X Factor Recommendations for New Zealand Electricity Distribution Price Controls

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Economic and Litigation Consulting

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1. INTRODUCTION AND SUMMARY

1.1 Introduction

The electricity distribution businesses (EDBs) in New Zealand are subject to Part 4 of the Commerce Act 1986 (The Act), as amended by the Commerce Amendment Act 2008. The Act specifies that default/customized price paths will apply to all EDBs that are not defined as consumer-owned. The default price-quality path (DPP) establishes initial prices, quality standards, and a rate of change in allowed prices for a multi-year period. An EDB can also apply for a customized price path, if it believes an alternative customized path is needed to satisfy its particular circumstances. The Commerce Commission (the Commission) must set a DPP that will take effect from April 1, 2010.

The DPP must comply with a number of requirements specified in the legislation. In particular, Paragraph 53P of the Act says that:

- The Commission must set only one rate of change in prices for each type of regulated service (subsection five), unless the Commission decides that an alternative rate of change is needed to minimize undue financial hardship to the supplier or price shock to consumers, or as an incentive for a supplier to improve its quality of supply (subsection eight)
- The rate of change must be based on the long-run average productivity improvement achieved by suppliers operating in the industry in New Zealand, or by suppliers in comparable countries (subsection six)
- The selected rate of change may take into account the effects of inflation in the prices of inputs used by suppliers in the industry (subsection seven)

In its Discussion Paper, the Commission noted that it must use productivity analysis when setting the X factor, but also wrote that “the Commission should not mechanistically apply the results from any analytical technique such as TFP. Rather, it should use the results of the analysis to inform its thinking, with those results given appropriate weight in light of other relevant considerations," such as current economic conditions.[1]

Pacific Economics Group (PEG) was hired by New Zealand's Electricity Networks Association (ENA) to advise on an appropriate value for the X factor in the rate of change formula. Our recommendation was to be consistent with the Act's requirements that the rate of change be based on long-run productivity improvement in the industry, as well as consider the effects of input price inflation. Information on total factor productivity (TFP) was also translated into an X factor recommendation using the B-factor formula that was established in the previous thresholds regime.[2]

One of PEG's main tasks was to obtain the most objective measure of the EDBs' TFP trend. In addition, PEG carefully analyzed the TFP and input price research with an eye towards developing an X factor recommendation that was best supported by the available evidence and the broader economic climate. This work had two complementary goals. The first was to set objective bounds on a reasonable range for the X factor, where the bounds were based directly on the results of rigorous empirical research. Second, we assessed the impact of recent industry and broader economic trends which should inform the Commission's thinking and appropriate exercise of regulatory discretion in choosing a particular X factor from within the X factor range. We believe this approach is generally consistent with the views presented in the Discussion Paper on how best to utilize the results of productivity analysis.

PEG has ample experience advising energy utilities and regulators on these topics. We are North America's leading provider of energy industry productivity studies. Our personnel have estimated TFP trends for numerous North American clients and testified many times on productivity research. We advised Powerco during the establishment of the previous thresholds regime and testified on behalf of New Zealand's gas distributors and Telecom New Zealand in other proceedings before the Commission. Since 2004, PEG has also prepared a series of five TFP reports for the EDBs in Victoria Australia.

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[1] Commerce Commission, *Reset of Default Price Quality Path for Electricity Distributors Discussion Paper*, June 19 2009, p. 82.

[2] This approach is also supported in the Commission's *Discussion Paper* (*e.g.* p. v), although that Paper also does discuss potential modifications to that formula. These modifications which will be addressed in a separate PEG document.

We first estimated the Victorian EDBs' TFP growth over the 1995-2003 period, and these results have been updated annually to roll in new data for the 2004, 2005, 2006 and 2007 years (with a further update to take place in 2009). In addition to our work in Australia and New Zealand (ANZ), the US and Canada, PEG has advised on appropriate X factors in a variety of diverse jurisdictions including the UK, Germany, Jamaica, Mexico and Bolivia.

Following a brief summary of the study, our report is organized as follows:

- Chapter Two presents details on the data and indexing methods used to develop TFP and related index-based results
- Chapter Three presents the results of our TFP and related indexes for NZ's electricity distribution industry as a whole
- Chapter Four reports multi-factor productivity (MFP) and CPI data from Statistics New Zealand and uses these data to compute TFP and input price trends for the New Zealand economy
- Chapter Five summarizes our main findings and X factor recommendation
- There are also two appendices that provide further details that support the reasonableness of PEG's TFP specification, particularly for CPI-X applications. The first concerns the output quantity specification. The second discusses the merits of financial versus physical capital measures

1.2 Summary of Results

1.2.1 Total Factor Productivity

A TFP index is the ratio of an output quantity index to an input quantity index. The growth trend of a TFP trend index is the difference between the trends in output and input quantity indexes. The TFP index developed for this study measured the TFP growth trend for New Zealand's electricity distribution industry. Our output quantity index measures trends in the number of customers served, total volumes delivered, and (non-coincident) peak demands of New Zealand's EDBs. Our input quantity index summarizes trends in the amounts of capital and operation and maintenance (O&M) inputs that the EDBs used.

1.2.2 TFP and Input Price Research for EDBs

We calculated the TFP trend for New Zealand's EDBs using Tornqvist indices. The sample period was 1999-2008. We estimate that the EDBs' TFP grew at an average annual rate of 1.21% over the 1999-2008 period. Output quantity grew at an average rate of 2.27% per annum. This exceeded the input quantity trend of 1.07% per annum.

Within the input quantity index, capital inputs grew at an average annual rate of 1.75% per annum over the sample period. O&M inputs, by contrast, declined at an average annual rate of 0.97% per annum. This measured decline in O&M inputs stems entirely from the substantial O&M cost savings the EDBs registered in the first two years of the sample. Since 2001, O&M input quantity has increased at an average annual rate of 2.97%.

In fact, all of the EDBs' TFP growth over the 1999-2008 period resulted from cost cutting between 1999 and 2001. TFP has declined slightly, at a 0.08% annual rate, between 2001 and 2008. This TFP decline has also accelerated over time, primarily because of the growth in capital investment since 2005.

PEG also computed industry input price indexes. We estimate that industry input prices grew at an average rate of 3.73% over the 1999-2008 period. Capital input prices increased by 4.08% per annum over this period, while O&M input prices increased at an average rate of 2.71% per annum.

1.2.3 TFP and Input Price Research for the NZ Economy

PEG also examined data on MFP trends developed by Statistics New Zealand (StatsNZ). The StatsNZ data show that MFP for the broadest available measure of the New Zealand economy grew by 1.09% over the same 1999-2008 period that PEG used to estimate the EDBs' TFP trend. This value is essentially identical to the MFP growth rate for the 1978-2008 period and to the NZ MFP estimate used in the B Factor in the previous thresholds regime. However, StatsNZ also reports that the New Zealand economy began a new economic cycle in 2000, and that MFP "series are of most value when analyzed from the peak of one cycle to the peak of another."[3] Given the worldwide

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[3] Statistics New Zealand, *Productivity Statistics: 1978-2008*, 13 March 2009, p. 2.

recession that began in late 2008, there is a very high probability that 2008 will prove to be the "peak" of New Zealand's current business cycle. The latest peak to peak TFP trend for the NZ economy would therefore be computed for the 2000-2008 period. StatsNZ reports that NZ MFP grew by an average of 0.55% over this period. The most recent information may therefore imply that the long-run MFP trend of the NZ economy is only about half of the value that was used to calculate the previous B factor.

The input price trend for the NZ economy is equal to inflation in the NZ economy plus the long-run trend in NZ MFP. Annual growth in the NZ CPI averaged 2.71% over the 1999-2008 period and 2.72% over the 2000-2008 period. If we use 1.09% as the long-run MFP trend of the New Zealand economy, the long-run input price trend for the economy is equal to 1999-2008 average CPI inflation of 2.71% plus 1.09%, or 3.80% per annum. In contrast, if we use the more modest 0.55% estimate for long-run MFP growth, the current input price trend for the NZ economy is equal to 2000-2008 CPI inflation of 2.72% plus 0.55%, or 3.27% per annum.

1.2.4 X Factor Recommendations

The formula for the X factor is equal to the sum of the TFP differential and the input price differential. The TFP differential is equal to the growth in industry TFP minus the growth in economy-wide TFP. The input price differential is equal to the economy-wide input price trend minus the industry input price trend.

Given the available information, a reasonable estimate of the EDBs' long-run TFP trend can be computed over two possible sample periods. The first is 1999-2008. This represents all available information since the EDBs were created as stand-alone distribution utilities. The alternative is 2001-2008. This is reasonable since industry TFP growth in 1999-2001 appears to be anomalous and, indeed, is responsible for all the EDBs' TFP gains over the entire nine-year period. It is widely agreed that estimates of long-run TFP trends should not be distorted by structural or regulatory changes that lead to a one-time "burst" of TFP gains that are unlikely to be repeated. The creation of stand-alone distribution entities in 1998 and 1999 was in fact a significant structural change for New Zealand's electricity distribution industry, and this change apparently led to a burst of TFP growth over the 1999-2001 period. The best estimate of the EDBs's long-run TFP growth should arguably exclude these one-time TFP gains and be measured over a period beginning in 2001.

As discussed, there are also two reasonable estimates of New Zealand's economy-wide MFP trend. The first is 1.1%, which is equal to the growth in New Zealand MFP over the 1999-2008 period and over the longer 1978-2008 period. A 1.1% economy-wide MFP trend was also used to estimate the previous B factor. The second possible estimate is 0.55%. While this is half of the previously estimated long-run MFP trend, it does represent the TFP growth inherent in the country's most recent business cycle measured on a peak to peak basis. It may also be reasonable to expect the New Zealand MFP trend to slow during the term of the reset DPP, especially given the current economic conditions.

Since there are two reasonable estimates for both the industry and economy-wide TFP trends, it follows that there are four possible estimates of the TFP differential:

1) the 1999-2008 industry TFP trend of 1.21% minus the 1999-2008 NZ MFP trend of 1.09%; this would lead to an estimated TFP differential of 0.12% (*i.e.* 1.21% - 1.09% = 0.12%).
2) the 1999-2008 industry TFP trend of 1.21% minus the 2000 -2008 NZ MFP trend of 0.55%; this would lead to an estimated TFP differential of 0.66% (*i.e.* 1.21% - 0.55% = 0.66%).
3) the 2001-2008 industry TFP trend of -0.08% minus the 1999-2008 NZ MFP trend of 1.09%; this would lead to an estimated TFP differential of -1.17% (*i.e.* -0.08% - 1.09% = -1.17%).
4) the 2001-2008 industry TFP trend of -0.08% minus the 2000-2008 NZ MFP trend of 0.55%; this would lead to an estimated TFP differential of -0.63% (*i.e.* -0.08% - 0.55% = -1.17%).

Input price trends for the industry and the economy can also be computed for each of the four options above. The input price differential can then be calculated as the difference between the growth trends in economy-wide and industry input prices. The associated input price trends and differentials would be as follows:

1) the 1999-2008 NZ input price trend of 3.80% minus the 1999-2008 industry input price trend of 3.73%; this would lead to an estimated input price differential of 0.07% (*i.e.* 3.80% - 3.73% = 0.07%).
2) the 2000-2008 NZ input price trend of 3.27% minus the 1999-2008 industry input price trend of 3.73%; this would lead to an estimated input price differential of -0.46% (*i.e.* 3.27% - 3.73% = -0.46%).
3) the 1999-2008 NZ input price trend of 3.80% minus the 2001-2008 industry input price trend of 2.05%; this would lead to an estimated input price differential of 1.75% (*i.e.* 3.80% - 2.05% = 1.75%).
4) the 2000-2008 NZ input price trend of 3.27% minus the 2001-2008 industry input price trend of 2.05%; this would lead to an estimated input price differential of 1.22% (*i.e.* 3.27% - 2.05% = 1.22%).

The latter two options lead to estimates of industry input price inflation that are more than 1% per annum below economy-wide input price inflation trends. We do not believe these estimates are plausible in the current environment. Indeed, a number of factors (including rising prices for many construction materials, a relatively aging workforce and shortage of new laborers in ANZ for many electricity distribution jobs) make it far more likely that input price inflation for the EDBs will exceed aggregate input price trends. These and related factors have led Australian regulators to conclude that input price growth for energy utility industries will exceed CPI inflation. Because input price differentials greater than 1% are highly unlikely during the term of the DPP, PEG does not believe these scenarios can be used to develop reasonable X factor recommendations.

However, we do believe that a reasonable value for the input price differential is zero. This is equivalent to the value that was approved in the previous thresholds regime. An input price differential of zero is arguably more reasonable for the reset DPP in light of the current, extraordinarily uncertain economic conditions. Broader macroeconomic conditions will have a significant impact on how aggregate consumer prices and EDB input prices change over the term of the DPP. Given the current uncertainties, policymakers should exercise considerable caution when extrapolating what may be the most recent economic data into the future.

PEG therefore believes that zero is a reasonable value for the input price differential, and this conclusion expands the range of scenarios that should be considered when developing X factor recommendations. In particular, a zero input price differential can reasonably be assumed for each of the four TFP differentials that were presented above. Doing so leads to four additional scenarios regarding TFP and input price information that could be used to develop an X factor recommendation. PEG therefore believes that our research and assessment leads to the following eight specific options for developing an X factor for the DPP:

1) a TFP differential of 0.12%, computed as the 1999-2008 industry TFP trend of 1.21% minus the 1999-2008 NZ MFP trend of 1.09%; plus an input price differential of .07%, equal to the 1999-2008 NZ input price trend of 3.80% minus the 1999-2008 industry input price trend of 3.73%; this would lead to an X factor of 0.19% (*i.e.* 0.12% + .07% = 0.19%).
2) a TFP differential of 0.66%, computed as the 1999-2008 industry TFP trend of 1.21% minus the 2000-2008 NZ MFP trend of 0.55%; plus an input price differential of -0.46%, equal to the 2000-2008 NZ input price trend of 3.27% minus the 1999-2008 industry input price trend of 3.73%; this would lead to an X factor of 0.20% (*i.e.* 0.66% - 0.46% = 0.20%).
3) a TFP differential of -1.17%, computed as the 2001-2008 industry TFP trend of -0.08% minus the 1999-2008 NZ MFP trend of 1.09%; plus an input price differential of 1.75%, equal to the 1999-2008 NZ input price trend of 3.80% minus the 2001-2008 industry input price trend of 2.05%; this would lead to an X factor of 0.58% (*i.e.* -1.17% + 1.75% = 0.58%).
4) a TFP differential of -0.63%, computed as the 2001-2008 industry TFP trend of -0.08% minus the 2000-2008 NZ MFP trend of 0.55%; plus an input price differential of 1.22%, equal to the 2008-2008 NZ input price trend of 3.27% minus the 2001-2008 industry input price trend of 2.05%; this would lead to an X factor of 0.59% (*i.e.* -0.63% + 1.22% = 0.59%).

5) a TFP differential of 0.12%, computed as the 1999-2008 industry TFP trend of 1.21% minus the 1999-2008 NZ MFP trend of 1.09%; plus an input price differential of zero; this would lead to an X factor of 0.12%.
6) a TFP differential of 0.66%, computed as the 1999-2008 industry TFP trend of 1.21% minus the 2000-2008 NZ MFP trend of 0.55%; plus an input price differential of zero; this would lead to an X factor of 0.66%.
7) a TFP differential of -1.17%, computed as the 2001-2008 industry TFP trend of -0.08% minus the 1999-2008 NZ MFP trend of 1.09%; plus an input price differential of zero; this would lead to an X factor of -1.17%.
8) a TFP differential of -0.63%, computed as the 2001-2008 industry TFP trend of -0.08% minus the 2000-2008 NZ MFP trend of 0.55%; plus an input price differential of zero; this would lead to an X factor of -0.63%.

The Commission has said that it will use the results of TFP studies to inform its judgment on setting appropriate X factors. Our TFP and input price research supports a range of values for the X factor, or objective bounds on an appropriate value of X that are based directly on the results of rigorous empirical research. The upper bound for the X factor that can be supported using existing evidence is 0.66% (option six); the lower bound for the X factor that can be supported using existing evidence is -1.17% (option seven).

Further analysis can further reduce the range of X factors that should be considered for the DPP. In particular, we believe that carefully considering the components of the X factor computations implies that some of these combinations are unlikely during the term of the DPP. For example, PEG believes that generally sluggish economic conditions are likely to persist over the term of the DPP, which lends more support to 0.55% (rather than 1.09%) as the best measure of New Zealand's long-term TFP trend. If the economy remains sluggish, it will be very difficult for the EDBs to increase TFP at a rate greatly exceeding the -0.08% achieved over the 2001-08 period (in part because output growth will slow). This implies that Options Two and Six - which are based on an acceleration of industry TFP to 1.21% at the same time that the economy is sluggish and experiences 0.55% TFP – are implausible. PEG therefore believes that these options should be eliminated from the computation of the reasonable X factor range.

On the other hand, it is possible that the economy may experience a robust recover over the term of the DPP. If so, economy-wide TFP growth rates may be closer to the 1.09% trend. But if the economy's TFP accelerates due to broader economic recovery, this recovery may also lead to somewhat more rapid output and TFP growth for the EDBs as well. This implies that Options Seven and Three – where the EDBs' TFP growth remains 0.08% per annum while the economy's TFP accelerates to 1.09% annual growth – are also implausible. PEG believes these options should be eliminated from the computation of the reasonable X factor range as well.

As discussed, PEG believes input price differentials in excess of 1% are implausible. If anything, pressures on input prices for the EDBs are likely to be greater than those of the overall economy, due to a relative scarcity of labor in the EDB sector and perhaps greater acceleration in materials prices. Option Four assumes an input price differential of 1.22%, so PEG believes this option should be eliminated as well.

This analysis leads to three remaining X factor options: Option One, Option Five and Option Eight. The upper bound for this X factor range is 0.19% (Option One); the lower bound is -0.63% (Option Eight). PEG therefore recommends an X factor between 0.19% and -0.63% for the DPP.

We note that a negative X factor is perfectly consistent with the theory of incentive regulation and a number of recent CPI-X regulatory decisions. A negative X should not be interpreted as evidence that NZ's electricity distribution industry is becoming "less efficient;" it simply means that the inputs that are needed for EDBs to provide service have been growing more rapidly than their outputs. This trend has been particularly evident since 2005, when output growth has generally slowed while the pace of capital investment accelerated. If these trends are expected to continue, then TFP will decline at an even more rapid rate than has been the case since 2001. This would argue for an X factor towards the lower end of the reasonable range.

2. DATA AND METHODOLOGICAL ISSUES

This chapter presents an overview of the data and methods used to calculate TFP and related trends for New Zealand's EDBs. We begin by discussing data issues. We then provide a relatively non-technical discussion of the methods employed for index calculation.

2.1 Data

2.1.1 Data Sources

The primary source of data used in our productivity research is each EDB's Information Disclosure data supplemented with data extracted from threshold compliance statements. These compliance statements are published by EDBs to demonstrate compliance with regulatory price and quality thresholds. The raw data used in our TFP estimates has been compiled by PricewaterhouseCoopers (PwC) from these data sources. PwC provided this data to PEG. It should be noted that, during the sample period, United Networks was sold to Vector, Unison and Powerco. Because it was impossible to determine from available data what assets, cost and outputs of United Networks were allocated to the purchasing companies, we aggregated the data for all four of these EDBs and treated it as a consolidated entity over the entire sample period.

PEG also relied on MFP, CPI and capital goods price data collected by Statistics New Zealand. These data are clearly used to develop the economy-wide components of both the TFP differential and input price differential. PEG also used the CPI and capital goods price index in the computation of the industry input price index, as explained further in Section 2.3.2.

2.1.2 Choices and Definitions of Outputs and Inputs

The growth in the output quantity index was a weighted average of growth in three output quantity subindexes: the number of customers, total delivery volumes (GWh), and non-coincident demands (GW). These output choices correspond to the billing determinants for the EDBs, or the services which actually generate the EDBs' allowed revenues. As explained in Appendix One, these billing determinants are the appropriate choices for outputs in a TFP study that is used to set CPI-X price controls.

PEG also used the associated revenues (*e.g.* fixed customer charges for number of customers) to weight the respective output when aggregating into a comprehensive output index. These revenue shares were updated annually for each EDB, which leads to a "chain weighted" output quantity index. In CPI-X indexing applications, it is appropriate to weight each determinant by its revenue shares, for reasons that are discussed further in Appendix One. In practice, however, revenue data for specific outputs are often not available, and in these instances it is appropriate to use proxies such as relative cost elasticities to weight outputs.

We divided inputs into two categories: operation and maintenance (O&M) expenses and capital inputs. While it would have been desirable to divide O&M further into labor and non-labor inputs, reliable time series on EDBs' labor expenses were not available. We describe the measurement of input costs and quantities in section 2.3.2.

2.2 Indexing Methods

PEG calculated TFP using the Törnqvist index form.[4] PEG and many other researchers have used Törnqvist indices to estimate TFP growth. With the Törnqvist form, the annual growth rate of the input quantity index is determined by the formula:

$$\ln\left(\mathit{Input\ Quantities}_t \big/ \mathit{Input\ Quantities}_{t-1} \right) = \sum_j \frac{1}{2} \cdot \left(S_{j,t} + S_{j,t-1} \right) \cdot \ln\left(X_{j,t} \big/ X_{j,t-1} \right). \qquad [1]$$

Here in each year *t*,

$\mathit{Input\ Quantities}_t$ = Input quantity index

$X_{j,t}$ = Input quantity subindex for input category *j*

$S_{j,t}$ = Share of input category *j* in applicable total cost.

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[4] The Tornqvist is one of two "superlative" index forms that are used in most productivity research; the other is the Fisher Ideal form. In practice, these two forms typically lead to almost identical TFP index results, as Economic Insights has acknowledged in its most recent reports to the Commission.

It can be seen that the growth rate of the index is a weighted average of the growth rates of the quantity subindexes. Each growth rate is calculated as the logarithm of the ratio of the quantities in successive years.

With the Törnqvist form, the annual growth rate of the output quantity index is determined by the formula:

$$\ln\left(\frac{Output\ Quantities_t}{Output\ Quantities_{t\text{-}1}} \right) = \sum\nolimits_j \ \frac{1}{2}\cdot\left(S_{k,t}+S_{k,t-1}\right)\cdot\ln\left(\frac{Y_{k,t}}{Y_{k,t-1}} \right). \qquad [2]$$

Here in each year *t*,

$Output\ Quantities_t$ = Output quantity index

$Y_{k,t}$ = Output quantity subindex for output category *k*

$S_{k,t}$ = Share of input category *k* in applicable total revenue.

In both instances, it can be seen that the growth rate of the index is a weighted average of the growth rates of the quantity subindexes. Each growth rate is calculated as the logarithm of the ratio of the quantities in successive years. For the output quantity index, weights are equal to the share of each quantity subindex’s share of electricity distribution revenues. For the input quantity indexes, weights are equal to the average shares of each input in the aggregate applicable total cost of sampled distributors during these years.

The annual growth rate in the TFP index is given by the formula

$$\begin{aligned}\ln\left(\frac{TFP_t}{TFP_{t-}} \right) = \ln\left(\frac{Output\ Quantities_t}{Output\ Quantities_{t\text{-}1}} \right) - \\ \ln\left(\frac{Input\ Quantities_t}{Input\ Quantities_{t\text{-}1}} \right)\end{aligned} . \qquad [3]$$

We estimated TFP trends for New Zealand’s EDBs for the 1999-2008 period. Since the index formulas involve annual growth rates, some method is needed to calculate trends from the annual growth rates. The trend in each TFP index was computed using the formula

$$trend\ TFP_t = \frac{\sum_{t\ 1999}^{2008} \ln\left({TFP_t}/{TFP_{t-1}} \right)}{9} = \frac{\ln\left({TFP_{2008}}/{TFP_{1999}} \right)}{9} \qquad [4]$$

It can be seen that the trend is the average annual growth rate during the years of the sample period. The reported trends in other indexes that appear in this report are computed analogously.

2.3 Indexing Details

2.3.1 Scope

The applicable total cost of electricity distribution was calculated as power distribution O&M expenses plus the cost of plant ownership. O&M cost figures were drawn directly from the Information Disclosure Statements. Capital cost was determined using a capital service price methodology. Under this approach, the cost of capital is the product of a capital quantity index and the price of capital services. This method has a solid basis in economic theory and is well established in the scholarly literature.

2.3.2 Input Quantity and Price Subindexes

The input quantity index was constructed as a weighted average of input quantity subindexes for capital and O&M inputs. Growth in each input quantity subindex must be expressed in real, inflation-adjusted terms. Each input quantity subindex must therefore be "deflated" by an associated input price subindex.

The approach to quantity trend measurement taken in each case relies on the theoretical result that the growth rate in the cost of any class of input *j* is the sum of the growth rates in appropriate input price and quantity indexes for that input class. Thus,

$$growth\ Input\ Quantities_j = growth\ Cost_j - growth\ Input\ Prices_j . \qquad [5]$$

The quantity subindex for O&M was the ratio of the aggregate O&M expenses to the CPI. The CPI was chosen as the opex price subindex in part because PEG did not have access to detailed data on the composition of the EDBs' O&M costs. If such detail were available, it might have allowed us to construct an O&M input price index that was more closely tailored to the EDBs' spending on more disaggregated classes of inputs.[5] However, our investigation into alternate opex input price measures from StatsNZ revealed that most of them grew at similar rates to the CPI, which lends support to our decision to use the CPI as the input price subindex for all O&M inputs.

A simplified service price approach was chosen to measure capital cost. This approach has a solid basis in economic theory and is widely used in scholarly empirical work.[6] In the application of the general method used in this study, the cost of a given class of utility plant *j* in a given year *t* ($CK_{j,t}$) is the product of a capital service price index ($WKS_{j,t}$) and an index of the capital quantity at the end of the prior year (XK_{t-1}).

$$CK_{j,t} = WKS_{j,t} \cdot XK_{j,t-1}. \qquad [6]$$

Each capital quantity index is constructed using inflation-adjusted data on the value of utility plant.

In constructing indexes, we took the value of each EDB's RAB in 2004 as the benchmark or starting year. This is the year of the most recent revaluation of the EDBs' capital stock. The following formula and data were used to compute subsequent, and prior, values of the capital quantity index:

$$XK_{j,t} = (1 - d) \cdot XK_{j,t-1} + \frac{VI_{j,t}}{WKA_{j,t}}. \qquad [7]$$

Here, the parameter d is the depreciation rate and VI_t is the value of gross additions to utility plant. The asset-price index (WKA_t) was equal to the capital goods price index for electricity distribution and control apparatus.

The depreciation rate for each company was measured as the regulatory value of its depreciation expenditures divided by the RAB of the previous year. We computed an average regulatory depreciation rate in this manner for each company for the 1999-2004 period. Each company's average regulatory depreciation rate over this period was also applied in the 2005-2008 years.

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[5] PEG prepared a tailored opex input price index in our TFP reports for EDBs in Victoria.

[6] See Hall and Jorgensen (1967) for a seminal discussion of the service price method of capital cost measurement.

This regulatory depreciation rate was then used as a component of an ex-post approach towards measuring capital cost. An ex post approach to capital cost measurement looks at the actual gross returns to capital at the end of each period. In each year, this was measured as each EDB's regulated revenues minus its O&M and regulatory depreciation expenses, divided by the value of the RAB at the end of the preceding year. This approach constrains regulated cost to equal regulated revenue. For this "adding up" property to be satisfied, the regulatory depreciation rate discussed above must be used.

The full formula for a capital service price index is:

$$WKS_t = r_t \cdot WKA_{j,t-1} + d \cdot WKA_{j,t} \quad . \tag{8}$$

The two terms in this formula correspond to the ex post return to capital and depreciation. This is sometimes referred to as the "return on" and the "return of" capital. The term r_t is the ex post return to capital. The term d_t is the regulatory depreciation rate.

2.3.3 TFP Indexes

The growth rate in each EDBs TFP index was the difference between the growth rates in the industry's output and input quantity indexes. Growth in the output quantity index was a weighted average of growth in the number of customers, power delivery volumes, and non-coincident peak demands on the system. Weights were equal to the share of revenues generated by each of these outputs in EDBs' overall revenues, updated annually. The growth rate in each input quantity index was a weighted average of the growth rates in quantity subindexes for capital and O&M inputs. The weights were based on the shares of these input classes in total electricity distribution cost.

2.3.4 Input Price Indexes

PEG also developed input price indexes for the electricity distribution industry as part of our work. This was computed as a cost-share weighted average of the growth in input price subindexes for capital and O&M inputs. It should also be noted that, with an ex post approach to capital measurement, total "cost" is effectively constrained to equal total revenue, so that the long-run trend in industry revenues is equal to the trend in industry costs. We believe this result is consistent with the Commission's model of using a "workably competitive" market paradigm for setting the rate of change formula.

3. SUMMARY OF EDB RESULTS

This chapter will briefly summarize the results of PEG's research on TFP and related trends for New Zealand's electricity distribution industry.

3.1 Output Quantities

Table One presents information on the output quantity index and component subindexes. It can be seen that the overall output quantity index grew at an average annual rate of 2.27% over the 1999-2008 period. Output quantity is somewhat variable, with growth rates ranging from 0.91% in 2008 to 3.75% in 2005.

The number of customers served grew by an average of 1.63% over the sample period. This is both the smallest and most stable growth rate of the component subindexes. Annual customer growth ranged from 1.13% to 2.08% over 1999-2008.

Delivery volumes increased by 2.37% per annum over the 1999-2008 period. Volumes were more variable than customer numbers, with growth rates that ranged from -0.10% in 2002 to 4.58% in 2001. Changes in peak demand were similar, and its growth rate of 2.54% was slightly greater than the growth in volumes.

3.2 Input Quantities

Table Two presents information on overall changes in the input quantity index. It can be seen that overall input quantity increases by an average 1.07% per annum over the 1999-2008 period. There were substantial input declines in 2000 and 2001, when input quantity declined by a cumulative 5.6%. Since 2001, however, overall input quantity has grown at a relatively rapid rate of 2.18% per annum.

These divergent input quantity trends are due overwhelmingly to differences in O&M cost cutting over time. The 2000-01 input declines resulted entirely from a 29.5% decline in O&M quantity during those years. This input quantity decline reflects a substantial reduction in O&M costs. Since then, however, O&M inputs have grown at about a 3% average annual rate.

Table 1

Output Quantity Trends for New Zealand Electricity Distributors, 1999-2008

Year	Output Quantity Index		Total Customers		Volumes		Demand Charge Quantity	
	Index	Growth	Level	Growth	Level	Growth	Index	Growth
	yndxa							
1999	1.000		1,676,010		24,405		4,854	
2000	1.024	2.37%	1,705,300	1.73%	24,931	2.13%	4,986	2.7%
2001	1.059	3.38%	1,739,790	2.00%	26,098	4.58%	5,130	2.8%
2002	1.071	1.11%	1,770,800	1.77%	26,072	-0.10%	5,294	3.1%
2003	1.109	3.45%	1,804,410	1.88%	27,286	4.55%	5,385	1.7%
2004	1.124	1.41%	1,842,270	2.08%	27,834	1.99%	5,339	-0.9%
2005	1.167	3.75%	1,866,240	1.29%	29,030	4.21%	5,604	4.8%
2006	1.186	1.59%	1,895,720	1.57%	29,582	1.89%	5,642	0.7%
2007	1.216	2.50%	1,919,670	1.26%	30,172	1.97%	5,979	5.8%
2008	1.227	0.91%	1,941,570	1.13%	30,200	0.09%	6,099	2.0%
Average Annual Growth Rate 1999-2008		2.27%		1.63%		2.37%		2.54%

Table 2

Input Quantity Trends for New Zealand Electricity Distributors, 1999-2008

	Input Quantity Index		Capital Quantity		O&M Quantity	
Year	**Index**	**Growth**	**Index**	**Growth**	**Index**	**Growth**
1999	1.000		5,326		331,082	
2000	0.968	-3.2%	5,346	0.4%	288,051	-13.9%
2001	0.945	-2.4%	5,395	0.9%	246,395	-15.6%
2002	0.949	0.4%	5,440	0.8%	243,224	-1.3%
2003	0.956	0.7%	5,480	0.7%	246,055	1.2%
2004	0.974	1.9%	5,507	0.5%	266,820	8.1%
2005	1.011	3.7%	5,624	2.1%	293,461	9.5%
2006	1.031	2.0%	5,809	3.2%	287,230	-2.1%
2007	1.082	4.8%	6,006	3.3%	318,769	10.4%
2008	1.101	1.7%	6,234	3.7%	303,386	-4.9%
Average Annual Growth Rate 1999-2008		1.07%		1.75%		-0.97%

Capital quantity has grown at very different rates than O&M inputs. Capital inputs increased at an average annual rate of 1.75% over the 1999-2008 period. Capital inputs have also increased in each sample year. However, there is a discernible acceleration in capital spending in the last three years. Capital inputs increased at an average rate of 3.43% per annum over the 2005-2008 period, which is nearly four times greater than the 0.91% annual growth in capital quantity over the 1999-2005 period.

Tables Three and Four provide more detail on the changes in O&M and capital inputs, respectively. These tables decompose changes in the cost of each input into changes in input quantity and changes in input price. The changes in input quantity figures are relevant for when computing the TFP differential component of the X factor, while the changes in input price are used to compute the input price differential.

Overall, it can be seen that there has been an acceleration in the growth of input quantity in recent years. While opex input growth has been somewhat variable, it has grown at an average rate of nearly 3% over the last seven years. Capital input has grown at a 3.43% rate since 2005, which is well above the growth rate observed in the previous six years. If these trends continue, overall input quantity would grow by more than 3% per annum, which is approximately triple the average growth rate in input quantity over the entire 1999-2008 period. All else equal, the more rapid growth in input quantity would reduce the calculated TFP trend by about 2% per annum.

3.3 Input Price Trends

Table Five presents information on input price trends for the EDBs. It can be seen that the overall input price index grew by 3.73% per annum. Capital input prices grew at an average annual rate of 4.08% over the 1999-2008 period. O&M input prices grew somewhat less rapidly, at an average rate of 2.71%. For both input price subindexes, these historical growth rates are roughly similar to what PEG has observed for electricity distribution industries in other industrialized countries.

Table 3

Capital Cost, Quantity and Price Index for New Zealand Electricity Distributors, 1999-2008

Year	Capital Quantity		Capital Price Index		Capital Cost	
	Index	Growth	Index	Growth	Index	Growth
1999	5,326		157.804		840,474	
2000	5,346	0.4%	196.091	21.7%	1,048,210	22.1%
2001	5,395	0.9%	201.148	2.5%	1,085,280	3.5%
2002	5,440	0.8%	212.779	5.6%	1,157,580	6.4%
2003	5,480	0.7%	213.758	0.5%	1,171,420	1.2%
2004	5,507	0.5%	211.686	-1.0%	1,165,690	-0.5%
2005	5,624	2.1%	215.282	1.7%	1,210,830	3.8%
2006	5,809	3.2%	225.842	4.8%	1,312,000	8.0%
2007	6,006	3.3%	229.841	1.8%	1,380,350	5.1%
2008	6,234	3.7%	227.787	-0.9%	1,420,000	2.8%
Average Annual Growth Rate 1999-2008		1.75%		4.08%		5.83%

Table 4

O&M Quantity Trends for New Zealand Electricity Distributors, 1999-2008

	O&M Quantity		O&M Price Index		O&M Cost	
Year	**Index**	**Growth**	**Index**	**Growth**	**Index**	**Growth**
	xoa				**coa**	
1999	331,082		1.023		338,859	
2000	288,051	-13.9%	1.050	2.6%	302,543	-11.3%
2001	246,395	-15.6%	1.078	2.6%	265,587	-13.0%
2002	243,224	-1.3%	1.106	2.6%	269,110	1.3%
2003	246,055	1.2%	1.126	1.7%	276,999	2.9%
2004	266,820	8.1%	1.152	2.3%	307,336	10.4%
2005	293,461	9.5%	1.187	3.0%	348,291	12.5%
2006	287,230	-2.1%	1.227	3.3%	352,357	1.2%
2007	318,769	10.4%	1.256	2.3%	400,341	12.8%
2008	303,386	-4.9%	1.306	3.9%	396,106	-1.1%
Average Annual Growth Rate 1999-2008		-0.97%		2.71%		1.73%

Table 5

Input Price Index Trends for New Zealand Electricity Distributors, 1995-2008

	Input Price Index		Capital Input Price		O&M Price	
Year	**Index**	**Growth**	**Index**	**Growth**	**Index**	**Growth**
1999	1,179,330		157.804		1.023	
2000	1,395,288	16.8%	196.091	21.7%	1.050	2.6%
2001	1,429,719	2.4%	201.148	2.5%	1.078	2.6%
2002	1,503,361	5.0%	212.779	5.6%	1.106	2.6%
2003	1,515,702	0.8%	213.758	0.5%	1.126	1.7%
2004	1,512,683	-0.2%	211.686	-1.0%	1.152	2.3%
2005	1,542,568	2.0%	215.282	1.7%	1.187	3.0%
2006	1,614,128	4.5%	225.842	4.8%	1.227	3.3%
2007	1,646,348	2.0%	229.841	1.8%	1.256	2.3%
2008	1,650,055	0.2%	227.787	-0.9%	1.306	3.9%
Average Annual Growth Rate 1999-2008		3.73%		4.08%		2.71%

It should be noted that there was a significant increase in the capital input price in 2000. This results largely from the large increase in profits that the EDBs earned in that year. These profit gains were almost certainly the fruits of the large cost savings and productivity gains that the EDBs made in that year, as discussed before. In our “ex post” approach to capital cost measurement, these profit gains are reported as an increase in the return to the EDBs’ capital. The return on capital is a component of the user cost of capital, so this increase in returns will be manifested in a higher capital input price. While this may appear to be surprising result, in Chapter Four we will see that there is also a large increase in the input price index for the New Zealand economy in this same year. This increase in economy-wide input prices also resulted from large productivity gains in that year. Thus, in 2000, there are large increases in economy-wide input prices reflected in the StatsNZ data and in PEG’s input price estimates for the EDBs. The coincidence of these large input price changes for the electricity distribution industry and the NZ economy supports the reasonableness of our estimate.

3.4 Total Factor Productivity Trends

Table Six presents information on TFP trends for the EDBs. It can be seen that TFP grew by 1.21% per annum over the 1999-2008 period. Output quantity grew by 2.27% per year and input quantity increased by an average 1.07% per annum.

The largest TFP gains were registered in 1999-2001. TFP grew by an average rate of 5.7% per annum in these two years. This corresponds to the years where O&M costs were cut dramatically. Table Six also reports the average change in EDBs’ TFP for the 2001-2008 period. It can be seen that, since 2001, TFP has actually declined at a small 0.08% annual rate. This trend has accelerated since 2005, primarily because of the surge in capital investment. If the most recent trends in output and input quantity growth persist into the price control period that commences in 2010, they would augur for substantially slower TFP growth (in fact, continued and more rapid TFP declines) compared to the average 1.21% TFP growth rate measured for the 1999-2008 period.

The Act says the X factor can also be calibrated with TFP information from comparable countries, so PEG compared our estimate of the EDBs’ TFP trend with TFP estimates for electricity distribution industries in other countries that could be considered

Table 6

Total Factor Productivity Trends for New Zealand Electricity Distributors, 1999-2008

Year	Total Factor Productivity		Output Quantity Index		Input Quantity Index	
	Index	**Growth**	**Index**	**Growth**	**Index**	**Growth**
1999	1.000		1.000		1.000	
2000	1.058	5.6%	1.024	2.4%	0.968	-3.2%
2001	1.121	5.8%	1.059	3.4%	0.945	-2.4%
2002	1.129	0.7%	1.071	1.1%	0.949	0.4%
2003	1.160	2.8%	1.109	3.5%	0.956	0.7%
2004	1.155	-0.5%	1.124	1.4%	0.974	1.9%
2005	1.155	0.0%	1.167	3.7%	1.011	3.7%
2006	1.150	-0.4%	1.186	1.6%	1.031	2.0%
2007	1.124	-2.3%	1.216	2.5%	1.082	4.8%
2008	1.115	-0.8%	1.227	0.9%	1.101	1.7%
Average Annual Growth Rate						
1999-2008		1.21%		2.27%		1.07%
2001-2008		-0.08%		2.10%		2.18%

comparable. In a major incentive regulation proceeding in the Canadian Province of Ontario, the Ontario Energy Board determined that 0.72% was the best available estimate of TFP trends for Ontario distributors.[7] This estimate was based on a proxy TFP trend from the US that was nevertheless shown to be a good approximation for TFP changes that had been computed (although not on a consistent, uninterrupted time series basis) for the Ontario industry. In that same Ontario proceeding, PEG estimated the recent TFP trend for US electricity distributors to be 0.88% per annum. PEG also estimates that the most recent TFP trend for electricity distributors in Victoria Australia is 1.32% per annum.[8] A TFP study for electricity distributors in the Netherlands estimates recent TFP growth to be 1.1% per annum.[9]

PEG believes these TFP trends are broadly similar to the 1.21% TFP growth rate we have estimated for the EDBs. This international evidence therefore supports the credibility of our TFP estimate. It may be noteworthy, however, that the 1.32% TFP trend that we estimated for the Victorian distributors excludes the 1995-98 period. These were the years immediately following the privatization of the industry, which led to a one-time "burst" of TFP gains. PEG has always excluded these one-time TFP gains when reporting long-run TFP trends for the Victorian industry. This practice supports potentially excluding the one-time TFP gains from the EDBs' measured long-term TFP trend as well. Like the Victorian distributors in 1995, the EDBs in 1999 underwent a significant structural change. Some EDBs report that the creation of stand-alone distributors for the first time may have led to a "rationalization" or "right-sizing" of distribution operations. If so, this would represent a one-time source of TFP gains that – as in Victoria – should not be included in the NZ industry's estimated long-term TFP trend.

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[7] Ontario Energy Board, *Supplemental Report of the Board on 3rd Generation Incentive Regulation for Ontario's Electricity Distributors*, September 17, 2008.

[8] Kaufmann, L. and D. Hovde, *TFP Research for Victoria's Power Distribution Industry: 2007 Update*, December 2008.

[9] See the Netherlands Competition Authority documents, *Method Decision*, *Addendum A to the Method Decision: Description of the Method for Determining the X Factor and the Volume Parameters*, and *Addendum B BIJ to the Method Decision: Technical Description of the Method for Determining the X Factor and the Volume Parameters*, all issued on June 27, 2006.

4. NZ MFP AND INPUT PRICES

PEG also examined data on MFP trends developed by Statistics New Zealand (StatsNZ). The StatsNZ data show that MFP for the broadest available measure of the New Zealand economy grew by 1.09% over the same 1999-2008 period that PEG used to estimate the EDBs' TFP trend. This value is essentially identical to the MFP growth rate for the 1978-2008 period and to the NZ MFP estimate used in the B Factor in the previous thresholds regime. However, StatsNZ also reports that the New Zealand economy began a new economic cycle in 2000, and that MFP "series are of most value when analyzed from the peak of one cycle to the peak of another."[10] Given the worldwide recession that began in late 2008, there is a very high probability that 2008 will prove to be the "peak" of New Zealand's current business cycle. The latest peak to peak TFP trend for the NZ economy would therefore be computed for the 2000-2008 period. StatsNZ reports that NZ MFP grew by an average of 0.55% over this period. The most recent information may therefore imply that the long-run MFP trend of the NZ economy is only about half of the value that was used to calculate the previous B factor.

The input price trend for the NZ economy is equal to inflation in the NZ economy plus the long-run trend in NZ MFP. Annual growth in the NZ CPI averaged 2.71% over the 1999-2008 period and 2.72% over the 2000-2008 period which is, arguably, the most recent peak to peak MFP trend for the NZ economy. If we use 1.09% as the long-run MFP trend of the New Zealand economy, the long-run input price trend for the economy is equal to 1999-2008 average CPI inflation of 2.71% plus 1.09%, or 3.80% per annum. In contrast, if we use the more modest 0.55% estimate for long-run MFP growth, the current input price trend for the NZ economy is equal to 2000-2008 CPI inflation of 2.72% plus 0.55%, or 3.27% per annum. As discussed, it should be noted that input prices for the NZ economy grew by a very rapid 8.1% in 2000. This is the most rapid annual increase over the sample period and broadly consistent with the EDBs' input price experience in that same year.

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[10] Statistics New Zealand, *Productivity Statistics: 1978-2008*, 13 March 2009, p. 2.

Table 7

New Zealand Multi-Factor Productivity Trend

Year	Level	Growth
1999	1,250	
2000	1,320	5.4%
2001	1,324	0.3%
2002	1,336	0.9%
2003	1,362	1.9%
2004	1,370	0.6%
2005	1,380	0.7%
2006	1,379	-0.1%
2007	1,367	-0.9%
2008	1,379	0.9%

Average Annual Growth Rate	
1999-2008	1.09%
2000-2008	0.55%

Table 8

New Zealand Input Price Trend

Year	Multi Factor Productivity		CPI		NZ Input Price	
	Level	Growth	Level	Growth	Level	Growth
1999	1,250		1.023		1.000	
2000	1,320	5.4%	1.050	2.6%	1.084	8.1%
2001	1,324	0.3%	1.078	2.6%	1.116	2.9%
2002	1,336	0.9%	1.106	2.6%	1.156	3.5%
2003	1,362	1.9%	1.126	1.7%	1.199	3.7%
2004	1,370	0.6%	1.152	2.3%	1.234	2.9%
2005	1,380	0.7%	1.187	3.0%	1.281	3.7%
2006	1,379	-0.1%	1.227	3.3%	1.323	3.2%
2007	1,367	-0.9%	1.256	2.3%	1.343	1.5%
2008	1,379	0.9%	1.306	3.9%	1.408	4.8%
Average Annual Growth Rate						
1999-2008		1.09%		2.71%		3.80%
2000-2008		0.55%		2.72%		3.27%

5. X FACTOR RECOMMENDATIONS

The formula for the X factor is equal to the sum of the TFP differential and the input price differential. The TFP differential is equal to the growth in industry TFP minus the growth in economy-wide TFP. The input price differential is equal to the economy-wide input price trend minus the industry input price trend.

Given the available information, a reasonable estimate of the EDBs' long-run TFP trend can be computed over two possible sample periods. The first is 1999-2008. This represents all available information since the EDBs were created as stand-alone distribution utilities. The alternative is 2001-2008. This is reasonable since industry TFP growth in 1999-2001 appears to be anomalous and, indeed, is responsible for all the EDBs' TFP gains over the entire nine-year period. It is widely agreed that estimates of long-run TFP trends should not be distorted by structural or regulatory changes that lead to a one-time "burst" of TFP gains that are unlikely to be repeated. The creation of stand-alone distribution entities in 1999 was in fact a significant structural change for New Zealand's electricity distribution industry, and this change apparently led to a burst of TFP growth over the 1999-2001 period. The best estimate of the EDBs's long-run TFP growth should arguably exclude these one-time TFP gains and be measured over a period beginning in 2001.

As discussed, there are also two reasonable estimates of New Zealand's economy-wide MFP trend. The first is 1.1%, which is equal to the growth in New Zealand MFP over the 1999-2008 period and over the longer 1978-2008 period. A 1.1% economy-wide MFP trend was also used to estimate the previous B factor. The second possible estimate is 0.55%. While this is half of the previously estimated long-run MFP trend, it does represent the TFP growth inherent in the country's most recent business cycle measured on a peak to peak basis. It may also be reasonable to expect the New Zealand MFP trend to slow during the term of the reset DPP, especially given the current economic conditions.

Since there are two reasonable estimates for both the industry and economy-wide TFP trends, it follows that there are four possible estimates of the TFP differential:

1) the 1999-2008 industry TFP trend of 1.21% minus the 1999-2008 NZ MFP trend of 1.09%; this would lead to an estimated TFP differential of 0.12% (*i.e.* 1.21% - 1.09% = 0.12%).
2) the 1999-2008 industry TFP trend of 1.21% minus the 2000 -2008 NZ MFP trend of 0.55%; this would lead to an estimated TFP differential of 0.66% (*i.e.* 1.21% - 0.55% = 0.66%).
3) the 2001-2008 industry TFP trend of -0.08% minus the 1999-2008 NZ MFP trend of 1.09%; this would lead to an estimated TFP differential of -1.17% (*i.e.* -0.08% - 1.09% = -1.17%).
4) the 2001-2008 industry TFP trend of -0.08% minus the 2000-2008 NZ MFP trend of 0.55%; this would lead to an estimated TFP differential of -0.63% (*i.e.* -0.08% - 0.55% = -1.17%).

Input price trends for the industry and the economy can also be computed for each of the four options above. The input price differential can then be calculated as the difference between the growth trends in economy-wide and industry input prices. The associated input price trends and differentials would be as follows:

1) the 1999-2008 NZ input price trend of 3.80% minus the 1999-2008 industry input price trend of 3.73%; this would lead to an estimated input price differential of 0.07% (*i.e.* 3.80% - 3.73% = 0.07%).
2) the 2000-2008 NZ input price trend of 3.27% minus the 1999-2008 industry input price trend of 3.73%; this would lead to an estimated input price differential of -0.46% (*i.e.* 3.27% - 3.73% = -0.46%).
3) the 1999-2008 NZ input price trend of 3.80% minus the 2001-2008 industry input price trend of 2.05%; this would lead to an estimated input price differential of 1.75% (*i.e.* 3.80% - 2.05% = 1.75%).
4) the 2000-2008 NZ input price trend of 3.27% minus the 2001-2008 industry input price trend of 2.05%; this would lead to an estimated input price differential of 1.22% (*i.e.* 3.27% - 2.05% = 1.22%).

The latter two options lead to estimates of industry input price inflation that are more than 1% per annum below economy-wide input price inflation trends. We do not believe these estimates are plausible in the current environment. Indeed, a number of factors (including rising prices for many construction materials, a relatively aging workforce and shortage of new laborers in ANZ for many electricity distribution jobs) make it far more likely that input price inflation for the EDBs will exceed aggregate input price trends. These and related factors have led Australian regulators to conclude that input price growth for energy utility industries will exceed CPI inflation. Because input price differentials greater than 1% are highly unlikely during the term of the DPP, PEG does not believe these scenarios can be used to develop reasonable X factor recommendations.

However, we do believe that a reasonable value for the input price differential is zero. This is equivalent to the value that was approved in the previous thresholds regime. An input price differential of zero is arguably more reasonable for the reset DPP in light of the current, extraordinarily uncertain economic conditions. Broader macroeconomic conditions will have a significant impact on how aggregate consumer prices and EDB input prices change over the term of the DPP. Given the current uncertainties, policymakers should exercise considerable caution when extrapolating what may be the most recent economic data into the future.

PEG therefore believes that zero is a reasonable value for the input price differential, and this conclusion expands the range of scenarios that should be considered when developing X factor recommendations. In particular, a zero input price differential can reasonably be assumed for each of the four TFP differentials that were presented above. Doing so leads to four additional scenarios regarding TFP and input price information that could be used to develop an X factor recommendation. PEG therefore believes that our research and assessment leads to eight specific options for developing an X factor for the DPP. These eight options are summarized in Table Nine. They are:

1) a TFP differential of 0.12%, computed as the 1999-2008 industry TFP trend of 1.21% minus the 1999-2008 NZ MFP trend of 1.09%; plus an input price differential of .07%, equal to the 1999-2008 NZ input price trend of 3.80% minus the 1999-2008 industry input price trend of 3.73%;

Table 9

X Factor Options for DPP

	TFP Industry	TFP Economy	TFP Differential	Input Price Economy	Input Price Industry	Input Price Differential	X Factor
	(1)	(2)	(3) = (1) - (2)	(4)	(5)	(6) = (4) - (5)	(8) = (3) + (6)
Option One	1.21%	1.09%	0.12%	3.80%	3.73%	0.07%	0.19%
Option Two	1.21%	0.55%	0.66%	3.27%	3.73%	-0.46%	0.20%
Option Three	-0.08%	1.09%	-1.17%	3.80%	2.05%	1.75%	0.58%
Option Four	-0.08%	0.55%	-0.63%	3.27%	2.05%	1.22%	0.59%
Option Five	1.21%	1.09%	0.12%	-	-	0	0.12%
Option Six	1.21%	0.55%	0.66%	-	-	0	0.66%
Option Seven	-0.08%	1.09%	-1.17%	-	-	0	-1.17%
Option Eight	-0.08%	0.55%	-0.63%	-	-	0	-0.63%

this would lead to an X factor of 0.19% (*i.e.* 0.12% + .07% = 0.19%).

2) a TFP differential of 0.66%, computed as the 1999-2008 industry TFP trend of 1.21% minus the 2000-2008 NZ MFP trend of 0.55%; plus an input price differential of -0.46%, equal to the 2000-2008 NZ input price trend of 3.27% minus the 1999-2008 industry input price trend of 3.73%; this would lead to an X factor of 0.20% (*i.e.* 0.66% - 0.46% = 0.20%).
3) a TFP differential of -1.17%, computed as the 2001-2008 industry TFP trend of -0.08% minus the 1999-2008 NZ MFP trend of 1.09%; plus an input price differential of 1.75%, equal to the 1999-2008 NZ input price trend of 3.80% minus the 2001-2008 industry input price trend of 2.05%; this would lead to an X factor of 0.58% (*i.e.* -1.17% + 1.75% = 0.58%).
4) a TFP differential of -0.63%, computed as the 2001-2008 industry TFP trend of -0.08% minus the 2000-2008 NZ MFP trend of 0.55%; plus an input price differential of 1.22%, equal to the 2008-2008 NZ input price trend of 3.27% minus the 2001-2008 industry input price trend of 2.05%; this would lead to an X factor of 0.59% (*i.e.* -0.63% + 1.22% = 0.59%).
5) a TFP differential of 0.12%, computed as the 1999-2008 industry TFP trend of 1.21% minus the 1999-2008 NZ MFP trend of 1.09%; plus an input price differential of zero; this would lead to an X factor of 0.12%..
6) a TFP differential of 0.66%, computed as the 1999-2008 industry TFP trend of 1.21% minus the 2000-2008 NZ MFP trend of 0.55%; plus an input price differential of zero; this would lead to an X factor of 0.66%.
7) a TFP differential of -1.17%, computed as the 2001-2008 industry TFP trend of -0.08% minus the 1999-2008 NZ MFP trend of 1.09%; plus an input price differential of zero; this would lead to an X factor of -1.17%.
8) a TFP differential of -0.63%, computed as the 2001-2008 industry TFP trend of -0.08% minus the 2000-2008 NZ MFP trend of 0.55%; plus an input price differential of zero; this would lead to an X factor of -0.63%.

The Commission has said that it will use the results of TFP studies to inform its judgment on setting appropriate X factors. Our TFP and input price research supports a range of values for the X factor, or objective bounds on an appropriate value of X that are based directly on the results of rigorous empirical research. The upper bound for the X factor that can be supported using existing evidence is 0.66% (option six); the lower bound for the X factor that can be supported using existing evidence is -1.17% (option seven).

Further analysis can further reduce the range of X factors that should be considered for the DPP. In particular, we believe that carefully considering the components of the X factor computations implies that some of these combinations are unlikely during the term of the DPP. For example, PEG believes that generally sluggish economic conditions are likely to persist over the term of the DPP, which lends more support to 0.55% (rather than 1.09%) as the best measure of New Zealand's long-term TFP trend. If the economy remains sluggish, it will be very difficult for the EDBs to increase TFP at a rate greatly exceeding the -0.08% achieved over the 2001-08 period (in part because output growth will slow). This implies that Options Two and Six - which are based on an acceleration of industry TFP to 1.21% at the same time that the economy is sluggish and experiences 0.55% TFP – are implausible. PEG therefore believes that these options should be eliminated from the computation of the reasonable X factor range.

On the other hand, it is possible that the economy may experience a robust recover over the term of the DPP. If so, economy-wide TFP growth rates may be closer to the 1.09% trend. But if the economy's TFP accelerates due to broader economic recovery, this recovery may also lead to somewhat more rapid output and TFP growth for the EDBs as well. This implies that Options Seven and Three – where the EDBs' TFP growth remains 0.08% per annum while the economy's TFP accelerates to 1.09% annual growth – are also implausible. PEG believes these options should be eliminated from the computation of the reasonable X factor range as well.

As discussed, PEG believes input price differentials in excess of 1% are implausible. If anything, pressures on input prices for the EDBs are likely to be greater than those of the overall economy, due to a relative scarcity of labor in the EDB sector and perhaps greater acceleration in materials prices. Option Four assumes an input price differential of 1.22%, so PEG believes this option should be eliminated as well.

The results of PEG’s additional analysis are summarized on Table Ten. It can be seen that there are three remaining X factor options: Option One, Option Five and Option Eight. The upper bound for this X factor range is 0.19% (Option One); the lower bound is -0.63% (Option Eight). PEG therefore recommends an X factor between 0.19% and -0.63% for the DPP.

We note that a negative X factor is perfectly consistent with the theory of incentive regulation and a number of recent CPI-X regulatory decisions. A negative X should not be interpreted as evidence that NZ’s electricity distribution industry is becoming “less efficient;” it simply means that the inputs that are needed for EDBs to provide service have been growing more rapidly than their outputs. This trend has been particularly evident since 2005, when output growth has generally slowed while the pace of capital investment accelerated. If these trends are expected to continue, then TFP will decline at an even more rapid rate than has been the case since 2001. This would argue for an X factor towards the lower end of the reasonable range.

Table 10

Further Assessment of X-Factor Options and Recommended X-Factor Range

	TFP Industry	TFP Economy	TFP Differential	Input Price Differential	X Factor	Further Assessment of Option
Option One	1.21%	1.09%	0.12%	0.07%	0.19%	Acceptable: Upper Bound of X Factor Range
Option Two	1.21%	0.55%	0.66%	-0.46%	0.20%	Implausible Industry TFP and Economy TFP Combination
Option Three	-0.08%	1.09%	-1.17%	1.75%	0.58%	Implausible Industry TFP and Economy TFP Combination
Option Four	-0.08%	0.55%	-0.63%	1.22%	0.59%	Implausible Input Price Differential
Option Five	1.21%	1.09%	0.12%	0	0.12%	Acceptable
Option Six	1.21%	0.55%	0.66%	0	0.66%	Implausible Industry TFP and Economy TFP Combination
Option Seven	-0.08%	1.09%	-1.17%	0	-1.17%	Implausible Industry TFP and Economy TFP Combination
Option Eight	-0.08%	0.55%	-0.63%	0	-0.63%	Acceptable: Lower Bound of X Factor Range

APPENDIX ONE

Indexing Logic, Outputs and Output Weights

PEG believes that there is a strong analytical foundation for determining the choices for outputs and inputs for in CPI-X indexing plans for EDBs. We believe this foundation flows directly from the indexing logic which establishes the link between industry TFP growth rates and the calibration of tariff indexing formulas. This indexing logic is generally accepted in Australia and New Zealand, but its implications for output and input choices are not widely recognized. We believe this Review by the Commission provides an excellent opportunity to explore this issue and, in the process, ideally resolve many of the debates regarding TFP measurement that have taken place to date in ANZ. We present this logic below and then discuss its implications for appropriate output choices in TFP measurement.

The indexing logic relies on what is sometimes referred to as the competitive market paradigm *i.e.* that utility tariff adjustments should be set at a rate that is consistent with how prices evolve in competitive markets. The indexing logic therefore examines long-run changes in revenues and costs for an industry. In the long run, the trend in revenue (R) for an industry equals the trend in its cost (C).

$$Trend\ R = Trend\ C \qquad \textbf{(1)}$$

The trend in the revenue of any industry will be equal to the sum of trends in revenue-weighted output price indexes (P) and revenue-weighted output quantity indexes (Y).

$$Trend\ R = Trend\ P + Trend\ Y \qquad \textbf{(2)}$$

The growth rate in the cost incurred by an industry is the sum of the trends in a cost share-weighted input price index (W) and a cost-share weighted input quantity index (X).

$$Trend\ C = Trend\ W + Trend\ X \qquad \textbf{(3)}$$

Substituting (2) and (3) into equation (1) and rearranging, we find

$$\begin{aligned} Trend\ P &= (Trend\ W + Trend\ X) - Trend\ Y \\ &= Trend\ W - (Trend\ Y - Trend\ X) \\ &= Trend\ W - Trend\ TFP \end{aligned} \qquad \textbf{(4)}$$

This is the basic result of the indexing logic. It shows that the change in an industry output price index can be decomposed into changes in the industry's input price index minus changes in its TFP index. When this result is applied to utility regulation, it implies that allowed changes in utility prices (the left-hand side variable in (4)) can be linked to industry input price inflation minus changes in industry TFP. If the chosen inflation factor (such as the CPI) is a good proxy for long-run trends in industry input prices, then it is appropriate to set the X factor equal to the trend in the regulated industry's TFP.

These results, which show the usefulness of TFP trends for tariff adjustments, are generally understood, but the implications of this same indexing logic for appropriate TFP measurement are less recognized. For example, while equation (1) is only the starting point for the analysis, it has two important implications. First, it focuses only on the rate of change in prices and revenues. The indexing logic applies only to calibrating the terms of tariff adjustment formulas, not setting rate levels at the outset of an indexing regime. The competitive market paradigm therefore focuses on only a narrow issue – how revenues and costs evolve over time in competitive markets – and works from this premise towards deriving implications for the appropriate calibration of changes in tariffs for regulated markets. Equation (1) has no implications for the regulated industries' price levels; for example, it never says that regulated prices should approximate marginal costs, as occurs in perfectly competitive markets. This distinction between what the paradigm implies for appropriate price changes and price levels is sometimes not appreciated.

Second, equation (1) has implications about the dimensions of efficiency which need to be captured in a TFP measure used to adjust tariffs. Economists often distinguish between productive efficiency and allocative efficiency. Productive efficiency focuses on cost efficiency *e.g.* whether firms use the minimal number of inputs to produce a given level of output. Productive efficiency is focused exclusively on costs, which appear only on the right-hand side of equation (1). If an industry is productively efficient, then the trend rate of change in costs on the right-hand side of (1) will be the lowest possible change in costs that is necessary to satisfy the industry's changing output (given existing technology).

There are a number of components of allocative efficiency, but in a regulatory context one important consideration is whether changes in revenues approximately track changes in its costs. Equation (1) clearly embodies this dimension of allocative efficiency on an industry-wide basis. This is obvious since the change in the variable on the left-hand side of (1) [revenues] is explicitly set equal to the change in the variable on the right-hand side of (1) [costs].

The indexing logic which links TFP trends to changes in tariffs begins with equation (1). Our exposition above indicates that equation (1) necessarily reflects both allocative efficiency (in the relationship between changes in revenues and changes in costs for the industry) and productive efficiency (with respect to the efficient change in costs that appears on the right-hand side of (1)). It follows that the TFP measure that emerges from the further elaboration of this logic – and which appears in equation (4) - must also embody both productive and allocative efficiency. Importantly, the appropriate measure of industry TFP growth that is used in TFP-based regulation must be one that would tend to promote changes in industry revenues that approximate changes in industry costs. It should be emphasized that this relationship applies to the *industry* and not an individual utility; any individual utility would still have incentives to keep its cost growth below what is reflected in the industry-wide norms, as is the case in competitive markets.

This important point has not been appreciated in the TFP debates that have taken place to date in ANZ. For example, much of the criticism of PEG's TFP research in Victoria has implicitly been motivated by the concern that it does not adequately measure productive efficiency, but these critiques do not consider the (at least) equally important issue of allocative efficiency. For example, in arguing for its output specification (including the addition of a network capacity variable and the use of cost elasticities rather than revenue shares as weights), Meyrick and Associates has written that "the objective is to measure TFP which is output produced per unit of input (or total real cost)."[11] Meyrick has also written that "the objective of the X factor is to calculate achievable TFP gains going forward. As such, the use of cost elasticity shares to aggregate outputs in calculating TFP is unambiguously preferable to revenue shares which may bear little resemblance to relative costs."[12]

Both of these statements focus exclusively on the linkage between TFP and cost – or productive – efficiency. This focus is often warranted in academic research where the objective *is* to obtain the best possible measures of productive efficiency. But equation (1) makes it clear that this focus is not sufficient for TFP measures that are used to regulate utility tariffs, since an exclusive focus on productive efficiency would concentrate only on the right hand side of this equation. The TFP trend measures that appear in equation (4) of this logic, and which are used for utility regulation, must go beyond measuring productive efficiency to include allocative efficiency as well. The latter reflects the relationship between changes in costs and changes in revenues; this is an essential part of the indexing logic that cannot be ignored.

We next consider equation (2). This equation shows that the change in revenue can be decomposed into a change in output prices and output quantities. The change in output quantities in this equation is the same output quantity trend that appears in the TFP trend measure in equation (4). Equation (2) therefore draws a direct link between the outputs that are used to measure TFP and revenues. In other words, the outputs that are used in the TFP measure *must* have a direct link to the revenues of the regulated industry. If this was not the case, then the index decomposition in (2) – which gives rise to the output quantity index used in the TFP measure – would not be satisfied.[13]

More specifically, equation (2) has two direct implications for the output quantity specification. One is that the specific output quantities that are used to compute the output quantity index must be the billing determinants that are used in the tariffs for the regulated sector. No other output quantity measures can be compatible with equation (2)

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[11] Meyrick and Associates, *Response to Pacific Economics Group 'Evaluation of Meyrick and Associates Review of PEG TFP Report*, Report prepared for AGLE, CitiPower, Powercor, TXU Networks and United Energy, 29 March 2005, p. 3.

[12] Meyrick and Associates, *op cit*, p. 4.

[13] More technically, equation (2) says that the revenue, price and output quantity indexes that are used in TFP-based regulation must satisfy what is known as the product test.

in the logic above. This can perhaps be clarified by considering a particular TFP controversy that has arisen in Australia. In its original TFP research for Victoria's electricity distribution sector, PEG measured output using the quantities that these utilities actually billed its customers for – customer numbers (via the customer charge), on-peak kWh deliveries, off-peak kWh deliveries and peak demands. Their rationale was that these are the billing determinants and hence the only quantities that are consistent with equation (2). Meyrick criticized this specification, in large part because it ignored what it called the network capacity output. Meyrick compared energy networks to roads, and said that electricity distributors were responsible for providing and maintaining this "road" but not responsible for the traffic (*e.g* the kWh deliveries) on that road. Meyrick claimed that PEG's TFP specification was deficient since it did not consider this important consideration, which is critical to how distributors actually operate and manage their businesses. Meyrick's critique could have had merit if the only objective of the TFP study was to measure distributors' how effectively managers are running their business *i.e.* their productive efficiency. But as our exposition of equation (1) indicates, this is not the objective for TFP measures that are used for rate adjustment mechanisms, which must consider both productive and allocative efficiency. Meyrick's network capacity output is not consistent with the allocative efficiency prerogative, nor is it consistent with equation (2), which links changes in utility outputs to changes in utility revenues. Distributors do not charge directly for the network capacity measure that Meyrick recommended, so there is no logical relationship between this output and distribution revenue. Thus while Meyrick's critique raised interesting points that may be relevant for academic research, they were not material for the specific objective of PEG's TFP study. In a TFP study used in CPI-X regulation, there must be a link between the outputs used in the TFP study and utility revenues, and only a utility's billing determinants can satisfy this criterion.

The second implication of equation (2) is that each billing determinant should be weighted by its revenue share when computing the output quantity index. Again, this is necessary for the changes in revenues to be decomposable into changes in output prices and output quantities. If output quantities were weighted by anything other than each output's share of revenues, equation (2) would not be satisfied (except by chance).

APPENDIX TWO

PHYSICAL VERSUS MONETARY CAPITAL MEASURES AND ALTERNATIVE DEPRECIATION ASSUMPTIONS

In the past several years, there has been an extensive debate in Australia and New Zealand about whether physical or monetary values of capital assets should be used to measure capital input quantities in TFP studies. These options have also sometimes been referred to as the direct (*i.e.* physical) and indirect (*i.e.* monetary) approaches to capital measurement. This appendix will consider the issue of using physical versus monetary measures for capital inputs. With extremely rare exceptions, PEG believes that only monetary measures of capital stocks should be used to measure capital in energy utility TFP studies. This view is overwhelmingly supported by economic theory, empirical evidence and regulatory precedent.

One important factor supporting the use of monetary capital values is the indexing logic which demonstrates the role that industry total factor productivity (TFP) trends can play in adjusting utility rates. This logic shows that only monetary capital values are internally consistent with the TFP trend measures that should be used in rate adjustment mechanisms. Recall that the indexing logic examines long-run changes in revenues and costs for an industry. In the long run, the trend in revenue (R) for an industry equals the trend in its cost (C).

$$Trend\ R = Trend\ C \qquad \textbf{(1)}$$

The trend in the revenue of any industry will be equal to the sum of trends in revenue-weighted output price indexes (P) and revenue-weighted output quantity indexes (Y).

$$Trend\ R = Trend\ P + Trend\ Y \qquad \textbf{(2)}$$

The growth rate in the cost incurred by an industry is the sum of the trends in a cost share-weighted input price index (W) and a cost-share weighted input quantity index (X).

$$Trend\ C = Trend\ W + Trend\ X \qquad \textbf{(3)}$$

Substituting (2) and (3) into equation (1) and rearranging, we find

$$\begin{aligned} Trend\ P &= (Trend\ W + Trend\ X) - Trend\ Y \\ &= Trend\ W - (Trend\ Y - Trend\ X) \\ &= Trend\ W - Trend\ TFP \end{aligned} \qquad \textbf{(4)}$$

It can be seen that the trend in (revenue-weighted) prices depends on the difference between the trends in two indexes. The first is a *cost-share weighted* input price index. The second is a total factor productivity (TFP) index. The trend in output quantities used in the TFP index is calculated using revenue-share weights; the trend in input quantities used in the TFP index is calculated using cost-share weights.

In terms of the choices for capital inputs, the critical relationship in this logic is equation (3). This equation shows that there is a direct link between the input quantity measure used in TFP calculations and the costs of the industry. In other words, the trend change in the industry's input quantity (which is used, in turn, to compute industry TFP trends) should be associated with trend changes in industry cost. This relationship naturally applies to capital inputs, which account for the largest share of energy network inputs.

Clearly, the total cost of the industry is measured in monetary terms, and internal consistency requires this value to be decomposed into two component indices (for input prices and input quantities) that are measured on the same, monetary basis. This is almost invariably the case for opex inputs, which are measured using the monetary values for operating expenditures. These monetary values are "deflated" using an opex input price index, which functionally divides the monetary value of opex changes into a price change component (reflected in the change in the overall input price index, *W*) and a quantity change component (reflected in the change in the overall input quantity index, *X*). Capital input quantities will be logically consistent with the total cost and opex input quantity measures only if these indices are also calculated using monetary capital values.[14]

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[14] Indexes that obey this property are sometimes said to satisfy the "product test"; for example, see Waters, W.G. and J. Street (1998), "Monitoring the Performance of Government Trading Enterprises," *The Australian Economic Review*, Vol. 31, no. 4, p. 368.

The link between monetary capital values and TFP trends is also consistent with how utility prices are set in practice. When prices under a CPI-X regulation plan are updated using measures of industry input price and TFP trends, prices at the outset of the plan are typically set to recover the company's cost of service in a base year. These initial year costs include the costs associated with capital assets. When a utility sets its rates to recover the depreciation and carrying costs of these capital goods, it does so with reference to the aggregated monetary values of these disparate assets, net of their depreciation. It follows that if monetary costs – including the monetary costs of physical capital assets - are used to set rates at the outset of a plan but a "physical method" for measuring capital is used to set the X factor, the X factor to *adjust* distribution rates will not be consistent with how those rates were originally set. This internal inconsistency between setting initial rates and adjusting rates over time can only reduce the transparency of the rate adjustment mechanism and perhaps exacerbate rate volatility when prices are updated, thereby undermining the predictability and effectiveness of the incentive regulation regime.

It should also be noted that the use of physical capital measures in TFP studies embody certain assumptions about depreciation. A necessary, but not sufficient, condition for using physical capital to measure the capital stock is for capital to obey what is known as "one-hoss shay" depreciation. The defining characteristic of one-hoss shay depreciation is that the asset undergoes *no* physical decay from the time it is installed until the day it is replaced. The classic example of a one-hoss shay "asset" is a light bulb.

The link between one hoss shay depreciation and physical capital can perhaps be clarified by considering that TFP growth is designed to measure the flow of services provided by aggregate inputs. The services provided by a given capital good depend on how efficiently that asset is operating compared with its potential. Economists sometimes term this relationship between actual and potential services as the "efficiency units" associated with a given capital good. Whenever there is any physical asset decay, then the efficiency units of older capital must be less than the efficiency units of the newer capital. If this is the case, then old and new capital goods cannot simply be added together and used to measure capital input because there is effectively less input quantity being provided by the older capital goods. Different physical values for capital goods (such as km of distribution line installed in different years) can therefore be added together and used as an overall capital measure only when there is **no** physical decay in assets *i.e.* when there is one-hoss shay depreciation. When this is not the case, then the capital inputs installed in different years must also be adjusted to take account of capital decay that has taken place since the assets were put in place.

PEG does not believe that a one-hoss shay depreciation pattern (*i.e.* zero physical decay in every year an asset is in place) is consistent with day-to-day experience in energy network industries. For example, scores of utilities have implemented "reliability centered maintenance" programs which are designed to optimize system performance and extend asset life. Distribution maintenance involves many concrete decisions about inspection cycles, washing insulators, whether and when to treat or "wrap" wood poles, vegetation management, etc. Even though distribution assets tend to be long-lived, the fact that they involve extensive maintenance programs is a sure sign that there is some physical decay over time. It would be imprudent and unprofitable for utilities to devote resources to asset maintenance unless doing so increased the services effectively provided by these capital inputs. Such maintenance programs would also not be consistent with a one-hoss shay depreciation pattern, where the assets must be providing a constant stream of services *before* maintenance programs are undertaken.[15]

A corollary of the "no physical decay" condition is that one hoss shay assets also provide unmistakable replacement signals. One-hoss shay capital goods work perfectly until the day they break down, at which point they never work again and must be replaced. This also does not reflect the reality of most energy network assets. Managers have a degree of discretion about when to replace assets and, to a lesser extent, about

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[15] It has been argued that the presence of maintenance expenditures can be consistent with one-hoss shay depreciation, since agricultural land sometimes includes expenditures to maintain the productivity of given lands and yet land typically is assumed not to depreciate in TFP studies. However, there is an important distinction to be made between "no depreciation" and one-hoss shay depreciation. The difference is that, with very rare exceptions, land is not physically replaced at all, so it is appropriate to assume that there is no depreciation since the concept is inherently designed to measure the extent to which assets are "used up" over time as they are utilized in production. Other than land, all assets will inevitably be completely used up at some point and hence must be replaced (assuming ongoing operation of the enterprise and that the asset has not become technologically obsolete). This disparity between land and

replacing current labor-based operations with capital equipment (*e.g.* in service restoration). Replacement decisions are, in fact, intertwined with operational and maintenance decisions. The complexity and inter-relatedness of these judgments is not consistent with the transparent simplicity of deciding when to replace a light bulb or other one-hoss shay assets.

The economics literature also generally supports the notion that energy network assets are not characterized by one-hoss shay depreciation. Indeed, this literature has found exceedingly few assets with one hoss shay depreciation profiles in any industry. One statement of this view comes from an OECD Manual titled *Measuring Capital: Measurement of Capital Stocks, Consumption of Fixed Capital, and Capital Services:*

> "There are probably rather few assets that maintain constant efficiency throughout their working lives. Light bulbs are sometimes cited as potential one-hoss shays, but light-bulbs are too short-lived to be classified as capital goods. More serious contenders might be bridges or dams. With a constant level of maintenance these structures may continue to provide constant rentals for very long periods. In general, however, few examples of the one-hoss shay have been identified in the real world."[16]

The literature also finds that when observers ignore the role of maintenance expenditures, they often incorrectly conclude that assets exhibit one hoss shay depreciation. This has been noted in the *Dictionary of Usage for Capital Measurement Issues*, released in conjunction with the Second Meeting of the Canberra Group on Capital Stock Statistics:

> "The concept of decay is a crucial one in capital measurement. Some additional remarks about input and output decay may clarify the concepts. The division between output decay and input decay is economically, not technologically, determined, because owners can often offset output decay by increased maintenance. However, increased maintenance as a capital good ages implies input decay. Accordingly, when increased maintenance does compensate for output decay, this does not create a one hoss shay asset, because a one hoss shay asset is by definition one with zero decay. There seems to be some confusion on this point in the literature: A good deal of the

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other assets implies that the zero depreciation for land assets is not equivalent to one-hoss shay depreciation.

[16] OECD Manual. (2001). Measuring Capital – Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services.

> anecdotal evidence that has been cited in favor of the plausibility of the one hoss shay model has ignored input decay."[17]

Arguments in favor of one hoss shay depreciation based on "casual experience" or "intuitive appeal" also run contrary to rigorous empirical depreciation studies. For example, when discussing alternative depreciation patterns, Charles Hulten (a depreciation expert) writes that observers often believe "...the one hoss shay pattern commands the most intuitive appeal. Casual experience with commonly used assets suggests that most assets have pretty much the same level of efficiency regardless of their age – a one year old chair does the same job as a 20 year old chair, and so on."[18] However, this author's own academic work shows that this "casual experience" conflicts with more scientific investigations of depreciation. Hulten and Wykoff examined the prices that were actually paid in secondary markets for used capital goods.[19] They found that these prices were most consistent with geometric and not one-hoss shay depreciation patterns. This work has been very influential and is used directly by a number of researchers (including the US Bureau of Economic analysis) to value capital stocks. Surveying the intuitive and empirical arguments, Hulten writes:

> "Taken together, these intuitive arguments (in favor of one hoss shay) above suggest that this is a case in which the econometric evidence leads to the wrong result. However, it may also be true that the intuition, not the econometrics, is faulty. Intuition tends to be based on personal experience of individual cases."[20]

Furthermore, Hulten notes that proponents of one-hoss shay depreciation ignore what is known as the "portfolio effect," *i.e.* the depreciation profile associated with a group of disparate assets – such as those owned by energy networks– will often differ from the depreciation of any individual asset. He writes:

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[17] Triplett, Jack. (1998). *A Dictionary of Usage for Capital Measurement Issues*, presented at the Second Meeting of the Canberra Group on Capital Stock Statistics (OECD).

[18] C. Hulten (1990), "The Measurement of Capital" in *Fifty Years of Economic Measurement* eds. E.R. Berndt and J. Triplett, Studies in Income and Wealth, vol. 54, the National Bureau of Economic Research, Chicago: The University of Chicago Press, p. 124.

[19] C. Hulten and F. Wykoff (1981), "The Measurement of Economic Depreciation," in *Depreciation, Inflation and the Taxation of Income from Capital* ed. C. Hulten, Washington DC: The Urban Institute Press, 81-125.

> "Moreover, what may be true on a case-by-case basis may not be true of an entire population of assets. If so, this has important implications for evaluating econometric results, which typically reflect the average experience of whole populations and not individual units. For instance, it may well be true that every single asset in a group of 1000 assets depreciates as a one-hoss shay, but that the group as a whole experiences near-geometric depreciation. This fallacy of composition arises from the fact that different assets in the group are retired at different dates: some may last only a year or two, others ten to fifteen years. When the experience of the short-lived assets is averaged against the experience of the long-lived assets, and the average cohort experience is graphed, it will look nearly geometric if the 1000 assets have a retirement distribution of the sort used by the Bureau of Economic Analysis (i.e., one of the Winfrey distributions). Thus, the average asset (in the sense of an asset that embodies the experience of 1/1000 each of 1000 assets in the group) is not one hoss shay, but something that is much closer to the geometric pattern. This can easily be verified by performing this experiment using the parameters of the Bureau of Economic Analysis's capital stock program."[21]

Other depreciation experts have also expressed the view that one hoss shay deprecation is not consistent with the empirical literature. One reason, again, is that arguments in favor of one hoss shay depreciation do not consider the implications of maintenance expenditures, which can be used to increase the flow of services that assets provide over their lifetimes. For example, Erwin Diewert has written:

> "The one hoss shay model of efficiency decline, while seemingly a priori attractive, does not seem to work well empirically; i.e. vintage depreciation rates tend to be much more accelerated than the rates implied by the one hoss shay model. We also saw in Section 11 that the simple one hoss shay model does not take into account the implications of rising maintenance and operating costs for an asset as it ages. Thus if maintenance costs are linearly rising over time, a "gross" one hoss shay model gives rise to a linearly declining efficiency model, which of course, is a model that exhibits very accelerated depreciation" (and therefore not consistent with one hoss shay depreciation)[22]

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[20] Hulten, Charles R & Wykoff, Frank C. (Jan 1996). Issues in the measurement of economic depreciation: Introductory remarks. *Economic Inquiry 34*(1), pp. 10-24.

[21] Hulten, Charles R & Wykoff, Frank C. (Jan 1996). Issues in the measurement of economic depreciation: Introductory remarks. *Economic Inquiry 34*(1), pp. 10-24.

[22] E.W. Diewert, (June 2001), Measuring the Price and Quantity as Capital Services under Alternative Assumptions. Discussion Paper No. 01-24, p. 73. Immediately below these lines, Diewert also writes "the straight line depreciation model, *while not as inconsistent with the data as the one hoss shay model,* also does not generate the pattern of accelerated depreciation that seems to characterize many used asset markets" (emphasis added). Thus of the three main candidates for depreciation profiles, these

It should also be noted that very few TFP studies used in regulatory applications have used physical capital measures. The only such precedent that PEG is aware of is in the New Zealand electricity thresholds regime. Far more regulatory plans have used monetary capital values as the basis for approved TFP trends. Simple capital measures have also been criticized in other Australian regulatory proceedings. In 1999, Denis Lawrence (then with Tasman Asia Pacific, currently with Economic Insights) made the following comments regarding the capital cost measure used by London Economics in a study done for the Independent Pricing and Regulatory Tribunal:

> "Of more fundamental concern, however, is the attempt to measure capital input simply by the route kilometers of lines and MVA of transformer capacity. The measure of capital inputs should take account not only of quality differences between capital inputs but also capture the amount of resources which have to be expended to construct the capital input. Particularly in the case of lines, simply adding kilometers of lines together is inappropriate. It fails to recognize the inherent differences between central business district, suburban and rural situations…Treating all kilometers of line as being identical is akin to measuring aircraft inputs by the number of miles flown. If one of those kilometers is flown by a Boeing 747 and another is flown by a Cessna, the inappropriateness of the assumption is apparent."[23]

It should also be noted that the issue of appropriate capital measures was the subject of considerable debate in a 2007-2008 update of an incentive regulation plan for power distributors in the Canadian Province of Ontario. PEG was advising the Ontario Energy Board (OEB) in this proceeding, and we estimated an industry TFP trend using monetary capital values. London Economics (represented by Julia Frayer) developed an alternative TFP measure which used physical capital measures in part. In its September 2008 final decision, the OEB accepted PEG's approach and wrote that "(o)f greatest concern with Ms. Frayer's approach is the (physical) measurement of capital, which is

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statements imply that one hoss shay is the least consistent with empirical depreciation studies, straight line depreciation is the second least consistent, and geometric depreciation is most consistent.

[23] Lawrence, Denis. (March 1999). *Report to Energy Australia on London Economics Efficiency and Benchmarking Study on the New South Wales (NSW) Distribution Business.* It should be noted that the London Economics studies included benchmarking and TFP results, but arguments regarding the merits of monetary versus physical capital measures are generally applicable to each type of empirical study. However, because there fewer concerns about the consistency with the underlying indexing logic, PEG

inconsistent with the prior Ontario TFP studies and does not appear to have been adopted in any jurisdiction other than New Zealand."[24] This is one of the few, and perhaps only, instances in which the merits of physical versus monetary capital values was debated extensively and transparently in a regulatory setting.

In sum, PEG agrees that "the measure of capital inputs should…capture the amount of resources which have to be expended to construct the capital input." We believe that this view is supported by the fundamentals of utility ratemaking, the logic underlying productivity-based regulation plans, day-to-day experience in energy network industries, the empirical evidence on observed depreciation patterns, and the overwhelming bulk of regulatory precedents.

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believes that physical capital measures are generally less problematic in benchmarking than TFP applications.

[24] Ontario Energy Board, *Supplemental Report of the Board on 3rd Generation Incentive Regulation for Ontario's Electricity Distributors*, September 17, 2008, p. 12.

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