per cent for the past decade.

Industry capital partial productivity growth rates

Table 7: **Distribution industry capital partial productivity indexes, 1996–2013[a]**

Year	Specification #1	Specification #2	Specification #3	Specification #4	Specification #5
1996	1.000	1.000	1.000	1.000	1.000
1997	0.996	1.004	1.008	1.008	1.017
1998	0.990	0.984	0.990	0.992	1.005
1999	0.978	0.974	0.982	0.985	0.982
2000	0.979	0.988	0.996	0.991	1.005
2001	1.012	1.013	1.022	1.022	1.043
2002	1.019	1.001	1.011	1.013	1.023
2003	1.021	1.012	1.020	1.008	1.037
2004	1.022	1.011	1.019	0.997	1.043
2005	1.038	1.016	1.025	1.002	1.062
2006	1.036	1.005	1.015	0.990	1.051
2007	1.042	1.008	1.021	0.990	1.060
2008	1.046	1.006	1.021	0.989	1.055
2009	1.038	0.979	0.996	0.970	1.009
2010	1.052	0.986	1.004	0.975	1.033
2011	1.040	0.973	0.993	0.959	1.015
2012	1.046	0.976	1.001	0.965	1.020
2013	1.039	0.966	0.996	0.952	1.005
G'th 1996–2013	0.22%	–0.20%	–0.02%	–0.29%	0.03%
G'th 1996–2004	0.27%	0.14%	0.23%	–0.04%	0.52%
G'th 2004–2013	0.18%	–0.51%	–0.25%	–0.52%	–0.41%

[a] Specification #1 has outputs of Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)
Specification #2 has outputs of Energy (28%), Maximum demand (10%), Customer nos (62%)
Specification #3 has outputs of Energy (24%), Ratcheted maximum demand (23%), Customer nos (53%)
Specification #4 has outputs of Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit kms (40%)
Specification #5 has outputs of Energy, Maximum demand, Customer nos – with revenue–based weights
Output cost shares in brackets
Source: Economic Insights estimates

EDB capital partial productivity indexes and average annual growth rates are presented in table 7 for the five different output specifications using the physical quantities proxy for capital input quantity.

The capital partial productivity indexes have generally had less movement away from their initial values than have the opex partial productivities. Capital partial productivity average annual growth rates are in the range of 0.2 to –0.3 per cent for the whole 18 year period. For the period up to 2004, the range of capital partial productivity average annual growth rates was zero to 0.5 per cent and over the last decade it has been 0.2 to –0.5 per cent. Using output specification #1 (as used in Economic Insights 2009a) the capital partial productivity average annual growth rate has generally been in the 0.2 to 0.3 per cent range. Average annual opex partial productivity growth rates using the other capital input quantity proxy of the constant price depreciated asset value are similar for the period as a whole but slightly higher for the period up to 2004 and slightly lower for the period since.

4.3 Non–exempt distribution productivity growth

Non–exempt distribution accounted for around 80 per cent of electricity distribution industry throughput, maximum demand and customer numbers in 2013. It accounted for just over 80 per cent of the industry's underground cable length but just under 70 per cent of its overhead line length.

Non–exempt EDB output has grown slightly less fast than distribution industry output over both the last 18 years and the last decade with an average annual growth rate of around 0.2 per cent less than that for the industry as a whole using the output specification used in Economic Insights (2009a). However, non–exempt input use has grown at an average annual rate of around 0.3 less than that for the industry over the same periods. This has led to non–exempt TFP average annual growth being around 0.1 per cent higher than that for the industry as a whole.

Non–exempt TFP indexes and growth rates for the five different output specifications and two input specifications are reported in table 8. Taking an average across the six TFP indexes reported, non–exempt average annual TFP growth is around 0.2 per cent higher for the non–exempt EDBs than it is for the industry as a whole across each of the three time periods reported.

Non–exempt EDB opex partial productivity indexes and average annual growth rates are reported in table 9 for each of the five output specifications used in this report. The average difference between non–exempt and distribution industry growth rates across the five opex partial productivity measures is around 0.1 per cent.

Although not presented in tabular form, non–exempt capital partial productivity grew at an average annual rate of 0.2 per cent higher than that for the distribution industry as a whole across the different partial productivity measures and each of the time periods examined.

The non–exempt EDBs in aggregate have thus exhibited marginally stronger TFP and partial productivity growth across each of the three time periods examined – 1996 to 2013, 1996 to 2004 and 2004 to 2013 – than has the distribution industry as a whole. However, the difference in growth rates is not large and decisions regarding the setting of the X factor and what opex partial productivity growth rate to use in forming opex forecasts for the next regulatory period should be relatively robust to whether results for the industry as a whole or non–exempt EDBs in aggregate are used.

Table 8: **Non–exempt EDB total factor productivity indexes, 1996–2013[a]**

Year	Output#1 and Input#1	Output#2 and Input#1	Output#3 and Input#1	Output#4 and Input#1	Output#5 and Input#1	Output#5 and Input#2
1996	1.000	1.000	1.000	1.000	1.000	1.000
1997	0.977	0.986	0.991	0.991	0.997	0.984
1998	1.007	1.009	1.017	1.016	1.029	1.037
1999	1.016	1.023	1.033	1.032	1.027	1.071
2000	1.084	1.108	1.118	1.109	1.122	1.187
2001	1.130	1.144	1.157	1.155	1.175	1.228
2002	1.169	1.157	1.172	1.175	1.179	1.259
2003	1.163	1.165	1.177	1.162	1.187	1.248
2004	1.138	1.141	1.152	1.124	1.171	1.241
2005	1.129	1.120	1.134	1.107	1.168	1.242
2006	1.144	1.126	1.139	1.110	1.173	1.239
2007	1.149	1.128	1.146	1.112	1.183	1.247
2008	1.145	1.120	1.140	1.104	1.169	1.203
2009	1.158	1.109	1.131	1.106	1.134	1.169
2010	1.164	1.108	1.131	1.103	1.154	1.182
2011	1.155	1.100	1.125	1.090	1.140	1.160
2012	1.151	1.093	1.124	1.087	1.138	1.149
2013	1.153	1.098	1.137	1.087	1.134	1.139
Gr 1996–2013	0.84%	0.55%	0.76%	0.49%	0.74%	0.76%
Gr 1996–2004	1.61%	1.65%	1.76%	1.46%	1.97%	2.70%
Gr 2004–2013	0.15%	–0.42%	–0.14%	–0.37%	–0.36%	–0.96%

[a] Output specification #1: Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)
Output specification #2: Energy (28%), Maximum demand (10%), Customer nos (62%)
Output specification #3: Energy (24%), Ratcheted maximum demand (23%), Customer nos (53%)
Output specification #4: Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit length (40%)
Output specification #5: Energy, Maximum demand, Customer nos – with revenue–based weights
Output cost shares in brackets
Input specification #1: Opex, Overhead lines, Underground cables, Transformers and other capital
Input specification #2: Opex, Constant price depreciated asset value
Source: Economic Insights estimates

Table 9: **Non–exempt EDB opex partial productivity indexes, 1996–2013[a]**

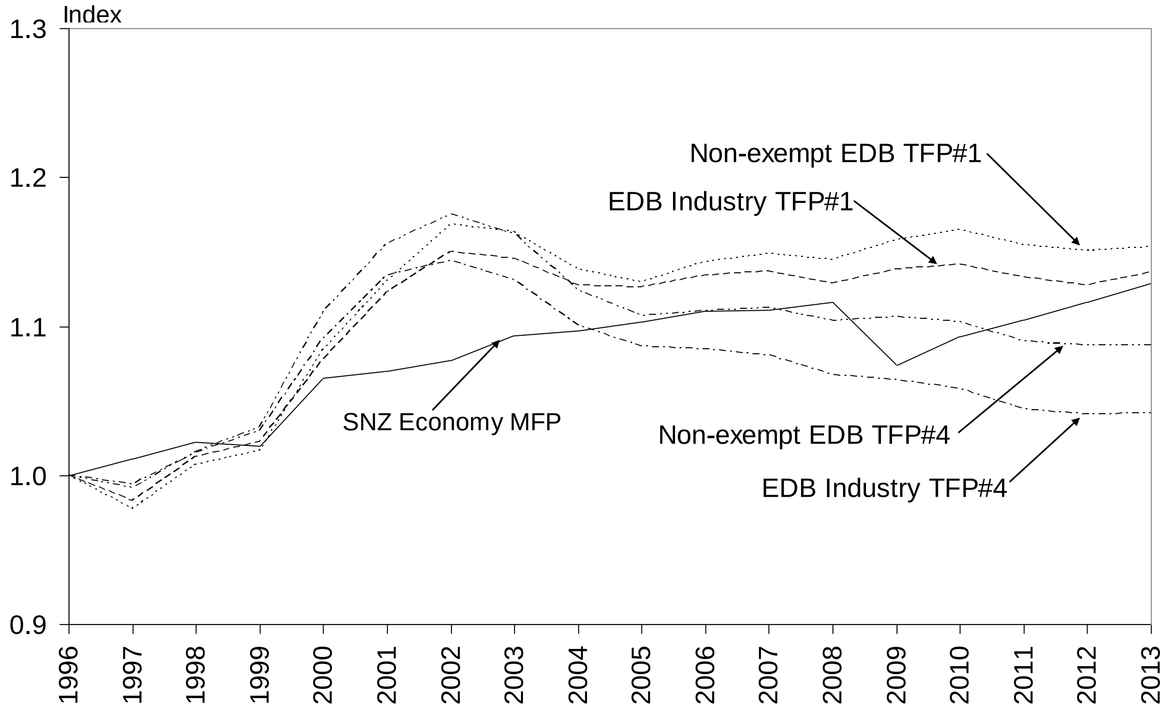
Year	Specification #1	Specification #2	Specification #3	Specification #4	Specification #5
1996	1.000	1.000	1.000	1.000	1.000
1997	0.944	0.952	0.957	0.958	0.963
1998	1.051	1.053	1.061	1.060	1.073
1999	1.108	1.116	1.126	1.126	1.120
2000	1.356	1.386	1.399	1.387	1.404
2001	1.405	1.422	1.439	1.436	1.461
2002	1.535	1.520	1.540	1.544	1.549
2003	1.502	1.504	1.520	1.500	1.532
2004	1.390	1.394	1.407	1.374	1.431
2005	1.315	1.304	1.320	1.290	1.360
2006	1.367	1.345	1.362	1.327	1.402
2007	1.377	1.353	1.374	1.333	1.419
2008	1.333	1.305	1.328	1.285	1.362
2009	1.419	1.360	1.386	1.356	1.390
2010	1.394	1.327	1.354	1.321	1.382
2011	1.387	1.321	1.351	1.309	1.370
2012	1.332	1.266	1.301	1.259	1.317
2013	1.374	1.309	1.355	1.296	1.351
G’th 1996–2013	1.87%	1.58%	1.79%	1.52%	1.77%
G’th 1996–2004	4.12%	4.15%	4.27%	3.97%	4.48%
G’th 2004–2013	-0.13%	-0.70%	-0.42%	-0.65%	-0.64%

[a] Specification #1 has outputs of Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)
Specification #2 has outputs of Energy (28%), Maximum demand (10%), Customer nos (62%)
Specification #3 has outputs of Energy (24%), Ratcheted maximum demand (23%), Customer nos (53%)
Specification #4 has outputs of Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit kms (40%)
Specification #5 has outputs of Energy, Maximum demand, Customer nos – with revenue–based weights
Output cost shares in brackets
Source: Economic Insights estimates

Non–exempt EDB TFP, distribution industry TFP and economy market sector multifactor productivity (MFP) are plotted in figure 4. TFP#1 is the three output specification used in Economic Insights (2009a) but with updated output cost share weights and TFP#4 is the four output specification used by PEGR (2013a). The four electricity distribution TFP indexes all increase faster than economy–wide MFP in the period from 1996 to 2002.

In the decade since 2004, the economy–wide MFP has increased at an average annual growth rate of 0.3 per cent while TFP#1 has increased at an average annual rate of 0.2 per cent for non–exempt EDBs and 0.1 per cent for the distribution industry as a whole. Over the same period TFP#4, which places a high weight on the slowest growing EDB output of circuit length has grown at an average annual rate of –0.4 per cent for non–exempt EDBs and –0.6 per cent for the distribution industry as a whole.

Figure 4: **Non–exempt, industry and economy TFP indexes, 1996–2013[a]**



[a] TFP#1: Outputs of Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%) and Inputs of Opex, Overhead lines, Underground cables, Transformers and other capital

TFP#4: Outputs of Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit length (40%) and Inputs of Opex, Overhead lines, Underground cables, Transformers and other capital

Output cost shares in brackets
Source: Economic Insights estimates and SNZ (2014)

Over the 18 year period as a whole, economy–wide MFP has grown at an average annual rate of 0.71 per cent while TFP#1 for non–exempt EDBs has grown at 0.84 per cent and for the distribution industry as a whole at 0.75 per cent. Corresponding average annual growth rates for TFP#4 were 0.5 per cent and 0.2 per cent, respectively. The average annual growth rates for the other TFP specifications considered in this report all lie within the range of those observed for TFP#1 and TFP#4.

4.4 Overseas EDB productivity growth

It is useful to compare the trend TFP growth rates presented in this report with comparable results that have been presented for overseas jurisdictions. This provides a worthwhile means identifying any anomalies. The Act also states that the Commission can draw on information on EDB productivity growth from comparable countries in setting the rate of change of prices.

Australian EDBs present a ready point of comparison for NZ EDBs. However, there have been no Australian EDB productivity studies published since those reported in Economic Insights (2009a). The AER is currently undertaking an extensive data collection and economic benchmarking exercise which will likely include EDB productivity growth results. At the time of preparation of this report, the Australian EDB results are not publicly available. However, as noted in section 4.2, Australian energy throughput and maximum demands have both declined significantly from their peaks around 2009. Combined with increases in both opex and capex allowances included in recent regulatory reviews, this means Australian EDB productivity is more likely to have declined than improved over the last several years.

PEGR (2013a,b) has recently reported productivity growth results for the Ontario electricity distribution industry. These results are of particular interest since the Ontario industry shares many features with the New Zealand industry including a large number of EDBs made up of a small number of larger EDBs and many small to very small EDBs. The methodology used to measure productivity growth in PEGR (2013a,b) is also broadly similar to that used in the current study. For the period 2002 to 2012 PEGR (2013b) found that the Ontario electricity distribution industry had an average annual TFP growth rate of –0.3 per cent. Excluding the year 2012 which was thought to be influenced by a number of data reporting changes, the average annual TFP growth rate for 2002 to 2011 was still only 0.2 per cent. These growth rates are of similar magnitude to those obtained in the current study.

While less comparable to New Zealand, evidence on recent productivity growth for the United States electricity distribution industry is mixed. PEGR (2013c) reports average annual TFP growth rates for US EDBs in different parts of the country ranging from 0.6 per cent to 1.1 per cent for the period 2002 to 2011 and average annual opex partial productivity growth rates of around 1.5 per cent. However, while a report by Makholm, Ros and Case (2011) reported an average annual TFP growth rate of 0.9 per cent based on a sample of 72 US EDBs over a nearly 40 year period, the average annual TFP growth rate over the decade to 2009 (the most recent year reported) was around –1.1 per cent.

There is limited comparable information on productivity growth rates available for United Kingdom EDBs. However, recently Oxera (2013, p.6) found that ‘the net ongoing efficiency achieved by the DNOs [distribution network operators] in recent years has not been statistically significant, indicating that the technology (net of any input price inflationary effects) has been largely constant’. This would be consistent with a zero growth rate for EDB TFP, assuming the EDBs were operating efficiently.

Our review of studies of the recent productivity performance of EDBs in countries broadly comparable to New Zealand finds that reported EDB productivity growth rates are generally similar to those found in the current study although there is some evidence of ongoing positive productivity growth in the more mature US industry in recent years.

4.5 Input price growth

The remaining components of equation (2) from section 3.2 we require information on are the input price growth terms for the electricity distribution industry and the economy as a whole. As demonstrated in Economic Insights (2009b), where industry assets have sunk cost characteristics the appropriate industry input price term is the cost share weighted sum of the change in the opex price and unit changes in amortisation charges. The amortisation charges used in this study have been calculated on the basis of ex ante financial capital maintenance as would be found in building blocks regulation.

We adopt the same approach to measuring electricity distribution industry and economy–wide input prices as that used in Economic Insights (2009a). Relevant indexes are presented in table 10.

Table 10: **Distribution industry and economy–wide input price indexes, 1996–2013**

	Electricity Distribution Industry				Economy–Wide		
Year	Opex	EW CGPI	Amortisation	Total Inputs	LCI	CGPI	Total Inputs
1996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1997	1.012	1.001	1.008	1.009	1.020	1.000	1.012
1998	1.020	1.012	1.022	1.021	1.043	0.991	1.023
1999	1.029	1.037	1.027	1.028	1.062	0.991	1.035
2000	1.049	1.063	1.015	1.025	1.077	1.000	1.047
2001	1.090	1.096	1.028	1.046	1.095	1.035	1.073
2002	1.125	1.108	1.048	1.071	1.116	1.060	1.096
2003	1.143	1.115	1.060	1.084	1.141	1.071	1.114
2004	1.160	1.131	1.089	1.110	1.167	1.086	1.136
2005	1.190	1.169	1.100	1.127	1.195	1.127	1.169
2006	1.238	1.229	1.134	1.165	1.231	1.161	1.205
2007	1.292	1.294	1.188	1.219	1.270	1.205	1.246
2008	1.350	1.340	1.250	1.280	1.311	1.235	1.282
2009	1.431	1.407	1.301	1.340	1.359	1.284	1.331
2010	1.436	1.441	1.355	1.379	1.386	1.306	1.356
2011	1.473	1.489	1.409	1.428	1.410	1.303	1.368
2012	1.512	1.579	1.479	1.489	1.438	1.311	1.387
2013	1.538	1.606	1.513	1.520	1.464	1.324	1.408
Gr 96–13	2.53%	2.79%	2.44%	2.46%	2.24%	1.65%	2.01%
Gr 96–04	1.85%	1.54%	1.07%	1.31%	1.93%	1.03%	1.59%
Gr 04–13	3.13%	3.90%	3.65%	3.49%	2.52%	2.20%	2.39%

Source: Economic Insights EDB Database and Statistics New Zealand

For the economy as a whole we form a total input price index by aggregating the SNZ LCI for all salaries and wages for all industries and the capital goods price index using labour and capital shares given in the productivity growth accounting table of SNZ (2009). This approach is based on the assumption that depreciation rates and real opportunity cost rates remained constant over time for the economy so that changes in user costs can be proxied by the change in the all groups CGPI. While not ideal, we feel this approach provides a better approximation than alternative approaches such as assuming that the change in economy–wide input prices can be approximated by the sum of changes in economy–wide MFP and the consumer price index. The latter approximation is also impacted significantly by the reduction in economy–wide MFP growth in 2009 following the global financial crisis.

We form the overall input price index for the electricity distribution industry by aggregating the opex price described in section 3.3 and the amortisation price of capital. To be consistent with the sunk cost nature of electricity distribution assets while also allowing for ex ante FCM, we use the amortisation price for capital inputs rather than the traditional user cost formula. We do this by dividing the distribution industry amortisation values for pre–tax amortisation by the capital quantity index. The capital quantity index was formed by aggregating overhead lines MVA–kilometres, underground cable MVA–kilometres and transformer kVAs using the shares of the three capital inputs in the 2004 ODV given in the 2008 IDD. For the industry as a whole these shares are around 30 per cent for overhead lines, 34 per cent for underground cables and 36 per cent for transformers and other capital. The difference in trend growth rates between the industry amortisation price and the user cost–based price reflects the fact that the amortisation price is based on actual expenditure whereas the user cost–based price is based on the replacement price of all assets and, hence, largely on expenditure which is not actually incurred. To give an idea of the difference between the two approaches, we also present the Electrical works CGPI in table 10.

From table 10 we see that average annual growth rate in EDB opex prices has been around 0.3 per cent higher than that for the economy–wide increase in labour prices over the 18 year period as a whole. However, for the period up to 2004, EDB opex price growth was marginally less than economy–wide labour price growth. This early pattern has reversed over the last decade where EDB opex prices have had a higher average annual growth rate than economy–wide labour prices by 0.6 per cent. A similar pattern has been observed in Australia where EGW labour price growth has increased in recent years as utilities have had to compete to retain field staff who possess skills in demand by the rapidly expanding mining industry (see Economic Insights 2013b, p.57).

A more marked gap has emerged between average annual price growth rates for capital inputs between the distribution industry and economy as a whole. There was negligible difference in the growth rates between the industry and the economy as a whole up to 2004. However, in the decade since 2004, electricity distribution amortisation prices have grown by nearly 1.5 per cent annually on average more than the economy–wide CGPI. The difference is more marked if we look at the Electrical works CGPI which has in turn increased annually by around 0.3 per cent more than the amortisation price over the last decade on average. A likely reason for this difference is the civil construction intensive nature of electricity distribution assets compared to the more machinery and equipment intensive nature of the market sector of the economy as a whole. Machinery and equipment price increases have been moderated by the ongoing reduction in the effective price of greater computerisation of machinery and equipment manufacture and of machinery and equipment itself. By comparison, the price of poles and wires assets, in particular, is more influenced by raw materials prices and construction labour costs.

Overall, while there was a gap of less than 0.3 per cent between average annual total input price growth for the distribution industry and the economy as a whole in the nine years up to 2004, this has widened to 1.1 per cent for the last decade.

5 RECOMMENDATIONS

The objective of this report has been to provide information to inform the Commission's decisions regarding the 2014 default price–quality path reset. The reset will involve either resetting EDB starting prices taking account of current and future profitability or, alternatively, rolling over the prices applying in the last year of the preceding regulatory period. If prices are reset, this will be done by the application of the building blocks methodology. The information contained in this report relevant to the application of building blocks is:

- the long–run productivity growth rate for the electricity distribution industry, and
- opex and capital partial productivity growth rates for the electricity distribution industry.

If prices are rolled over from the last year of the preceding regulatory period, the Commission has indicated that the rate of change of prices will be determined using information on productivity and input price differentials between the electricity distribution industry and the economy as a whole. This is the approach generally used in productivity–based regulation.

Our recommendations on the relevant components for the building blocks and productivity–based approaches are presented in the following sections.

5.1 Building blocks component recommendations

X Factor

As described in section 2.2, in building blocks the starting prices and the rate of change (or X factor) are set as a pair to equate the net present values of forecast revenue and forecast costs (or the 'revenue requirement'). Changes in the X factor would be offset by changes in starting prices to maintain this equality. While there is an infinite number of starting price and X factor combinations that will achieve this equality, the Act states that the X factor should be based on the long run productivity improvement achieved by EDBs in New Zealand and/or comparable countries.

As shown in section 4.4, EDB productivity growth rates in New Zealand have been broadly similar to those found in comparable countries such as Canada, those likely to be found in Australia and those reported in larger countries such as the US and the UK. Consequently, we concentrate on New Zealand productivity growth rates in this section.

The next issue to resolve is what time period constitutes the 'long run'. We have observations for New Zealand spanning the past 18 years. Normally one would seek as long a time period as possible to form an estimate of a long run growth rate. This implicitly assumes that growth occurs and continues in a linear fashion and that there are no fundamental underlying changes occurring. However, productivity growth may not be linear and may instead converge over time to a given (lower) rate. This could occur if inefficiencies relative to current technological possibilities are progressively eliminated so that productivity growth eventually becomes constrained by the rate of underlying technical change. And significant changes in underlying market conditions may lead to a change or 'break' in the achievable rate of productivity growth.

There is some evidence from a range of comparable countries that a significant change in market conditions facing the energy supply industry has occurred recently. In New Zealand electricity throughput grew at an average annual rate of 2.4 per cent between 1996 and 2007 but since 2007 it has grown at less than 0.5 per cent. While the global financial crisis reduced demand for electricity in 2009, it recovered in 2010 but has remained virtually static since then. In Australia, electricity demand reversed in 2008 and has fallen at an average annual rate of 1.1 per cent since then. A similar pattern has been observed in Ontario (PEGR 2013a,b). Maximum demand also peaked in Australia in 2009 and has fallen in New Zealand in 2013.

The AER (2013, p.20) has attributed this reversal of electricity demand to higher prices, more energy efficient appliances and, importantly, more energy efficient buildings, and the increasing penetration of rooftop solar PV panels. In the US, Barclay's Bank has cautioned utility investors with the following[5]:

> 'In the 100+ year history of the electric utility industry, there has never before been a truly cost–competitive substitute available for grid power. Over the next few years, however, we believe that a confluence of declining cost trends in distributed solar photovoltaic (PV) power generation and residential-scale power storage is likely to disrupt the status quo. … The cost of solar plus storage for residential consumers is already competitive with the price offered by the traditional utility grid in Hawaii. … The sun–drenched states of California and Arizona are only a couple of years behind, as is solar friendly New York.'

The AER (2013, p.21) does, however, expect that electricity demand will return to positive growth as electricity price rises moderate and population growth continues. It is forecasting a considerably reduced annual growth rate of 1.3 per cent over the next decade.

The average annual productivity growth rates obtained in this study are presented in table 11.

Table 11: **Distribution industry productivity growth rates, 1996–2013, per cent pa[a]**

	1996–2013	1996–2004	2004–2013
TFP			
Using Output#1 and Input#1	0.75%	1.50%	0.09%
Using Output#4 and Input#1	0.24%	1.19%	–0.61%
Opex Partial Productivity			
Using Output#1	1.86%	4.08%	–0.12%
Using Output#4	1.34%	3.77%	–0.82%
Capital Partial Productivity			
Using Output#1	0.22%	0.27%	0.18%
Using Output#4	–0.29%	–0.04%	–0.52%

[a] Output specification #1 has Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)
Output specification #4 has Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit kms (40%)
Input specification #1: Opex, Overhead lines, Underground cables, Transformers and other capital
Output cost shares in brackets
Source: Economic Insights estimates

[5] Cited in ABC News, *Technology, not regulation, will kill coal fired power*, http://www.abc.net.au/news/2014-06-04/technology-not-regulation-will-kill-coal-fired-power/5500356

Using the three–output specification used in Economic Insights (2009a), electricity distribution industry TFP grew at an average annual rate of 1.5 per cent up to 2004 but at only 0.1 per cent in the decade since. Using the four–output specification used in PEGR (2013a), TFP grew at an average annual rate of 1.2 per cent up to 2004 but at –0.6 per cent in the decade since. The corresponding average annual growth rates for the 18–year period are 0.8 per cent and 0.2 per cent, respectively. The TFP growth rates for the other three output specifications examined in this report lie between those for these two specifications.

We are of the view that a significant change in market conditions facing the energy supply industry has occurred since around 2007 with a reduced growth rate in demand which has now lasted for 6 years and which seems to be separate from the short term effects of the global financial crisis. This change has also been observed in Australia, Canada and the US. While the TFP specification used in our 2009 report points to marginally positive TFP growth over the past decade, the other five specifications examined point to negative TFP growth rates with the specification used in PEG (2009) pointing to a TFP growth rate of –1 per cent.

Our view is that an estimated TFP growth rate of zero is a reasonable choice for the current long run productivity growth rate and, hence, the X factor for the next regulatory period. While five of the six TFP specifications we have examined have pointed to a negative TFP growth rate for the last decade, there is also some expectation from experts, including the AER and the Australian Energy Market Operator (AEMO), that positive electricity demand growth will resume, albeit at a reduced rate compared to the period before 2007. This is likely to contribute to a return to positive TFP growth in the electricity distribution industry in the medium term. We also note that PEGR (2013b, p.5) concluded that 'a negative productivity factor would not be appropriate' for the Ontario electricity distribution industry for several reasons despite an average annual growth rate of –0.3 per cent having been found for the period 2002 to 2012. A productivity factor of zero in the price cap was instead recommended.

Opex partial productivity growth

The other important productivity component in the building blocks approach is the rate of opex productivity growth to include in rolling forward the opex component of the revenue requirement. The Commission (2014a) has indicated it intends to roll opex forward by the sum of the forecast growth rate in opex prices plus the forecast growth rate in output (or scale effects) minus the forecast growth rate in opex partial productivity.

From table 11 we see that a similar situation exists with electricity industry opex partial productivity as with TFP. There was very strong average annual growth in opex partial productivity of around 4 per cent from 1996 to 2004 resulting from both stronger output growth and significant reductions in opex. In the past decade, however, opex partial productivity average annual growth has been in the range of –0.1 to –0.8 per cent as output growth has slowed and opex quantities have grown strongly.

As was the case with overall productivity, our view is that it would be reasonable to use an opex partial productivity growth rate of zero in forming the opex component of the building blocks revenue requirement. The Commission also used a zero opex partial productivity growth rate in its previous reset. Since then, electricity demand has been relatively flat and lower growth rates are likely to continue for some time. From figure 2 we see that opex quantity growth has moderated since 2005 and declined somewhat in 2013.

An opex partial productivity growth rate of zero would strike the appropriate balance between recognising the apparent changed circumstances facing electricity distribution over the last decade while anticipating a return to more positive output growth, albeit reduced compared to the period before 2007, while providing an incentive for efficiency improvements.

Capital partial productivity growth

While capital partial productivity is unlikely to be used in the building blocks approach (which focuses on capex whereas productivity measurement only provides overall capital stock productivity information), from table 11 we see that capital partial productivity has shown less variation than either TFP or opex partial productivity. Over the past decade estimates of the average annual capital partial productivity growth rate range from 0.2 to –0.5 per cent. Since we are recommending zero as the appropriate rate for both TFP and opex partial productivity forecasts, it follows that the capital partial productivity forecast is also zero.

5.2 Productivity–based regulation recommendations

If the Commission opts to roll over EDB prices from the last year of the preceding regulatory period, it has indicated it will do so using a productivity regulation based approach to setting the X factor. The formula for the X factor taking account of sunk costs and financial capital maintenance was given in equation (2) and is repeated here for convenience:

(6) $X \equiv [\Delta TFP - \Delta TFP_E] - [\Delta W - \Delta W_E]$

= TFP differential growth rate term – input price differential growth rate term.

where the industry capital price included is the unit amortisation charge.

Productivity growth differential

The first term in (6) involves the difference in TFP growth rates between the electricity distribution industry and the economy. In this report we have examined a number of different specifications for industry TFP growth and the range in the resulting productivity growth differentials is presented in table 12.

Table 12: **Industry productivity growth differentials, 1996–2013, per cent pa[a]**

	Industry TFP average growth	Market sector MFP average growth	Productivity growth differential
TFP using Output#1 and Input#1			
1996–2013	0.75%	0.71%	0.04%
2004–2013	0.09%	0.32%	–0.23%
TFP using Output#4 and Input#1			
1996–2013	0.24%	0.71%	–0.47%
2004–2013	–0.61%	0.32%	–0.93%

[a] Output specification #1 has Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)
Output specification #4 has Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit kms (40%)
Input specification #1: Opex, Overhead lines, Underground cables, Transformers and other capital
Output cost shares in brackets
Source: Economic Insights estimates

Using the electricity distribution industry TFP specification used in Economic Insights (2009a), the productivity growth differential relative to the economy–wide MFP growth rate is zero for the 18 year period to 2013 and –0.2 per cent for the last decade. Using the four–output specification used in PEGR (2013a), the productivity growth differential is –0.5 for the 18 year period to 2013 and –0.9 per cent for the last decade. The productivity differentials using the other three output specifications examined in this report lie within the range described above. If we use non–exempt EDB results rather than distribution industry results, the four productivity differentials lie in the range of 0.1 per cent to –0.7 per cent.

It should be noted that the calculations in table 12 bias the productivity differential downwards as the industry measure is a gross TFP measure while the economy–wide MFP measure is net or value added–based productivity measure. A gross productivity measure has materials and services inputs in the denominator along with labour and capital inputs. A net productivity measure, on the other hand, deducts materials and services inputs from output in numerator and has only labour and capital in the denominator. All else equal, a net productivity measure will always produce a higher productivity growth rate than the corresponding gross productivity measure. This is because the net measure has a smaller denominator which produces a higher rate of change.

Input price growth differential

Turning to the input price growth difference between the electricity distribution industry and the economy, input price growth rates are presented for the electricity distribution industry and the economy in table 13. The derivation of these price indexes was described in section 4.5.

Table 13: **Input price growth differentials, 1996–2013, per cent pa**

	Industry input price average growth	Market sector input price average growth	Input price growth differential
1996–2013	2.46%	2.01%	0.45%
2004–2013	3.49%	2.39%	1.10%

Source: Economic Insights estimates

For the period from 1996 to 2004, economy–wide input prices grew somewhat more rapidly than those for the electricity distribution industry. However, this situation has reversed over the last decade with electricity distribution industry input price growth having exceeded that for the economy. Distribution industry opex prices increased by 0.6 per cent more than economy–wide labour prices and distribution capital prices increased by nearly 1.5 per cent more than those for the economy as a whole. EDBs have had to pay more to retain their field staff in recent years and the civil construction–oriented nature of distribution capital means the industry has gained less from computerisation cost savings than have industries which use a higher proportion of machinery and equipment instead of structures. Overall, the input price differential has been around 0.5 per cent on average for the last 18 years and around 1.1 per cent for the past decade.

X factor

For the reasons outlined in section 5.1, we believe that a significant change in market conditions facing the energy supply industry occurred around 2007 and the short to medium term prospects for productivity growth are less strong than previously. This points to forming the X factor based on growth over the past decade rather than growth over the whole 18 year period. However, we expect productivity growth to resume, albeit at a reduced rate, in the medium term. We also noted above that the productivity measure available for the economy will lead to an overstatement of the productivity growth differential. Consequently, we believe a productivity growth differential of zero is a conservative choice for the next regulatory period. However, input price pressures the distribution industry has faced recently are likely to continue for some time although at likely reduced rates as competition for labour from other sectors reduces which should dampen both opex and capital construction price increases. Based on this we believe an input price differential – and, therefore, an X factor – of –1 per cent is appropriate.

Table 13: **Derived X factors, 1996–2008, per cent per annum**[a]

	Productivity growth differential	Input price growth differential	X factor
TFP using Output#1 and Input#1			
1996–2013	0.04%	0.45%	–0.41%
2004–2013	–0.23%	1.10%	–1.33%
TFP using Output#4 and Input#1			
1996–2013	–0.47%	0.45%	–0.92%
2004–2013	–0.93%	1.10%	–2.03%

[a] Output specification #1 has Energy (23%), System capacity (kVA*kms) (47%), Customer nos (30%)
Output specification #4 has Energy (15%), Ratcheted maximum demand (18%), Customer nos (26%), Circuit kms (40%)
Input specification #1: Opex, Overhead lines, Underground cables, Transformers and other capital
Output cost shares in brackets
Source: Economic Insights estimates

The full range of X factors considered is presented in table 13.

APPENDIX A: THE DATABASE USED

Table A1: **Electricity distribution industry database, 1996–2013**

Year	Distribution Revenue	Energy	System Capacity	Customer Nos	Maximum Demand	Ratcheted Max Demand
	$m	GWh	GVA*kms (000s)	No (000s)	MW	MW
1996	697	22,088	1,570	1,499	4,072	4,072
1997	782	22,778	1,560	1,499	4,190	4,224
1998	822	23,206	1,610	1,500	4,218	4,283
1999	697	22,911	1,620	1,526	4,214	4,328
2000	837	23,796	1,610	1,551	4,344	4,455
2001	885	24,903	1,690	1,581	4,610	4,670
2002	927	24,858	1,790	1,610	4,728	4,777
2003	923	25,761	1,800	1,653	4,767	4,825
2004	920	26,499	1,830	1,677	4,806	4,874
2005	981	27,634	1,920	1,697	5,057	5,089
2006	1,022	28,154	1,980	1,724	5,078	5,153
2007	1,092	28,722	2,040	1,745	5,381	5,398
2008	1,173	28,775	2,090	1,764	5,501	5,529
2009	1,242	27,904	2,190	1,790	5,497	5,568
2010	1,322	29,277	2,260	1,805	5,704	5,761
2011	1,363	29,271	2,280	1,816	5,637	5,803
2012	1,421	29,280	2,330	1,827	6,005	6,105
2013	1,510	29,520	2,330	1,842	5,615	6,112

Table A1: **Electricity distribution industry database, 1996–2013 (cont'd)**

Year	Circuit Length kms	Notional Rev Fixed $m	Notional Rev Energy $m	Notional Rev Demand $m	Opex $m	Opex Price Index	Overhead Lines GVAkms
1996	119,859	217	808	166	286	1.000	423
1997	121,101	214	836	169	303	1.012	426
1998	122,655	213	853	170	283	1.020	433
1999	124,253	216	842	173	272	1.029	436
2000	124,438	218	875	181	237	1.049	431
2001	129,490	222	915	199	241	1.090	438
2002	132,204	225	914	204	240	1.125	441
2003	131,200	250	943	182	254	1.143	445
2004	130,196	253	969	227	277	1.160	449
2005	132,642	255	1,011	238	307	1.190	449
2006	134,145	259	1,029	237	317	1.238	451
2007	134,827	261	1,051	252	341	1.292	453
2008	135,551	263	1,053	261	373	1.350	443
2009	138,236	275	1,048	259	386	1.431	446
2010	139,683	277	1,108	274	406	1.436	446
2011	138,862	279	1,109	270	420	1.473	451
2012	139,809	280	1,111	287	448	1.512	451
2013	137,526	282	1,119	272	439	1.538	460

Year	Underground Cables GVAkms	Transformers MVA	AUC Overhead $m	AUC Underground $m	AUC Transf'rs & Other $m	Const Price Asset Value 2014$'000
1996	50	13,078	156	177	187	5,034
1997	51	12,866	159	180	190	5,132
1998	54	13,100	165	187	198	5,179
1999	56	13,015	169	191	202	5,103
2000	59	12,946	168	191	202	5,043
2001	59	13,072	171	194	206	5,113
2002	61	13,502	179	203	215	5,081
2003	62	13,751	184	209	221	5,213
2004	63	14,077	193	218	231	5,250
2005	65	14,438	199	225	238	5,339
2006	68	14,797	210	238	252	5,523
2007	70	15,115	224	253	268	5,672
2008	72	15,424	238	270	286	5,891
2009	75	15,845	255	289	305	6,059
2010	77	16,193	269	305	323	6,202
2011	79	16,431	285	322	341	6,349
2012	79	16,660	301	341	361	6,413
2013	79	16,920	311	353	373	6,531

Table A2: **Non–exempt electricity distribution database, 1996–2013**

Year	Distribution Revenue	Energy	System Capacity	Customer Nos	Maximum Demand	Ratcheted Max Demand
	$m	GWh	GVA*kms (000s)	No (000s)	MW	MW
1996	563	18,046	905	1,196	3,264	3,264
1997	635	18,504	898	1,196	3,383	3,407
1998	674	18,795	912	1,194	3,413	3,463
1999	550	18,489	914	1,219	3,413	3,504
2000	680	19,231	906	1,240	3,515	3,605
2001	718	20,188	956	1,264	3,769	3,816
2002	761	20,124	1,020	1,289	3,859	3,897
2003	762	20,756	1,020	1,326	3,888	3,931
2004	762	21,437	1,030	1,341	3,918	3,965
2005	815	22,401	1,080	1,355	4,143	4,165
2006	846	22,791	1,110	1,377	4,124	4,194
2007	907	23,195	1,140	1,391	4,386	4,400
2008	945	23,076	1,160	1,406	4,469	4,493
2009	988	22,142	1,220	1,425	4,475	4,518
2010	1,057	23,382	1,260	1,437	4,612	4,660
2011	1,080	23,350	1,260	1,446	4,544	4,684
2012	1,121	23,336	1,290	1,454	4,876	4,952
2013	1,176	23,493	1,270	1,465	4,524	4,957

Table A2: **Non–exempt electricity distribution database, 1996–2013 (cont'd)**

Year	Circuit Length kms	Notional Rev Fixed $m	Notional Rev Energy $m	Notional Rev Demand $m	Opex $m	Opex Price Index	Overhead Lines GVAkms
1996	84,661	166	611	141	227	1.000	285
1997	85,646	165	628	143	244	1.012	287
1998	85,639	164	638	145	223	1.020	288
1999	86,801	166	627	149	214	1.029	290
2000	87,136	168	652	155	180	1.049	285
2001	91,287	170	685	173	189	1.090	289
2002	93,748	173	683	177	185	1.125	290
2003	92,647	198	700	155	195	1.143	293
2004	91,546	199	722	199	217	1.160	296
2005	93,680	201	755	210	244	1.190	296
2006	94,553	204	767	207	249	1.238	298
2007	95,218	205	781	221	263	1.292	299
2008	95,354	207	775	228	287	1.350	284
2009	98,028	217	767	227	291	1.431	290
2010	99,318	219	821	237	306	1.436	289
2011	98,180	220	820	235	316	1.473	293
2012	98,791	221	821	251	342	1.512	292
2013	96,711	223	825	237	336	1.538	297

Year	Underground Cables GVAkms	Transformers MVA	AUC Overhead $m	AUC Underground $m	AUC Transf'rs & Other $m	Const Price Asset Value 2014$'000
1996	45	10,687	107	156	148	4,019
1997	46	10,482	111	162	154	4,127
1998	48	10,649	114	167	158	4,080
1999	50	10,525	114	166	157	3,944
2000	53	10,402	112	164	156	3,889
2001	52	10,473	115	169	160	3,953
2002	53	10,847	120	175	166	3,927
2003	54	11,002	125	182	173	4,066
2004	55	11,209	130	190	180	4,083
2005	56	11,483	134	195	185	4,147
2006	58	11,752	141	206	195	4,279
2007	59	12,016	150	219	207	4,366
2008	60	12,199	158	232	219	4,525
2009	63	12,475	169	247	234	4,652
2010	65	12,728	179	261	247	4,759
2011	65	12,852	188	275	261	4,861
2012	65	13,010	199	291	275	4,908
2013	64	13,178	205	300	284	4,987

APPENDIX B: DERIVING OUTPUT COST SHARE WEIGHTS

This study uses a multi–output Leontief cost function to estimate output cost shares, using a similar procedure to that used in Lawrence (2003). This functional form essentially assumes that EDBs use inputs in fixed proportions for each output and is given by:

(B1) $$C(y^t, w^t, t) = \sum_{i=1}^{M} w_i^t \, [\sum_{j=1}^{N} (a_{ij})^2 \, y_j^t \, (1 + b_i t)]$$

where there are M inputs and N outputs, 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 requires the use of non–linear regression methods. To conserve degrees of freedom a common rate of technological change for each input across the three outputs was imposed but this can be either positive or negative.

The estimating equations were the M input demand equations:

(B2) $$x_i^t = \sum_{j=1}^{N} (a_{ij})^2 \, y_j^t \, (1 + b_i t)$$

where the i's represent the M inputs, the j's the N outputs and t is a time trend representing the 18 years, 1996 to 2013.

The input demand equations were estimated separately for each of the 24 EDBs using the non–linear regression facility in Shazam (Northwest Econometrics 2007) and data for the years 1996 to 2013. Given the absence of cross equation restrictions, each input demand equation is estimated separately. Autocorrelation is also corrected for.

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

(B3) $$h_j^t = \{\sum_{i=1}^{M} w_i^t \, [(a_{ij})^2 \, y_j^t \, (1 + b_i t)]\} / \{\sum_{i=1}^{M} w_i^t \, [\sum_{j=1}^{N} (a_{ij})^2 \, y_j^t \, (1 + b_i t)]\} .$$

We then form a weighted average of the estimated output cost shares for each observation to form an overall estimated output cost share where the weight for each observation, b, is given by:

(B4) $$s_b^t = C(b, y_b^t, w_b^t, t) / \sum_{b,t} C(b, y_b^t, w_b^t, t) .$$

APPENDIX C: THE FISHER INDEX

Mathematically, the Fisher ideal output quantity index is given by:

(C1) $Q_F^t = [(\sum_{i=1}^m P_i^B Y_i^t / \sum_{j=1}^m P_j^B Y_j^B)(\sum_{i=1}^m P_i^t Y_i^t / \sum_{j=1}^m P_j^t Y_j^B)]^{0.5}$

where: Q_F^t is the Fisher ideal output quantity 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 either three or four outputs depending on the output specification (so m = 3 or m = 4) and 18 years (so t = 1, …, 18).

Similarly, the Fisher ideal input quantity index is given by:

(C2) $I_F^t = [(\sum_{i=1}^n W_i^B X_i^t / \sum_{j=1}^n W_j^B X_j^B)(\sum_{i=1}^n W_i^t X_i^t / \sum_{j=1}^n W_j^t X_j^B)]^{0.5}$

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

W_i^B is the price of the ith input for the base observation;

X_i^t is the quantity of the ith input for observation t;

W_i^t is the price of the ith input for observation t; and

X_j^B is the quantity of the jth input for the base observation.

In this case we have either four or two inputs depending on the input specification (so n = 4 or n = 2) and 18 years (so t = 1, …, 18).

The Fisher ideal TFP index is then given by:

(C3) $TFP_F^t = Q_F^t / I_F^t$.

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:

(C4) $Q_F^{1,t} = 1 \times Q_F^{1,2} \times Q_F^{2,3} \times .... \times Q_F^{t-1,t}$.

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